Course 3 Waste Management Logistics

PG Diploma in
Waste Management & Environmental Hygiene

Mahatma Gandhi National Council of Rural Education
Hyderabad - 500004

Foreword

Logistics in waste management is primarily used as a tool for an appropriate management of all kinds of waste that not only enables the minimization of pollutants generated, but also allows for redevelopment or disposal of waste. A logistically integrated waste management system can be identified and constructed in terms of functional areas. Functional areas include waste transport, storage, use and regulating and controlling the system.Managing huge amount of wastes generated on a day-to-day basis added by the rising costs and unsafe disposal are the problems of the day. With the involvement of communities and the private sector, advanced technologies and safe disposal methods, and inculcating lifestyle changes and creating awareness, cities around the world are showing remarkable results by adapting good practices in waste management.

Now there is an urgent requirement to rethink and analyze if the waste generated is indeed waste or is it wealth in disguise. Can one's refuse become another's resource? As a global village, we have the responsibility of waste management. With the help of techniques like Polluter Pays Principle, Assimilative Capacity principle and Precautionary principles, the problem of waste management can be solved to an extent which further gets expanded in a gradual manner. Waste management can be tackled by using certain strategies that are designed to solve this issue in an intricate way which is beneficial for the greater good of the global community.

One of the best ways to combat waste management is to make sure that the collected waste is used and reused in the form of fuel, domestic gas and electricity. This is one of the major ways in which waste can be managed so that it becomes easier to dispose it and also use it to the best of its capacity. Waste management requires a lot of cost production and also the disposal of these materials requires a lot of machinery which has to be done in a cost effective manner. Containers and segregators for each segment of waste are to be maintained so that the correct way of managing the solid waste is completed in an effective manner.

Environmental engineering has improved the quality ofmethods and techniques of waste management by optimizing and increasing the benefits of the programme when the whole task is completed. Streamlining and simplifying the task of waste management. "Zero waste to Landfill" should be the goal of waste management professionals.

This course on Waste Management Logistics is suitable for students of all streams - Commerce, Humanities, Science, Management, Journalism, Mass Media, Healthcare services (B Pharm, Social Work), Education, and Engineering. The extent of environmental damage and the innovations in combating the issues require scientific understanding of the subject.

The subject has vast possibilities and several interlinking themes. There is extensive scope to explore and experience different aspects of sanitation, pollution, environmental hygiene and waste management during classroom learning, practical experiments in field and laboratory, internship and dissertation. There is a sea of opportunity in this field of waste management and environmental hygiene, and an urgent need of skilled as well as dedicated workers to make our country clean and green.

Nature has interlinked realms. Similarly, subjects dealt in this course cannot be compartmentalized. They necessarily have to merge with one another. It is therefore important that students try to make these linkages in their minds rather than treating subjects in isolation. Students can make the most of this learning opportunity as they prepare to launch their careers in a field that holds great premise.

Dr. W G Prasanna Kumar

Chairman, MGNCRE

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This Post Graduate Diploma course on Waste Management and Environmental Hygiene is a cumulative effort of several sincere and committed visionaries and academicians. Envisioned by Shri VLVSS Subba Rao, Senior Economic Advisor, MHRD, the curriculum took shape under his keen guidance.

The sincerity with which the course curriculum was completed and published can be assessed from the fact that a prior National Consultation Workshop was held with several subject matter experts and academicians across the country, to review the contents of the course material.

The workshop was held to familiarize Central, State and Private Universities, local and social bodies with the contents of the curriculum and to discuss and share feedback on ways to improve the course curriculum. The workshop also focused on building industry–academia partnerships in Waste Management and Environmental Hygiene through an intellectual interaction. The findings and inputs of the consultation were subsequently incorporated in the course material.

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Objectives

- To learn the human and technological components of waste management
- To know the social aspects and managerial goals
- To update on advancements in technology
- To develop thought processes for simplifying waste management

Rationale

Waste management and environmental hygiene is the need of the hour and needs to be addressed across all sectors and communities. The course on Waste Management and Environmental Hygiene gives the student an overview of waste management including collection, transfer, transport, and disposal along with methods of processing, basic disposal facilities, disposal options, recycling, project management and GIS applications, reclamation and remediation, entrepreneurship and job opportunities in waste sector. In addition, this course provides the student with relevant information about waste markets, recycling trends, cost and affordability of waste management practices, and incentive based concepts. This course is therefore essential for the students who wish to pursue a career in waste sector as moving ahead, waste management will become an infrastructural necessity.

Competency

The course will be taught and implemented with the objective to develop required skills sets in the students so that they are able to acquire following competencies: Plan segregation, collection, transportation, recycling and disposal of wastes, know recycling trends and available waste markets, acquire skill development and know the scope and entrepreneurship opportunities in the waste management sector.

Methodology

The theory will be taught and practicality of the course will be addressed through questionnaires, self-assessment and dissertation. The course will be through class room lectures, guest lectures, field visits, audio – video learning mode, brainstorming sessions, seminars and Q&A. A lecture series will strengthen students' understanding of waste management which will help in acquiring different learning outcomes in rational and theory to practice approach. Competency that will be gained as part of course outcome includes - understanding, learning, applying and implementing skills, knowing career prospects in waste management sector, and internship and placement opportunities.

Topics Covered

- Waste Audit
- Waste Collection, Segregation, Manifest, Transport, Treatment, Preventive Maintenance
- Technological Upgradation, Disposal
- Composting: Types and Processes
- Counter Current Management Recycling
- Changed Form Reducing
- Compacting
- Reusing: with and without Recasting
- Incineration and Pyrolysis, Gasification

- Landfills: Aerobic and Semi aerobic
- Earth Layer and HDPE Liner
- Capping of Waste
- Inventory and Material Management
- Carrying Capacity, Assimilation Capacity, Life Cycle Analysis, Extended Producer Responsibility

Waste Management Logistics - An Introduction

Logistics management in itself is a part of supply chain management.Itincludes planning, implementing, and controlling the efficient, effective forward (and reverse flow) and storage of goods, services and related information between the point of origin and the point of consumption in order to meet customer's requirements. It is a field with immense possibility.

Waste Management Logistics considers waste a commodity that demands the same attention and efficiency as supply chain logistics. As we will learn in the subsequent course, the cost of mismanaging our waste or ignoring it can be multifold andthe damage irreversible. However, if managed well, one's waste can well be another's wealth. The 1st chapter deals with how waste should be analysed from a recovery point of view as well as from the aspect of potential hazard to health and the environment. The second chapter analyses the people involved in the waste chain, both formally and informally. The steps in waste management as well as the role of individuals and communities in waste generation and their responsibilities are explored. The process of recycling, composting and extracting the best out of waste are the focus of chapter 3. Waste needs to be cut down at the consumer level as also at the producer level, as discussed in chapter 4.

Garbage clearance regularly and conscientiously is a huge responsibility. Without proper understanding, support and cooperation of all individuals, it cannot be performed efficiently. While the course lays emphasis on collection, proper segregation, regular and systematic transportation, sorting, recovery of recyclables and final disposal in landfills, it also speaks of the need to reduce the quantum of waste generated so that the problem can be contained and be manageable. The final chapter of the course is about waste reduction and ways to move towards 'zero- waste'.

The end of each chapter contains a guideline for the teachers to impart the knowledge to students through a blend of classroom teaching, activities, film viewing and discussions.

Chapter 1

Waste Analysis

Objectives

- To analyse the kind of waste being generated
- To know the basics of waste audit

Structure

1.1 Introduction to terminology of Waste
1.2 Waste Audit
1.3 Steps in Waste Audit

To Do Activities

1. Screen films on waste characterization
2. Read out Case study of Pomona College. Open discussion on possibilities for the class.
3. Conduct a waste audit of your department or hostel. Alternatively, conduct a clean-up drive in a public place and audit the waste.
4. Watch the film on Eco –Active Waste Audit.
5. Conduct practical activity in groups of 5 (if the class size is over 20). Make students analyse their results and express their findings in a short classroom seminar.

1.1 Introduction to Terminology of Waste

An unbelievable 62 million tonnes of garbage is generated everyday by the 377 million people who live in urban India, which is now the world's third-largest garbage generator. Waste is generated at multiple locations. Each facility (residential, educational, industrial, etc) has its own special composition of waste. We often use a wide variety of terms synonymous to waste such as: garbage, trash, refuse, scrap. In civil engineering, each term has its own connotation. These are described below.

Waste/Refuse: Waste is unwanted, material left after use. Waste is unwanted leftover material after use.
Litter: Litter is waste not put into a proper bin, but thrown carelessly around. Littering causes the surroundings to look untidy.
Solid waste: Any refuse, garbage, sludge, discarded material including solid, liquid, semisolid, or contained gaseous materials resulting from industrial, commercial, mining and agricultural operations and community activities. Solid waste does not include solid or dissolved material in domestic sewage, irrigation return flows or industrial discharge or by-product material of nuclear sources.
Refuse: All solid waste products having the character of solid. They are composed wholly or partially of garbage, trash, rubbish, litter, residues of clean-up of spills and contamination, or other discarded material.
Rubbish: British English for waste. It mostly refers to dry materials. It is combustible, or slowly putrescible discarded material which includes trees, wood, leaves, trimming, printed matter, plastic and paper products, grass, rags or any other material not classified as garbage.
Trash: Trash is materials thrown away, which could still be useful. Trash usually includes furniture, household hazardous wastes, broken equipments, etc. Trash is used interchangeably with rubbish.

Garbage: American English for waste. Garbage is mostly organic waste, including food scraps, cloth, paper, etc. It comes mostly from kitchens and bathrooms.

Putrescible waste: Solid waste which contains organic material capable of being decomposed by micro-organisms and causing odour.

Sanitary Landfill: An engineered land burial facility for the disposal of household waste which is located, designed, constructed and operated to contain and isolate the waste so that it does not pose a substantial present or potential hazard to human health or the environment. Commercial waste, non-hazardous sludge, hazardous waste from conditionally exempt small- quantity generators and non-hazardous industrial solid waste can be added to a sanitary landfill.

Sludge: Any solid, semi-solid or liquid waste generated from municipal, commercial or industrial waste water treatment plant, water supply treatment plant or air pollution control facility can be termed as sludge.

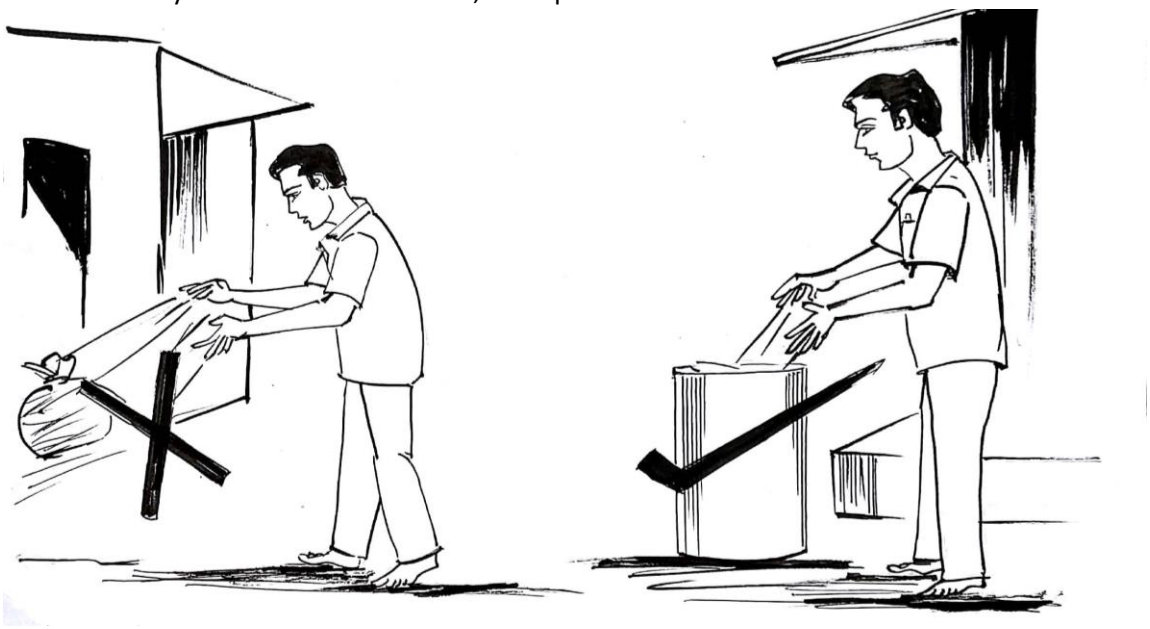
Scrap: Scrap material is a specific type of recyclable refuse such as materials left over from building supplies, vehicle parts, surplus metal, etc. Scrap is essentially re-usable. It is taken to a junk yard, or a wrecking yard and melted down to be turned into new products.

Special Wastes: Solid wastes that are difficult to handle and require special precautions due to their hazardous nature or management problems.

Street Litter: Leaf litter, animal waste, stray bits of plastic and other waste littered along roads is collected as street litter.

Yard Waste: A portion of municipal solid waste generated from general landscape maintenance, including grass clippings, leaf litter, tree pruning, etc.

It is interesting to note that institutions that manage their wastes without a waste audit throw away up to 77% of their recyclable waste in the West, and up to 60% in India.



Waste Analysis

All wastes are not equal. Waste from each source should be analysed thoroughly and treated accordingly. Waste should be strictly segregated into three broad categories: biodegradable, recyclable and the rest.

1. Biodegradable waste has three main characteristics: odour, germs, potential to fertilize. They need immediate attention.
2. Recyclable waste is material that can be recovered and used as raw material for some other manufacturing. This material can wait, if stored correctly. It is also a profitable resource.
3. Other waste like inert dust, non-recyclable trash. This makes the surroundings look untidy. They may also contain substances which are hard to recover. They are suitable for landfills
4. Hazardous waste could be waste with a potential to spread germs or cause accidents. Ex. diapers, sharps, broken glass, metals that could leach and cause land/ water pollution etc. Potentially dangerous waste should be moved away on a daily basis.

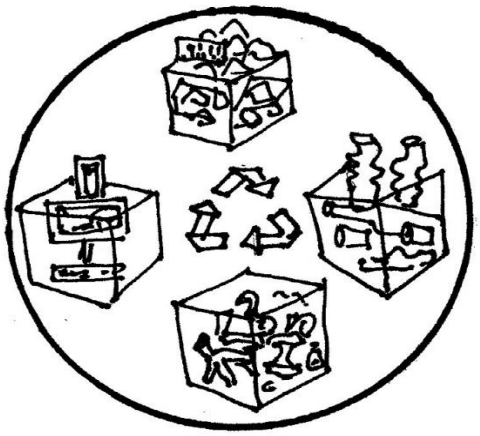
Watch films: Waste characterization study, Iowa City, Duration: 2.35 min:
https://www.youtube.com/watch?v=8i4Ztc3jFlA

Characterization of Waste: An MHRD production, Duration: 27 minutes:
https://www.youtube.com/watch?v=4Ixuv-qhRs8

1.2 Waste Audit

Waste audit involves systematic collection of data on waste generated by each institution- be it a household, a colony, an industry, a hospital, an educational institute, a store, or a business of any kind.
The objective is to determine: -

- Types and quantum of waste generated
- Locate the point of generation
- Effectiveness of operations.



Benefits of a Waste Audit

- Improves efficiency of operations

- Saves money: on-going cost saving, new sources of income, improved resource efficiency, improved environmental performance.

Based on the quality and quantity of each waste stream, it is further analysed based on the current waste management practices to determine how best to improve the system so that:-

a. Waste generation is minimized. Changes may be made to the present practices to reduce waste generation.
b. Portions of the waste are diverted for reuse or recycle from the source, thereby reducing the quantum of waste.
c. Improve the process for waste collection, scheduling transportation and further processing is designed.
d. Set benchmarks for year-on-year waste minimization.
e. Meet certification standards, like LEED, or regulatory compliances like CSR.

In this way, an end-to-end waste management logistics chain is created from the findings of a waste audit system.

Watch Film: ECO-ACTIVE Waste Audit, 2min, https://www.youtube.com/watch?v=AYcgw1rANMw

The above animated film gives a good brief about how a waste audit should be held.

Case Study: Water Stream Analysis at Pomona College, California

"Campuses that address the climate challenge by reducing global warming emissions and by integrating sustainability into their curriculum will better serve their students and meet their social mandate to help create a thriving, ethical and civil society."

With a conviction that Pomona College can become a leader in educating students for a sustainable world, a programme was launched in 2006. One aspect of this critical work was the campus waste stream. Previous data collection had demonstrated the extent of waste stream and its costs.

Background:
Pomona College (est. 1887) is a private, residential, liberal-arts institution located in Claremont, California. It enrols approximately 1,540 undergraduate students and employs 254 faculty and 473 staff, all of whom live, study, teach, research and/or work on a 140-acre suburban campus. Its structures include 62 buildings, 12 of which are dormitories, 3 dining halls and 2 cafés; the total built square footage is 1.4 million.

Sustainability Action:
From 2008, the College hired approximately 50 students to serve as Sustainability Assistants or Sustainability Action Fellows whose research and data analysis has been central to the college's evolving sustainability plans and management. The Sustainability Integration Office was created in 2009.

The Course:
Environmental Analysis (EA) 199- Greening the Waste Stream was introduced in 2010. EA-199 was a multi-student independent study that analyzed the campus waste stream and developed real-world solutions in accord with the college's sustainability commitments and goals.
This experimental class had a series of interrelated goals and objectives.

By developing a methodology to analyze what went into the college's trash cans, recycling bins, compost collectors and dumpsters and from what sectors of the campus these materials originated, it produced the first sustained assessment of the particulars of the campus waste stream (Donovan, et al., 2010).
It did so without the expenses usually associated with hiring outside consultants and contractors, yet provided data collection as rigorous as those professionals might have produced.

Stage 1- Seven weeks:

During the first seven weeks, students learnt about the history and present state of waste management globally and researched the strategies of other campuses in USA to audit and control their waste streams. They presented oral reports on the central concerns and began to develop appropriate methodologies, strategies and tools for investigating the campus waste stream. They were trained in the techniques available to audit, analyze and reconfigure Pomona College's system of trash collection and management.

From this emerged significant baseline data. The intention was to "green" their waste streams, further the college's efforts to reduce, reuse and recycle its waste and fulfill a key element in its commitment to sustainability.

- This first stage familiarized students with the different steps communities and institutions have taken to deal with waste.
- Explored the reliability and applicability of these techniques to Pomona and
- Gained experience working together, especially important given the range of their ages (from sophomores to seniors) and subfield emphases (from environmental economics and development to race, class, and gender).

This segment of the class concluded with two projects: students prepared and presented visual depictions of the Pomona waste stream, graphic representations that helped clarify their thinking in advance of the Waste Audit. The Project was a hands-on sorting of a small, random sampling of one day's worth of campus trash that Housekeeping had collected. Donning gloves, the students and the teachers went through six, 55-gallon bags that were designated as "trash" and "recycling," separating each into one of three categories (trash, recycling, compost).

The most striking finding from this exercise was that a large portion of what had been thrown into trashcans was in fact recyclable material.

Stage 2- Seven weeks:

The waste audit set the foundation for the one of the major activities of the final seven weeks of the semester–**a full-scale sorting of an estimated 400 pounds of waste during an all-afternoon session.**

In anticipation of that arduous labour, the class refined the analytical tools they would employ, established a ratio for the number of bags and types of material ("trash" and "recycling") that would be selected from five sectors of the campus - administrative; residential; academic (science and non-science and the campus center (student union). After determining the nomenclature they would ask Housekeeping to employ when it tagged the bags and denoting the kind of waste collected and from which sector, they also expanded the range of categories into which to place the sorted items .

Finally, they assembled the necessary protective gear, scales and other material to facilitate their analyses

The result:
The results confirmed that a large portion of Pomona College's trash actually was recyclable; changing that ratio would save the college money and divert material away from Los Angeles County landfills that are reaching capacity.

Outcomes:
- ✓ To build off their hands-on research, the students completed two additional assignments.
- ✓ They drafted a report of their findings (Donovan, et al., 2010), which was folded into the SIO's annual Sustainability Report (Pomona College Sustainability Annual Report, 2010).
- ✓ They also developed a power point presentation of their results that they presented in separate sessions to the class teachers, PACS and the Housekeeping staff.

In each setting, their findings were assessed and debated and important questions were raised about the local and larger implications of their research. These questions, when combined with the students' insights into the potential consequences of their findings, shaped their final task–individual projects that would help green the campus waste stream.

- ✓ Students wrote a project proposal identifying the problem, discussed its purpose, practicality, and value; determined the precise steps that the SIO could take to resolve this concern; established a working budget needed to fund the project; and then presented their findings to the class for its critique.
- ✓ Within months the SIO had begun to implement several of the suggestions–for instance, a detailed study of the presence and location of recycling bins on campus went to the Housekeeping supervisor for use in purchasing new bins; expanding recycling in one of the campus eateries, and other policy initiatives.
- ✓ Students learned the value of testing theory and applied knowledge, one against the other; and the pressing need to develop reliable data and to assess its reliability.
- ✓ Students realized that by collecting accurate information on the campus's waste stream they would have a direct impact on policymaking.
- ✓ The more detailed information they gather about the extent of their resource use and carbon footprint, the more they realize how complex their responses must be to reduce the flows of energy or waste (Pomona College, 2010; Wells, et al. 2009).
- ✓ Their research was included in the college's annual gathering of sustainability-related data.They presented it to administrators, staff, faculty and peers, from which they gained invaluable insights into the college's organizational structure, bureaucratic operations and facilities management.
- ✓ Students understood that their work could have broader implications to the school's commitments to environmental sustainability.
- ✓ Comparing and contrasting waste management across campuses and regions added a competitive and incentive-based drive, to narrow waste streams.

Lessons in Pedagogy:
When the course was studied for its pedagogy, it was realized that the practical and educational advantages of developing a class to audit the campus waste stream include:

- ✓ Offering students an unusual educational opportunity to apply theoretical insights to and test these against a real-world problem; their analyses and projects also has helped the college more sustainably manage its waste stream.

- ✓ It demonstrated that it is possible to create a pedagogical environment that blends historical and theoretical analyses of waste management with practical, hands-on experience with waste and its consequences.
- ✓ The class greatly increased their knowledge of waste-stream dynamics in general and Pomona College's in specific. This knowledge heightened their understanding of the links between their individual levels of consumption and waste-creation and the larger society's.

Take-away from the course:

At the end of the course, students were asked for a feedback. One student observed: "I am amazed at how much my awareness of my own consumption patterns increased as a result of this class. It made me acutely aware of the fact that everything we throw away ends up in a landfill and/or the ocean eventually."

- ✓ Students felt that the skills built designing, performing, and presenting on the waste audit could be applied to 'real-world' projects.
- ✓ They learned how to write an appropriate assessment of research they had done as well as look at data with a more critical eye.
- ✓ Students agreed that these real-world lessons were a key part of the class, and ought to be more widely available in the EA curriculum; the program, like the sciences, should have just such a "laboratory" component.
- ✓ Students felt that the class' activities (presentations; tour of the e-waste recycling facility, etc.) had deepened their knowledge of the complex issues involved in waste management and motivated them in their research. One student put it this way:

"I learned that to make environmental changes can be very difficult and much research must be done in order to have enough data to convince superiors that there is a problem that needs fixing."

1.3 Steps in Waste Audit

Step 1: Train the staff or recruit volunteers. Give specific instructions on how to conduct the survey. Share goals and expectations with the team. Maintain confidentiality regarding the audit.

Step 2: Provide safety equipment (gloves, masks, protective clothing) and give anti-tetanus vaccine. Provide bag audit forms.

Step 3: Plan the audit well to avoid overlooking or repeating certain areas. Set aside two to eight weeks to plan and organize the audit, three hours to complete the audit and extra time for travel.

Step 4: Conduct a practice audit. This will ensure everyone understands the objectives and the process.

Step 5: Sort the waste. Sort by categories to find types, quantities- by weight and by volume- and the source of certain types of wastes.

Step 6: Analyse the data. This analysis not only verifies what is being discarded but also ascertains the value of the loss being incurred.

Step 7: Share the results. Consult with all cleaning staff and participants regarding the analysis. Compare the results with previous results (if any).The results help to take corrective steps through recycling education, change in purchasing decisions, exposing wasteful problems and revealing breakdowns in the system.

Step 8: Repeat the exercise at varying intervals to observe a change in waste composition throughout the year for the first year, to observe the trend in waste generation.

Step 9: Repeat the waste audit every year. This is essential for measuring success, improving the mechanism and maximizing the efficiency of the waste management operations.

Please complete fully as per instructions

ITE LOCATION: DUBLIN ROAD, GALWAY

OB DESCRIPTION: NEW RESIDENTIAL DEVELOPMENT, 120 - UNIT DEVELOPMENT OF CONCRETE FRAME CONSTRUCTION

KIP SIZE REFERENCE: 24BW12 (9.175m²) AREA CODE: N/A COMPACTED/NON-COMPACTED

AUDITOR: 0024

Date	Material	EWC Code	% Full	Quantity (m^3)	Weight (tonnes)	Notes/Comments
20/07/05	TIMBER OFFCUTS		10%	0.918	0.551	FROM 1ST FIX
20/07/05	PACKAGING		5%	0.459	0.069	BLOCKWORK PACKAGING
20/07/05	METALS		10%	0.918	0.918	
21/07/05	PACKAGING		10%	0.918	0.138	BLOCKWORK PACKAGING
22/07/05	TIMBER		20%	1.835	1.101	DAMAGED FORMWORK
22/07/05	METALS		5%	0.459	0.459	
23/07/05	CONCRETE BLOCKS		10%	0.918	1.377	DAMAGED BLOCK
23/07/05	TIMBER PALLETS		10%	0.918	0.551	DAMAGED PALLETS
24/07/05	PACKAGING		10%	0.918	0.138	
24/07/05	CANTEEN WASTE		10%	0.918	0.551	
	TOTAL		100%	9.175m²	7.529	

Fig 1.1 Sample of Waste Audit Form 1

Audit Location and Date: Weather:		Auditor's name:		
Material	**Material and container combined weight**	**Empty bin weight**	**Calculated Material weight**	**Comments**
Glass (excluding mirror, ceramic, pyrex, plate glass)				
Sub total				
Metals				
Sub-total				
Aluminium, Steel, Foil				
Sub-total				
Paper and Cardboard				
Subtotal				
Plastics (excluding Styrofoam, rigid furniture, Tupperware, toys)				
Subtotal				
Biodegradables				
Subtotal				
Inerts				
Subtotal				
Hazardous				
Subtotal				
Others				
Subtotal				
TOTAL				

Fig 1.2 Sample Waste Audit Data Recording Worksheet

Summary

Waste management begins with waste characterization. Every waste audit gives an opportunity to analyse and improve the waste management process, minimize waste production and set new recycling goals. Waste audit is a simple yet effective method for waste characterization. It can also be a good career opportunity.

Self – Assessment Test

1. What are the steps in waste audit?
2. How is scrap different from garbage?
3. After waste characterization / audit, which categories will you try to increase waste in, and waste in which categories should be reduced?
4. What are the benefits of a waste audit?

Films

1. ECO-ACTIVE Waste Audit Animation, 2 min, https://www.youtube.com/watch?v=AYcgw1rANMw
2. Waste characterization study, Iowa City, Duration: 2.35 min:https://www.youtube.com/watch?v=8i4Ztc3jFlA
3. Characterization of Waste: An MHRD production, Duration: 27 minutes: https://www.youtube.com/watch?v=4Ixuv-qhRs8

Chapter 2
Waste Management Logistics

Objectives

- To understand the steps of waste management logistics
- To know human and technical input required for managing waste
- To know the complexity and efficiency involved in waste management
- To learn how to reduce the quantity of waste that reaches a landfill

Structure

2.1 Introduction to Waste Management Logistics
2.2 Human Components in Waste Management
2.3 Technological Components- Waste Handling Equipment
2.4 Social Aspects and Managerial Goals
2.5 Steps in a Waste Management Logistics Process

"To leave the world better than you found, sometimes you have to pick up other people's trash".

- Bill Nye, Science Educator

To Do Activities

1. View film on the waste pickers.
2. Discuss in class how the condition of waste pickers can be improved. In an ideal world, what kind of job opportunities would they like to give to the downtrodden if they themselves had a waste processing company?
3. View film on Floral Waste.
4. Visit/ survey of city's waste management. Facilitate students to identify gaps from a logistic point and enable them to analyse the reports.
5. Read Case study on festival waste and watch film. Is there a pilgrim spot or festival that generates large amounts of waste during a short period of time? If so, organize a field visit to the location. This visit can be scheduled to coincide with the event. Other sources of pollution (such as air and noise can be studied. Also water sampling, volunteering for a clean festival, etc can be encouraged).
6. Watch film on Ontario's recycling unit to understand the difficulties caused by improper segregation.
7. Organize a field visit to a transfer station. Observe the sorting. Make students participate in sorting of waste, with permission of authorities and proper safety equipment.
8. Film viewing of Nashik's waste management. Followed by classroom discussion between their field experience and the information from the film.
9. Show film on Sanquelim Mine reclamation.
10. Discuss steps in Capping. Use Jawaharnagar Case Study.
11. Visit a waste management facility. Conduct an exercise in waste segregation – wet waste, dry waste. Interview a waste handler- from the municipality, self-help group or waste-picker. Find out the practical issues they face during the course of their daily routine.
12. Discuss on what topics each student is interested in, scope out possibilities of career development, research or internship opportunities.

2.1 Introduction to Waste Management Logistics

Simply stated, waste management is a straight forward system.

Generate ⟹ Segregate ⟹ Collect ⟹ Transport ⟹ Re- segregate ⟹ Process ⟹ Dispose

This system requires the help of manpower and machinery. Unlike machinery that needs periodic servicing, the human component or manpower needs much more care and attention. To keep them motivated one must understand both managerial and social aspects of human workforce.

2.2 Human Components in Waste Management

India has a long history on waste collectors. Their poor living conditions, harsh behaviour towards them, segregation from society, by being considered 'unclean' due to their profession has led to their being a marginalized society even after seven decades of India's Independence.

(Watch Film: Waste Picker's life and livelihood. 11 min.
https://www.youtube.com/watch?v=aLda8O2ySMc)

This short film portrays the haplessness as well as government and public apathy towards waste pickers, even though their contribution to modern society is immeasurable. However, with time, this bias is changing. Today waste pickers have been turned into 'collectives' or 'micro and small enterprises' (MSE- comprising of fewer than 50 employees). They are the backbone of a good cost-recovery system out of waste collection. The garbage collected itself is the hidden wealth with potential to pay back. A fee collected from every household or business for collection and disposal is an important component.

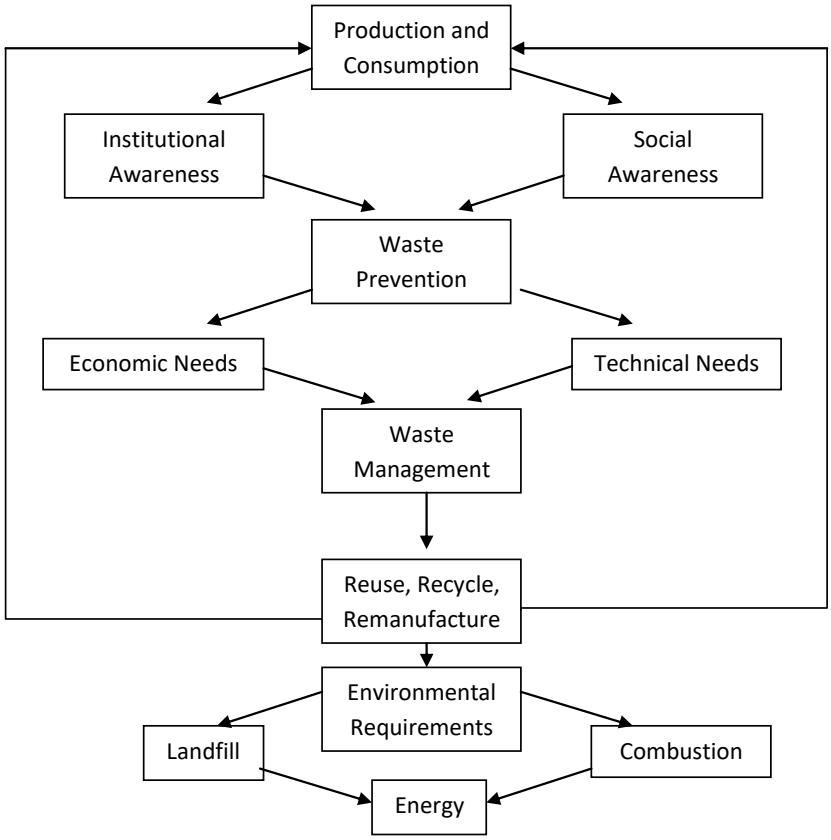


Fig 2.1 Flow Chart for Waste Management Process

Private sector organizations are better equipped than governmental organisations to collect payments and manage the finances. This arrangement, where the public and private sectors work together, is called a public-private partnership (PPP) or private sector participation (PSP). While the public sector unit gets the permits for waste collection, transport and treatment, plans the route and provides transport and equipment, the private partner operates the scheme with its manpower. Usually primary collection is done in pairs, with each team collecting waste from around 200 households in a day.

To make the scheme profitable, efficiency must be increased by:

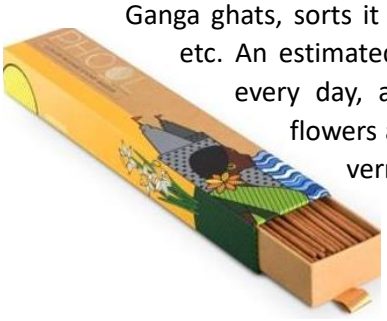
- raising awareness of the public health implications of poor waste management
- improving planning decisions and the enforcement of regulations
- increasing the number of transfer stations at accessible sites
- increasing the number of trucks available for transportation
- promoting compost production from organic waste
- promoting the separation of waste at the source (household level)
- enhancing the collaboration and participation of the private sector and communities.

To make significant and sustainable progress in solid waste management, an integratedapproach is needed that uses a combination of these methods.

Human Dignity through Floral Waste

'Help us Green' is a women's self-help group (SHG)initiative ofAnkit Agarwal and Karan Rastogi.

The SHG collects floral offerings directly from temples, and also from the Ganga ghats, sorts it to remove thread, plastics, incense sticks, etc. An estimated 8.4 tons of sacred flowers are collected every day, and turned into a circular economy. The flowers are turned into incensesticks, handmade paper with seeds embedded and vermicompost. It started in Kanpur in 2015 with an investment of INR 72, 000. Today the turnover is INR 2 crore rupees (FY 2018). Three more units are on the anvil.



Watch film: New life for waste flowers, Duration 6 min. https://www.youtube.com/watch?v=Boogipm_9Qg&feature=youtu.be

2.3 Technological Component: Waste Handling Equipment

To make the process of waste collection, transportation, processing and further action, every waste management service provider must be equipped with efficient waste management tools.

1. **Equipment for Collection- Bags and Bins**
   - **a.** Biodegradable Garbage Bags: Garbage liners and garbage bags are easy to use solutions to contain and transport waste. They are widely used across the globe. Linear Low Density (LLD) trash bags are strong, flexible and highly resistant to puncturing and tearing. They are ideal for kitchen trash, construction debris or trash that includes glass, metal, wood, cardboard or irregular shaped items. High Density (HD) can liners are a more cost-effective option. Manufactured from different resins, they are thinner than Linear Low Density bags and are not as puncture resistant, yet they can carry quite heavy loads. However, there are certain things to remember:
     - ✓ Garbage bags need exposure to sunshine, water and microbes to degrade.
     - ✓ These bags are grade 7 plastic and cannot be recycled with plastics of grades 1 and 2. Their presence can spoil the entire recycling process.
     - ✓ A better alternative to biodegradable garbage bags is compostable garbage bags. These break down in about 6 months (vis-a-vis a regular plastic bag ~~that~~ takes over 100years)

Note: 'Biodegradable' refers to any material that breaks down and decomposes in the environment while 'compostable' refers to organic matter that breaks down to become nutrient-rich soil. Compostable bags are made of corn-based materials such as polyactic acid blends, polycaprolactone, etc.

b. Household Bins: These must be lidded, with or without foot pedal/wheels. These bins are usually made of durable and leak proof material such as plastics. It is important to wash and dry the

Fig 2.1Community Bins with Lids

household bins every day after the waste is collected by the waste collectors.

c. Community Bins with Lids: Community bins must have lids to prevent entry of flies, rodents or stray animals. Special bins which can be lifted and tipped into the collection vehicle should be provided for convenience of service.

2. Transport Equipment

For Primary level transportation:

a. Wheel barrow: It has a single wheel. It is good only for carrying waste to the community collection centres. It is unsuitable for narrow streets, but suitable if the roads are paved well.

b. Hand cart: A three-wheeled cart is more stable especially on poor roads. It can carry larger volumes 1 m^3. It is suitable for door to door collection in crowded areas and for transporting till the community bin or local transfer centres.

c. Cycle cart: It can have separate compartments one for wet andanother for dry waste. It also has drop-down sides to make loading / unloading easy. It is not suitable for bad roads or steep slopes. It can carry up to 3 m^3. In some areas ~~use~~ animals like camel/donkey drawn carts are used. They can carry on steep gradients with ease hence do not need very good roads.

d. Tractor with a trailer: This is costlier. It can carry 4 m3 to a distance of about 20 km.

Fig 2.3 Equipment for Waste Collection and Transportation

A. Cycle Cart

B. Tractor with Trailer

C. Transfer Station

Fig 2.4 Secondary Collection Vehicles

D. Truck with Bin Lifter

E. Hydraulic Compactor

F. Flatbed Crane Truck

For Secondary level transportation:

a. Truck with bin lifter: These are suitable for transferring or collecting community bins.

b. Tipping lorries: A waste collecting tipper box is used for emptying curb-side bins. It needs good roads.

c. Flatbed crane truck: These are useful for transfer stations, markets and industrial areas. It has its own crane for loading and unloading.

d. Hydraulic compactors: This is good for low-density waste in large quantities where roads are good. They are not suitable for high density residential waste. This is expensive and involves high-maintenance cost. Other machines used for handling MSW include auto hopper (a tipping bin is fixed behind an auto rickshaw), high-rise auto, truck mounted street sweeper, mobile toilet, muljet (mini jetting three and four wheelers), super sucker (to empty septic tanks). Trucks are often equipped with GPS tracking devices.

3. Transfer Stations

Transfer stations allow waste to be deposited close to where it is produced and then be taken to disposal sites farther away. This makes the collecting and transporting system more efficient and cost-effective. It also allows the waste to be screened to remove recyclable materials. In addition, transfer stations reduce illegal dumping.

a. Simple transfer station: Manual transfer

b. Mechanically loaded transfer station: Waste is tipped on the concrete floor, from where mechanical shovelling is done.

4. Protective equipment

The staff should be provided with boots, gloves, hard hats, dust masks, high visibility jackets and safety glasses to protect them from sharp items, pathogens, heavy metals and dust and other chemicals.

5. Street Sweeping Machines

(Watch Film: Street Sweeping RAVO 5 Series Sweeper, Duration 4 min
https://www.youtube.com/watch?v=3p1M1C2gYsg)

Street sweeping is an important part of keeping the city clean. It improves air quality and creates a good ambience. Traditionally, sweeping streets is done manually, with brooms on bamboo sticks. This is a tedious, time consuming daily routine.

Street sweeping machines are replacing human street sweepers in many urban areas. The machines are mounted on truck bodies and can vacuum debris accumulated on streets.

Humans sweeping the streets can only remove large particles, and some dust. Smaller particles usually run off along with rain and can cause water pollution. The US-EPA considers the mechanical street sweeping as the best practice in protecting water bodies. The street sweeper machine is capable of collecting particles up to 2.5 μ in size. Water tanker with sprayer loosens dust and debris, which is ~~the~~ vacuumed into the collection bin/ hopper. Regenerative air street sweepers remove debris by centrifugal force, but can be noisy and requiring an extra vacuum pump. These machines have become popular on large railway stations and national highways in India. However, they cannot replace human labour entirely, as many streets are not compatible for this machine.

6. Baling Machines

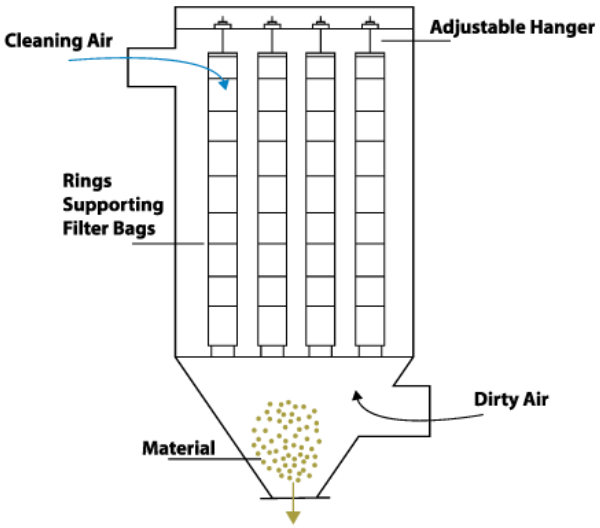
After the segregation of waste into recyclable categories, they need to be baled and tied with wires for easy transport.

Fig 2.5 Baling Machine

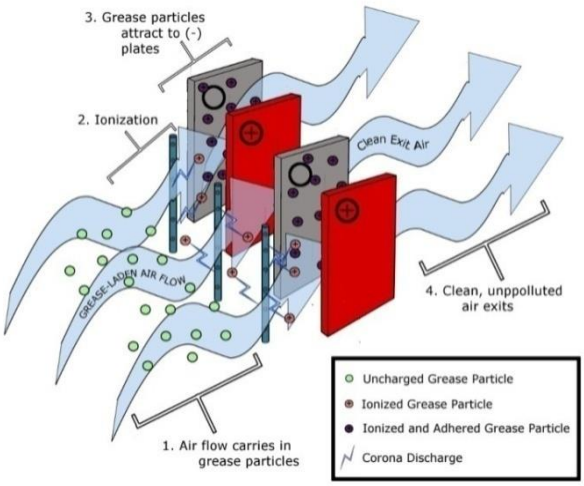
7. Technology to Control Air Pollution

As emission control designs get stringent, incinerators need to meet air pollution emission standards for particulates, sulphur oxides (SO2 and SO3), non-methane hydrocarbons, (H), Nitrogen oxides (NOx) and

carbon monoxide levels in the flue gases. Fine particles from the gas stream are removed by passing through baghouses or electrostatic precipitators.



A. **Bag Filters**



B. Electrostatic Precipitator

Fig 2.6 Equipment to Control Air Pollution

a) Baghouses: Baghouses have been in existence for a long time and their usefulness is being continually extended with advances in media? or substrate material. Baghouses may be reverse air, shakers or pulse jet. They contain a medium which acts as a substrate to which the fine particles adhere. In the process, a filter cake is produced, which needs to be removed physically. The filter media could be fibre glass or ceramic for high temperatures, or else cotton, polyesters or Teflon coatings, matched as per the gas stream's characteristics. These are usually rigid panels, fan-fold ganged together in parallel units.

b) Electrostatic precipitator (ESP): An ESP is a filtration device that removes fine particles, like dust and smoke, from a flowing gas using the force of an induced electrostatic charge minimally impeding the flow of gases through the unit.

Environmental Informatics for Waste Management

RFID technology, "radio-frequency identification", refers to a technology whereby digital data encoded in RFID tags or smart labels are captured by a reader via radio waves. RFID is one method for Automatic Identification and Data Capture (AIDC). RFID tags can be placed on waste bins, garbage trucks. The RFID transponders detect automatic reading, and also detect and signal irregularities in implementation of planned route and scheduling. In some places where bins are tagged, there is a feeling of outrage and intrusion of privacy among the people who fear that the information on the contents of the waste bin could be used to levy a fine for contamination of recycling bins or charge excess for the packaging waste in bins! There are mixed reactions. There are fears that by analysing the content of the trash, the Government bodies can identify personal information about the eating habits of your children or the volume of alcohol consumed. This could be linked to counselling by healthcare workers, etc. Nevertheless, there is great potential for using the information generated by RFID bins, along with RFID

tagging at item level to help manage communities, enforce ~~our~~ rules and improve the lives of those who need help to avoid petty crime and antisocial behaviour. Data collection, evaluation, assessment through GIS and GPS and associated special analysis methods are possible through environmental informatics of waste management.

Fig 2.7 RFID Tagged Bin

2.4 Social Aspects and Managerial Goals

Fig 2.8 Diagrammatic Representation of How RFID Works and Cloud-Based Management of Solid Waste in Cities (Source: Sharmin and Al Amin, 2016)

People do realize that solid waste is an issue. They are aware of the detrimental effects of littering. Yet, their awareness does not prevent them from littering or dumping mixed garbage arbitrarily. This attitude-behavior gap is often due to a variety of reasons including convenience, social norms, lack of public participation, and lack of education and awareness of effective waste management techniques. Causes of public littering include:

- a lack of social pressure to prevent littering,
- absence of realistic penalties or consistent enforcement,
- lack of knowledge of the environmental effects of littering,
- the amount of litter already present at a particular site,
- presence of signs referring to litter,
- number and/or placement and appearance (if any) of waste collection bins at the site.

It is observed that people participate in recycling buybacks and non-littering initiatives not only because of government support or economic reasons, but also because of the social pressure created by the community. They believe that by not adapting to social pressure, they are likely to be looked down upon by their neighbours. Failure to recycle is considered anti-social.

Improving solid waste management requires efforts to raise public awareness, increase funding, build expertise, and invest in infrastructure. To make progress, communities need to embrace new systems for SWM that are participatory, contextually integrated, complex, and adaptive. A positive and proactive partnership approach to waste contractors goes a long way in a successful waste management programme.

Managerial Goals

Certain managerial goals should be set by the municipality. A clear understanding of real waste performance through an audit of waste collection, segregation, recycling, reuse, energy recovery and disposal is needed. The economic model should also be strong. The citizens should pay for the services of waste handling. The waste management operators should get fair income from the sale of compost, recyclables, etc. It is possible that there are areas in the neighbourhood where the residents are too poor to pay a fee for waste collection. In such cases the municipality should pay the operator, based on the total volume of waste delivered to the transfer station.

A Special Case for Waste Management during Festivals

India is a country of rich cultural heritage. Many festivals and events are celebrated with great congregation of crowds. For instance, Pushkar, Ganesh Chaturthi, Sabarimala Yatra. The sudden influx of crowds and their behaviour specific to the occasion generates major stress on the environment. Pre-planning is necessary for maintaining law and order and the supply of basic necessities like water, electricity, and portable toilets. Similarly, a proper planning is needed for waste management.

1. Pushkar Festival and Kumbha Mela

Pushkaram is an Indian festival dedicated to worshiping of rivers. It is celebrated at shrines along the banks of 12 major sacred rivers in India, in the form of ancestor worship, spiritual discourses, devotional music and cultural programmes. The celebration happens annually, once in 12 years along each river: Ganga, Narmada, Saraswati, Yamuna, Godavari, Krishna, Kaveri, Bhima, Tapti, Tungabhadra, Indus and Pranhita. The Bhima Pushkar culminated on 23rd Oct, 2018. The Tapti Pushkar is scheduled in March

2019, followed by Tungabhadra Pushkar in March 2020 and so forth. The first 12 days draw the major crowds to the banks of the holy river.

Every year there are concerns regarding the river water quality and the reduced water volumes at different ghats ahead of the Pushkar. The 2015 Godavari Pushkaralu needed the aid of 25,000 sanitary workers to clear out an estimated 30,000 tonnes of solid waste from the river. The after-effects of chlorination have been studied in the Krishna River post-Pushkaralu, wherein it was found that if chlorination is done properly, the physical properties including pH, conductivity, alkalinity and chlorides is not significantly higher after Pushkaralu. However, turbidity and TDS remained high due to the flowers, cooked rice, fruit and leaf residues. Taking note, A.P and Telangana Governments acted together as they adopted the guidelines of the National Disaster Management Authority, including frequent removal of solid waste, prohibiting soaps and shampoos, as well as chlorination of the ghats to maintain 2 ppm chlorine during the Godavari Pushkaralu of 2015.

Similarly, the Kumbha Mela takes place once in 3 years at Haridwar, Allahabad, Nashik and Ujjain, each place getting a turn once in 12 years. Down to Earth magazine reported that the Kumbh Mela at Nashik in 2018 has left the Godavari River with a 130 times more bacterial load.

2. Ganesh Festival

Mumbai saw the immersion of 2.15 lakh idols into the Arabian Sea in 2017 alone. Only 40.5 thousand idols were immersed in artificial ponds. 1.7 thousand tonnes of floral offerings were made. 2,100 volunteers at Juhu and Versova collected over 1.2 lakh kilos of garbage a day after immersion. This floral waste is dispatched to 5 compost manure plants spread across the city. 7,400 large Ganapati idols were removed from the beach to keep the beach clean.

The city of Pune dumped 120 tonnes of idols and flowers, which were taken out of Mula- Mutha river by volunteers and rag pickers within two days of Ganesh immersion (2018). Led by the Solid Waste Collection and Handling (SWaCH), a ragpicker's cooperative, 'Nirmalaya Swachh River' initiative was successful in protecting the river by diverting over 33,000 idols, nearly 97 tonnes of nirmalaya (immersion wastes like flowers, leaves, decorations, etc.) and 24 tonnes of dry waste. While the nirmalaya was taken to a composting facility, the dry waste was sorted by the ragpickers and then sold to the local scrap dealers, the idols were immersed in artificial tanks placed on the river banks.

Started in the year 2008, the 'Swachh Nirmalaya Mission' has now turned into a mass movement where residents of Pune come together and celebrate an eco-friendly Ganapati festival. In their first year, 12 tonnes of garbage was diverted from the river. Over the years, with more and more households getting Ganapati idols at home, the waste generation has also increased and last year (2017) a whopping 140 tonnes of waste was saved from being discarded into the river.

3. Sabarimala Yatra

'Punyam Poonkavanam' campaign was launched in Sabarimala eight years ago to address the issues of plastic waste in Sabarimala, their effects on wildlife, the mass awareness drive by cinema stars, leaders and media personalities to bring a ban on plastics and cloth waste. The message is that pilgrims must take back the garbage with them on their return. They also must do voluntary cleaning up for one hour at the Sannidhanam. Though Sabarimala is much cleaner than before, the authorities feel that the pilgrims are not self-motivated to assist in keeping the holy place clean.

A 3.5 MLD sewage treatment plant set up in Oct 2015 broke down in 2017 and remains in disrepair, as it was inadequate. The Asianet news report of 2017 brings to light the poor sanitation conditions at the pilgrimage site. A separate 5 MLD STP at Nyunangaar is also insufficient. The sewerage network at the Sannidhanam requires urgent repairs. Amidst the flurry of news regarding women pilgrims attempting to visit Sabarimala, the important news about coliform bacteria rising to 20,000 in 100 ml in the holy Pamba river against the permissible 500/ 100 ml lays unattended. A 10 MLD STP is proposed to meet the needs during pilgrimage.

(Watch Film: Sabarimala temple a shining example of 'Swacch Bharat Abhiyan': PM Modi - ANI News Duration 2 min. https://www.youtube.com/watch?v=8HEyBZ1LpHY)

2.5 Steps in a Waste Management Logistics Process

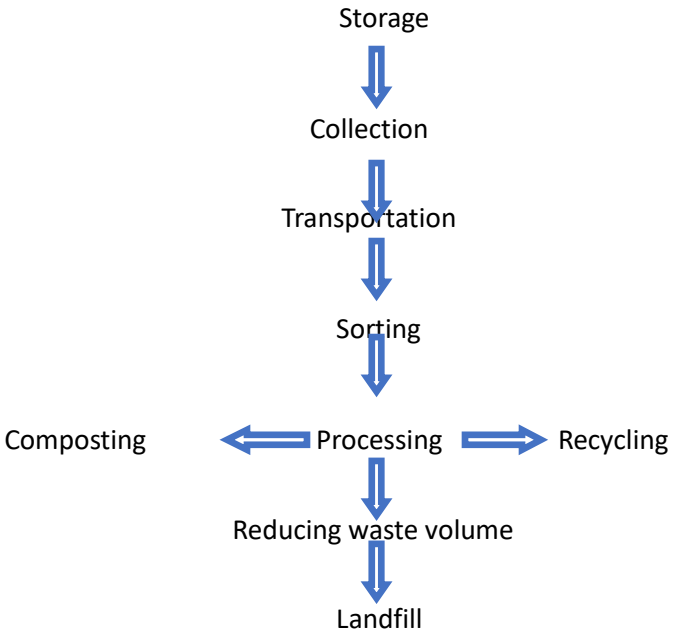


Fig 2.9 Steps in Waste Management Logistics

Storage

Before collection, it is important to ensure that the waste is stored properly in lidded bins to prevent the nuisance of pests, littering and odour.

It is often observed that where a proper waste management system is not in place, families do not keep their waste in closed bins, but instead put all their waste without segregation into a polythene cover, tie it and toss it in or around the nearest garbage heap, usually early in the morning, or before bedtime. This causes a secondary issue of cleanliness around the community bin. Food and drinks waste, vegetable and poultry waste are often carelessly tied into garbage bags and dropped off culverts/ bridges, or in vacant plots along the roadside. Dogs, rats, stray cows etc feed off the mixed waste, thereby creating a further mess and unhygienic conditions. This causes death due to choking in stray animals. Businesses and small shops often burn the sweepings and trash on to the pavement before closing shop for the day. Industrial waste, even from small units, is much larger in volume than residential waste. If not properly stored, it becomes extremely cumbersome and often hazardous to deal with. Often packaging waste, food waste, waste paper and plastics are deposited together, rendering the entire mix unsuitable for recycling.

The proper way of storage should be that waste should be stored in a leak-proof container made of plastic or metal. It should be fitted with a lid so that small children cannot open it and insects cannot get into it. The container should be emptied every day either in the compost pit or given for collection. After emptying, it should be rinsed with water and wiped out if necessary.

The basic rule of thumb should be to make primary segregation as simple as possible for the layperson. A minimum amount of education and training should suffice. Even a young child should be able to dispose waste in the correct bin.
The challenge is to ensure that waste streams never mix. If they do, then the resource potential of both streams is lost forever and the garbage problem stays unresolved and grows out of proportion. This problem can only be met by educating the waste producers (teaching every citizen, training every waste collector), making first-level segregation an auto response (a deeply ingrained habit), formalizing and strengthening the waste management logistics chain and perhaps putting stringent penalties on those who break this golden rule.

Though we have a 2-bin culture of waste segregation at household level in most parts of India, ideally it should be a 3- bin culture. This is the finding of studies across the world that when a 3-bin option is given for curb-side waste collection, the quantity of garbage to landfills diminishes, while organic waste increases.

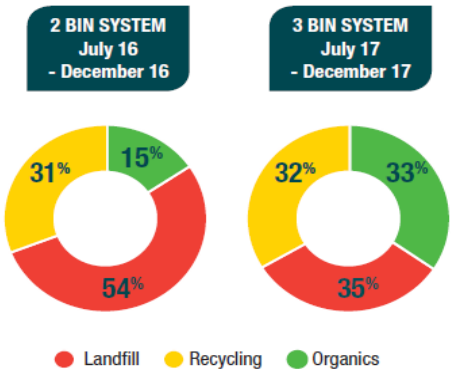


Fig 2.10 A 3-Bin System Keeps More Garbage out of Landfills

In 2015, the Karnataka High Court had directed citizens to adopt a '2-bin-1-bag' system of waste collection and disposal, the BBMP and two citizen groups are supporting the corporation in this initiative. The citizens of Bengaluru, and a few other cities like Gurgaon, Pune, Sikkim, Trichy and Coimbatore, are trying to adopt a three-way model. The three-way model, where sanitary/hazardous waste (sanitary napkins, diapers, blades, bandages, etc) makes up the third category, citizens say, is the best way to go about disposing one's garbage.

SWM in Lakshadweep

Lakshadweep Islands off the West coast of India are a group of 36 islands- 12 atolls, 3 reefs 5 submerged banks and 10 inhabited islands with a population of about 65,000. The calcareous sands are unfit for agriculture, but the islands are very important coral reef ecosystems which are extremely sensitive to pollution. The locals depend on fishing, coconut farming, coir making and tourism. They are the largest consumers of fish in the country! Most food and other resources for the Union territory comes from Kerala and Karnataka. Waste segregation is of utmost importance for coral health. The Ministry of Environment and Forests has a 3-bin waste segregation system that is followed across all the islands. The 3-bin system consists of a green bin for compostables, blue for recyclables and red for used sanitary napkins, etc. While biodegradable waste is composted centrally, a waste segregation unit separates out the recyclables and send it back to Calicut, Kerala, where an NGO looks after further recycling.

The importance of segregation at primary level is well explained in the film:
(Watch film on Tour of London's (Ontario) recycling Centre. https://www.youtube.com/watch?v=c2Tr-U0nALM)

Collection

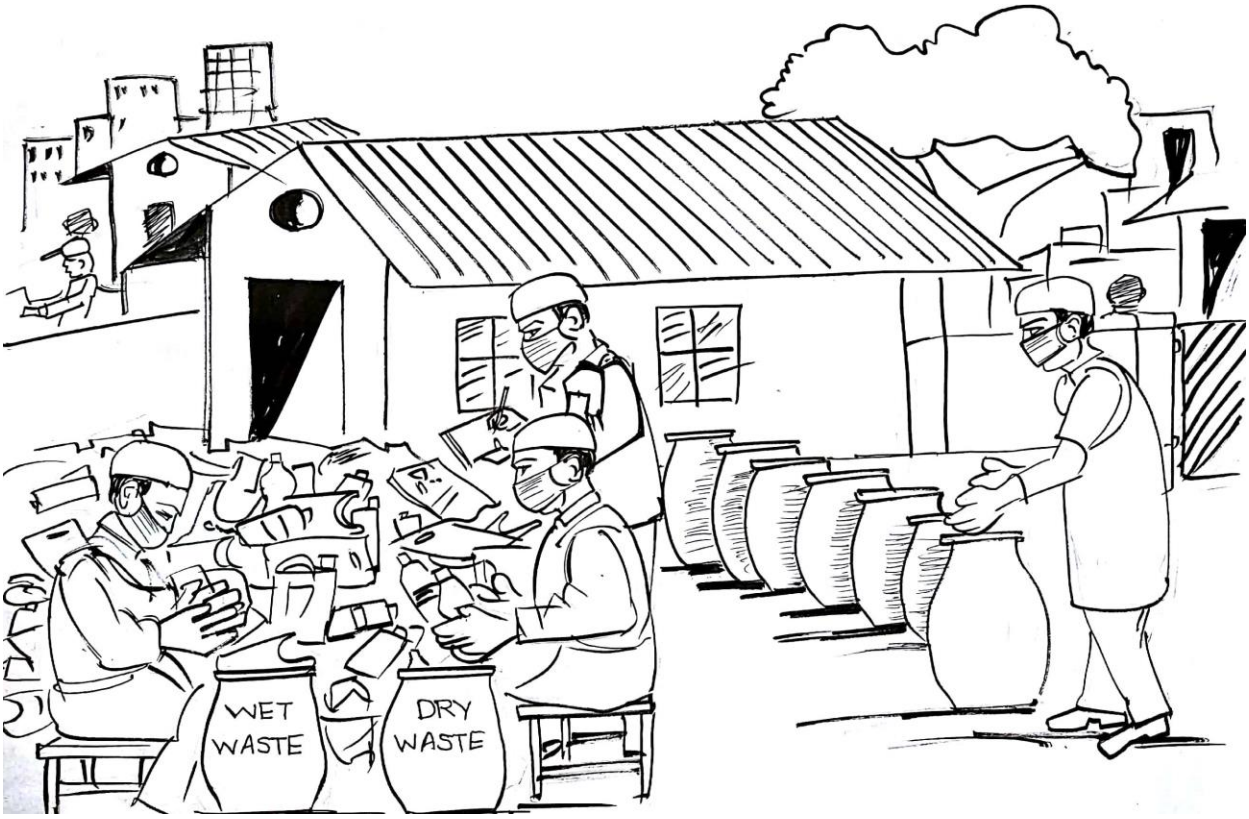
The work of a waste management logistician begins with collection. This process needs micro-planning to ensure:

- Maximum waste is collected with minimum transportation and minimum labour.
- No backlogs are created in the collection.
- There is a back-up plan if there is a breakdown of the collection plan.

For ensuring that waste is collected the customer- business or home must register ~~itself~~ and pay a monthly fee for waste collection. They must agree to follow the rules set by the waste collector, such as segregation, use of colour coded-bins, collection time and dates, method of keeping the waste at the curb side, avoiding putting certain kinds of waste in the garbage, etc. The example of the last category could be hazardous substances like sharps, explodable substances like aerosol cans, toxic material or certain recyclables like cardboard which are collected separately.

Workers collect waste usually in pairs, each pair collecting from 200 households per day. These are brought to community bins using handcarts, cycle carts etc. Road sweepings, waste from businesses etc are also collected and added to the community bins.

Collection is sometimes centralized, wherein bins are kept at a central location and the public bringtheir segregated waste to put in these bins. Such an arrangement also calls for varying degrees of environment awareness and consciousness among the citizens. On the whole, this trend of delivering waste to the common bin is on a decline in India. Countries like Sweden have a 7- bin system where people deposit different kinds of recyclable and dry waste only. They must compost all organic waste at home. It is important that segregation should be done with minimum mistakes to make the task of the waste managing agency easy when they deal with bulk quantities of waste.



Certain waste management companies have a customer care helpline, through which their waste collection needs can be scheduled or prioritized under unusual circumstances. Pre-registration ensures proper planning for manpower and transportation needs by the waste management company.

Under the Swachh Bharat Mission (urban) every effort is being made to practice a 2-bin waste segregation and door-to-door waste collection. Organized women groups (collectives) are being engaged

to do door-to-door waste collection. The municipality provides them with the means of transportation and other necessary safety equipments. Several municipal corporations have tried to outsource waste collection to private agencies in the past, but were disappointed. It has been repeatedly proven in Indian cities that the functioning of a successful garbage management programme requires people's participation as well as the involvement of organized collective bodies (e.g. waste-pickers association or self-help groups) along with municipal involvement.

Manifest

A manifest is a document which the recycler or the waste collector needs to create and the transporter needs to carry. A copy is sent to the recipient. A manifest document is imperative for hazardous waste. The EPA makes it compulsory to fill out a Uniform Hazardous Waste Manifest - a form required by the Department of Transportation for all generators who transport, or offer for transport, hazardous waste for off-site treatment, recycling, storage or disposal. It explains exactly what is present in the load of garbage. If a case of emergency arises during transit, the manifest gives an idea of how to manage the waste.

Manifest is also important for scrap trade, where it reveals the content of each container being shipped from one country to another. A manifest is preserved for at least 3 years. As garbage follows the path from cradle to grave, it is important to follow its journey till the end. Certain segments of waste transformed into useful material. This too can be tracked through the manifest document.
A picture of a manifest form is pasted as an example.

Transportation
The agency transporting waste from the collection site to the processing unit must have a licence to do so. This is the responsibility of the municipality. Sometimes they may use civil hired transport. Waste management logistics is of utmost importance for further processing which requires manpower, transportation, equipment, schedules, coordination and supervision. The government usually has compliance requirements for waste management companies and their employees that should be adhered to for safety purposes.

Planning the route for waste collection vehicles is an important step. A number of transfer stations are placed in urban areas. In most locations, there is only one site for final treatment and disposal, which is usually situated at the edge of the town. Route mapping consists of three stages:

I. Identifying the pickup points and the likely amounts of waste to be collected from each point.
II. Grouping pickup points to form 'collection rounds' that can be served by a single collection vehicle.
III. Planning the route of each collection round taking account of the distance travelled, traffic levels and safety to the public and the waste collectors.

Sometimes GPS is used to track the progress of the waste.

MANIFEST - MANIFESTE

THIS MANIFEST CONFORMS TO ALL FEDERAL AND PROVINCIAL TRANSPORT AND ENVIRONMENTAL LEGISLATION REQUIRING MANIFESTING

CE MANIFESTE EST CONFORME AUX LEGISLATIONS FEDERALE ET PROVINCIALE SUR L'ENVIRONNEMENT ET LE TRANSPORT, REQUERANT UN MANIFESTE

Manifest Reference No.
N° de référence du manifeste

A CONSIGNOR (GENERATOR)
EXPEDITEUR (PRODUCTEUR)

Provincial ID No. - N° d'id. provincial

Company Name - Nom de la compagnie

Mailing Address - Adress postale | City - Ville | Prov. | Postal code - Code postal

Shipping Site Address – Origine de l'expédition

City - Ville | Prov | Postal code - Code postal

Intended Consignee - Destinataire prévu | Provincial ID No. - N° d'id. provincial

Address - Adresse | City-Ville | Prov. | Postal code - Code postal

Receiving Site Address - Destination de l'expédition

City - Ville | Prov | Postal code - Code postal

Physical State Etat physique	Shipping Name of Waste Appellation réglementaire du déchet	Waste Identification Identification du déchet: N° Provincial No. (Quebec - Ontario only) (Québec - Ontario seul)	Waste Identification: TDGA / PIN LTMD / NIP	Quantity Shipped Quantité expédiée	Units L or/ou kg Unités	Classification	Packing Group Groupe d'emballage	Packaging Contenants: No - Nbre	Packaging Contenants: Codes int. - ext.

Special Handling/Emergency Instructions
Manutention spéciale/Instructions d'urgence
Attached [ ] Ci-jointes
Below Ci-dessus [ ]

Date Shipped - Date d'expedition
Yr - An | Mon - Mois | Day - Jour
Time - Heure [ ] A.M. [ ] P.M.

Scheduled Arrival Date/Date d'arrivée prévue
Yr - An | Mon - Mois | Day - Jour

Consignor Certification: I declare that the information contained in Part A is correct and complete
Declaration de l'expéditeur: Je déclare que tous les renseignements à la partie A sont exacts et complets

Name of authorized person (print)
Nom de l'agent autorisé (caractéres d'imprimerie)

Signature

Tel. No. (Area Code) - N° de tél. (ind. rég.)
( ) ( )

B CARRIER
TRANSPORTER

Provincial ID No. - N° d'id. provincial

Company Name - Nom de la compagnie

Address - Adresse

City - Ville | Prov | Postal code - Code postal

	Registration No. - N° d'immatriculation	Prov
Vehicle - Véhicule		
Trailer/Rail Car No. 1 - 1er remorque-wagon		
Trailer/Rail Car No. 2 - 2e remorque-wagon		

Point of Entry
Point d'entrée

Point of Exit
Point de sortie

Carrier Certification: I declare that I have received wastes as offered by the consigner in Part A for delivery to the intended consignee and that the information contained in Part B is complete and correct.
Déclaration du transporteur: J'atteste avoir reçu les déchets offerts par l'expéditeur dans la partie A en vue de leur livraison au destinaire prévu que les renseignements inscrits à la partie B sont exacts et complets.

Yr - An | Mon - Mois | Day - Jour

Name of authorized person (print)
Nom de l'agent autorisé (caractères d'imprimérie)

Signature

Tel. No. (Area Code) - N° de tél. (ind. rég.)
( ) ( )

Circulation No. - Quebec only
N° de circulation - Réservée au Québec

Reference No's of other Manifest(s) used
N°s de références des autres manifestes utilisées

C CONSIGNEE (RECEIVER)
DESTINATAIRE
(RECEPTIONNAIRE)

Provincial ID No. - N° d'id. provincial

Consignee information same as in Part A
L'information à fournir par le destinataire est la même qu'en A [ ]

IF NOT, COMPLETE SHADED AREA - SI NON, REMPLIR L'ESPACE OMBRAGE

Company Name - Nom de la compagnie

Address - Adresse

City - Ville | Prov | Postal code - Code postal

Receiving Site Address - Destination de l'expédition

City - Ville | Prov | Postal code - Code postal

Date Received - Date de réception
Yr - An | Mon - Mois | Day - Jour | Time - Heure [ ] A.M. [ ] P.M.

Quantity Received Quantitié reçue	Units L or/ou kg Unités	Identify Any Shipment Discrepancy Problems. Attach Addendum if Necessary. Indiquer toute différence relative à l'expédition. Annexer une feuille au besoin	Handling Code Code de manutention	Decontamination Décontamination: Packaging Contenants Yes Oui	Packaging Contenants No Non	Vehicule Véhicule Yes Oui	Vehicule Véhicule No Non

If Handling Code "Other" (Specify)
Si code de manutention "divers", spécifier

If waste to be transferred specify intended company name
Si les déchets doivent être transférés, précisier le nom du destinataire

Provincial ID No. - N° d'id. provincial

Address - Adresse | City - Ville | Prov.

Consignee Certification: I delcare that the information contained in Part C is correct and complete.
Déclaration du destinataire: Je declare que tous les renseignements à la partie C sont exacts et complets.

Name of authorized Person (print) - Nom de l'agent autorisé (caractéres d'imprimerie)

Signature

Tel No. (Area Code) - N° de tél (ind. rég)
( ) ( )

Innovative and Informative Idea- The Ghanta Gadi Jingle.

Nashik municipality has created a special jingle for the 'Nashik Ghanta Gadi' which collects waste from residential areas. Every waste collecting vehicle has a loudspeaker that plays this song. This has popularized waste segregation and educated the public as well.

Sorting at the secondary level (in transfer stations)

Segregation can be of several categories. The Japanese village of Kamikatsu has turned segregation into an exacting art, with 34 categories, that too at a primary level, at home. But without Japanese discipline, this model cannot be replicated across the world.

In India, most of the segregation is done by the informal sector of kabadi/ bhangar walas (waste collectors). This secondary level segregation takes place mostly at the waste dumps after collection and transport. Once the waste reaches the transfer station, it is to be decided how best to deal with it. It makes sense to extract as much usable material out of it to make the business profitable and prevent resources from reaching the dump yards.

Many of the items can be recycled easily. These include aluminium cans, glass, steel, paper and certain plastics**.** The film on 'Tour of Ontario's Recycling Centre' clearly depicts segregation within the recycling centre. A similar format of segregation is practiced in Indore, Pune.

(Watch Film on Sarthak Indore: Plastic Waste Management project -Movie made by UNDP Duration 2min. https://www.youtube.com/watch?v=7NwpQUw9gIs)

Care should be taken for proper segregation of dry waste into categories of metals, glass, paper, cardboard and plastics. Each segregated waste stream is sent separately for recycling. There are codes for segregation, which need to be understood and followed. Some of these are explained in the next chapter.

Other things that can be recycled include:

- Batteries: rechargeable batteries contain heavy metals, nickel, cadmium and zinc. Hence they MUST be recycled instead of throwing away.
- CDs/DVDs/Video Game Disks: These can be refurbished and resold.
- Eye Glasses: The lenses and frames of eyeglasses can be remade.
- Foam Packing
- Razors/Toothbrushes: If the plastic is recyclable, you can recycle these common toiletries.
- e-waste: electronic goods like cell phones, computers and old appliances.

There is also much confusion about categorizing certain waste. For instance, cardboards are often coated. They may be poly-coated, which makes them recyclable, but not compostable. Meanwhile wax coated items can be composted, but never recycled, because the wax comes off during the pulping process and makes the freshly recycled paper unfit for printing.

Composite materials are hard to recycle as they are made of many plastics. TerraCycle, a USA based innovative recycling company works on recycling hard-to-recycle waste including latex gloves, pens and cigarette butts to name a few. They have a setup with Colgate to recycle toothbrushes, floss boxes and toothpaste tubes. Most recyclers do not accept such material. TerraCycle is not yet present in India. It is a good business opportunity to venture into recycling of hard-to-recycle waste.

Once the waste is segregated, it is baled and sold off to the respective recycling centre. This is a major source of income for the waste management facility.

Processing of waste

Recycling, composting, reusing resources from the waste stream are discussed in the next chapter.

Reducing waste volume

After extracting all the recyclable, reusable, compostable materials, we need to find ways to reduce the bulk of the remaining matter. There is an option of burning the waste, which releases heat and noxious gases and the other option is to dump it on land or in water. These are both primitive and do much harm to the environment.

Burning is called Transformation, which "refers to incineration, pyrolysis, distillation, or biological conversion other than composting." They are very different things.

The advanced systems to burning are incineration and pyrolysis.

a. Pyrolysis is the thermal break down of materials at high temperatures in an inert atmosphere. It is Greek for 'separated by fire'. It involves the change of chemical composition and is irreversible. Pyrolysis is commonly used to treat organic materials. For instance wood starts charring at 200–300 °C. It produces volatile products and leaves a solid residue enriched in carbon, char. This is called carbonization. Dry distillation, destructive distillation, cracking, and thermal depolymerization are special methods of pyrolysis. Pyrolysis is used heavily in the chemical industry to produce ethylene, many forms of carbon and other chemicals from petroleum, coal and even wood, to produce coke from coal. Ethylene is produced by steam cracking of petroleum. Pyrolysis is also used for thermal cleaning of extruder screws, spinnerets and static mix.
b. Converting plastics to diesel: Anhydrous pyrolysis converts plastic waste back into the oil from whence it came. 1 Kilogram of plastic is turned into 1 Litre of diesel instead of 3 Kilograms of CO_2. Despite how simple it looks, it is not considered very effective because it uses up a lot more energy than it creates.
c. Incineration: This is a thermal treatment where waste is burned to become flue gas, heat and ash. The ash contains mostly inorganic matter. The flue gas must be cleaned thoroughly.

Incineration and pyrolysis are practiced particularly for hazardous wastes. There are stringent rules and regulations for the same. Incineration of municipal solid waste avoids the release of methane. Every ton of MSW incinerated, prevents about one ton of carbon dioxide equivalents from being released to the

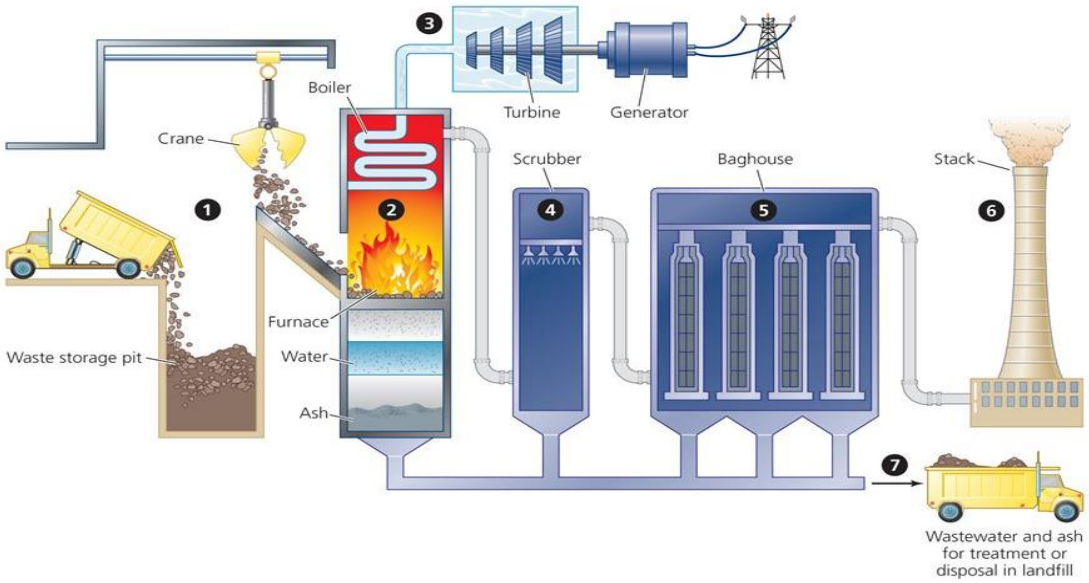


Fig 2.12 Diagrammatic Representation of a Solid Waste Incinerator

atmosphere.

d. Gasification: Gasification is similar to incineration in principle. Gasification produces a combustible gas. We need to maintain stringent watch on the exhaust gases, as burning of waste pollutes the atmosphere. However in Sweden, a country with several years experience in this field has proven that there are technologies available which can remove a good volume of pollutants from the flue gases resulting in a 50% cleaner exhaust.

Incineration and gasification can both be done with or without energy recovery. These three methods- incineration, pyrolysis and gasification- reduce solid mass of waste by 85% or more, incineration is particularly used in bio-medical waste management to destroy pathogens.

There could be many health hazards connected to incineration:

- Highly toxic flue gas must be safely deposited- this needs a separate specialist toxic landfill site.
- Old incinerators release furans and dioxins. They also emit varying levels of heavy metals which are toxic at the minutest level.
- Incinerator Bottom Ash is eco-toxic, with heavy metals like cadmium, vanadium, manganese, chromium, nickel, arsenic, mercury and lead present in it.
- Alternative technologies for the reuse of incinerator bottom ash are in their infancy.
- The fear of toxic air and the absence of monitoring fine and ultrafine particle emission, local people usually oppose incinerators.

Therefore it is heartening to note that most countries that use incineration (e.g. EU, Japan) understand the hazards of incineration and keep it to the minimum. As a result they have higher recycling rates than neighbours that do not.

e. Waste to Energy

In a waste to energy facility, extremely high-temperature combustion is used to generate electricity. Emissions from the waste to energy facility are thoroughly cleaned using state-of-the-art air quality control systems. Trash brought to the waste-to-energy plant is first inspected to ensure it contains only acceptable municipal waste. The waste is deposited into a refuse pit. A crane picks up the trash from the refuse pit and loads it into hoppers. Hydraulic rams feed the trash into furnace boiler units. Heat from the burnt trash converts water in the boiler walls into steam. The high pressure steam is routed to a turbine generator to produce electricity. Three tonnes of waste produces as much energy as one tonne of fuel oil.

A key barrier in waste to energy is the shortage of qualified engineers and environmental professionals with the experience to deliver improved waste management systems in India.

(Watch Film: Importing garbage for energy is good business for Sweden, Duration: 4 min.
https://vimeo.com/103801887)

Waste to energy plants are very clean since they filter out almost all of the dioxins and other gases that comes out of incinerators. What comes out is “99.9 per cent non-toxic carbon dioxide and water.” There are many who question whether carbon dioxide is non-toxic, given its effect on the climate.

Bioremediation

Remediation of the damaged environment is part of the process of ‘sustainable development’ and as such a polluter is liable to pay the cost of the individual sufferers as well as the cost of reversing the damaged ecology.

To remove, treat and dispose hazardous and non-hazardous industrial waste, a special licence is required. The technique to safely remove toxins from soil using natural methods is called bioremediation. A two-stage solid phase bioremediation technique is employed, which involves both aerobic and anaerobic treatment stages. Explosive-contaminated soil, chemical manufacturing waste, pesticide waste, or pesticide contaminated soils, spent molecular sieve from packing towers, soils containing aliphatic chlorinated hydrocarbons, petrochemical contaminated soils, etc can be bio-remediated. For each kind of soil, the first stage comprises of mixing in a carbon source, an inoculums, vitamins and water to achieve anaerobic conditions. The basic requirements for bioremediation are:

- ✓ Microorganisms
- ✓ Energy source
- ✓ Electron acceptor
- ✓ Moisture
- ✓ pH
- ✓ Nutrients
- ✓ Temperature
- ✓ Absence of toxicity
- ✓ Removal of metabolites
- ✓ Absence of competitive organisms

The inoculum contains spores or colonies of fungi, bacteria and other microorganisms which have been tested to tolerate high level of contamination and are capable of neutralizing the contaminants. Hence the inoculum is different for each kind of contaminant.

- Aerobic bacteria such as Pseudomonas, Sphingomonas, Rhodococcus and mycobacterium are shown to degrade pesticides and hydrocarbons, alkanes and polyaromatics.
- Methanotrophs are Aerobic bacteria that use methane for energy. Methanotropsh are useful for bioremediation of ethylene dichloride.
- Anaerobic Bacteria: For polychlorinated biphenyls (PCBs) in river sediments, trichloroethylene and chloroform.
- Fungus: for persistent and toxic pollutants.

After inoculating and mixing the right ingredients for supporting the growth of the inoculums, a static pile or berm structure is created and covered. After a few months, anaerobic bacteria from the inoculums digest the toxins making the treated soil ready for the next stage, i.e. aeration. By this process of bioremediation, harmful chemicals like TNT and DDT can be removed up to 99%. Large scale remediation can be done for acetone, alcohols, benzene, toluene, xylene, 2 to 3 ring PAHs and petroleum hydrocarbon.

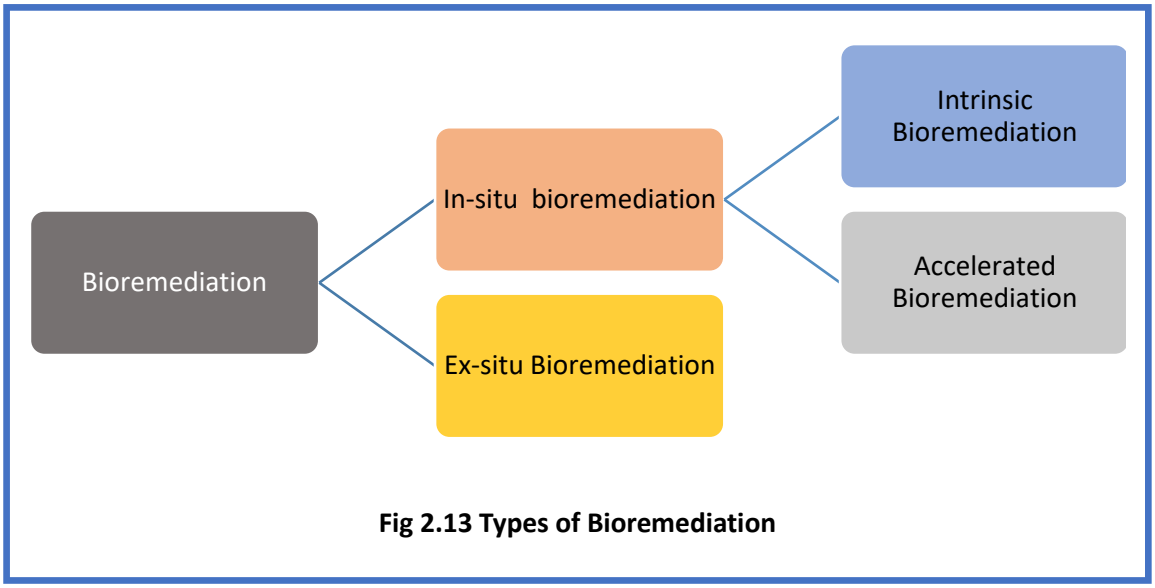


Fig 2.13 Types of Bioremediation

In intrinsic bioremediation, the microorganisms already present on-site are used. Human intervention is not required. This is the most common and inexpensive method. When it does not work, accelerated bioremediation is applied. In this either some substrate, or nutrients are added to help break down toxic spill, allowing the microbes to grow faster. In situ treatments manage sub-surface contaminants with optimal microbial biodegradation. Local (indigenous) microbes may be used, or specialized microbes efficient in degrading the particular contaminant may be introduced.

Accelerated bioremediation causes minimum disturbance to the site, particularly when the contaminants are moving under a permanent structure.

Steps in in-situ Bioremediation

Step 1: Site investigation
Step 2: Treatability Studies
Step 3: Recover free product, remove contamination source.
Step 4: Design and implement bioremediation system
Step 5: Monitor and evaluate performance.

Examples of In situ Bioremediation:

- Bioventing: This is the most common land treatment. Air and nutrients are supplied through wells to stimulated local bacteria.
- In-situ biodegradation: Here oxygen and nutrients are supplied by circulating an aqueous solution through contaminated soils.
- Biostimulation: Fertilizers are added to stimulate the growth of naturally present bacteria which are capable of degrading pollutants.
- Bio-augmentation: Also called 'seeding'. Bacteria are added to the contaminated soils to support indigenous microbes.
- Biosparging: Air is injected under pressure into the groundwater to increase dissolved oxygen so that the bacterial activity is accelerated. Biosparging increases contact between soil and groundwater.
- Natural Attenuation.
- Rhizofiltration

Examples of Ex-situ Bioremediation

- Land farming: Excavated contaminated soil is spread over a prepared bed and periodically tilled.
- Composting: Non-hazardous organic wastes like agricultural residues are mixed in and allowed to degrade together. Elevated temperatures and rich microbial growth accelerate the degradation.
- Bio-piles: ??
- Bio-reactors: for slurry based contaminants. Here water, oxygen and fertilizer is mixed into the slurry for degrading pollutants.

When contaminated soil is transferred for cleaning up, it is ex-situ bioremediation. This is expensive and damages the area, since the soil is physically removed.

Bioremediation is limited to those compounds that are biodegradable. Sometimes the resultant product may be more persistent than the parent compound. It is a longer process. A suitable environment must be given to the microbes- nutrients as well as contaminants. Sometimes genetically engineered microbial strains are applied, such as petroleum eating bacterial- Pseudomonas with encoded genes for breaking up pollutants. Or, Escherichia coli used to clean heavy metals - mercury, chromium and cadmium. Certain bacteria are used as indicators, or 'biosensors' to judge the presence of certain environmental pollutants. Certain phytoremediation (plant based bioremediation) can remove TNT.

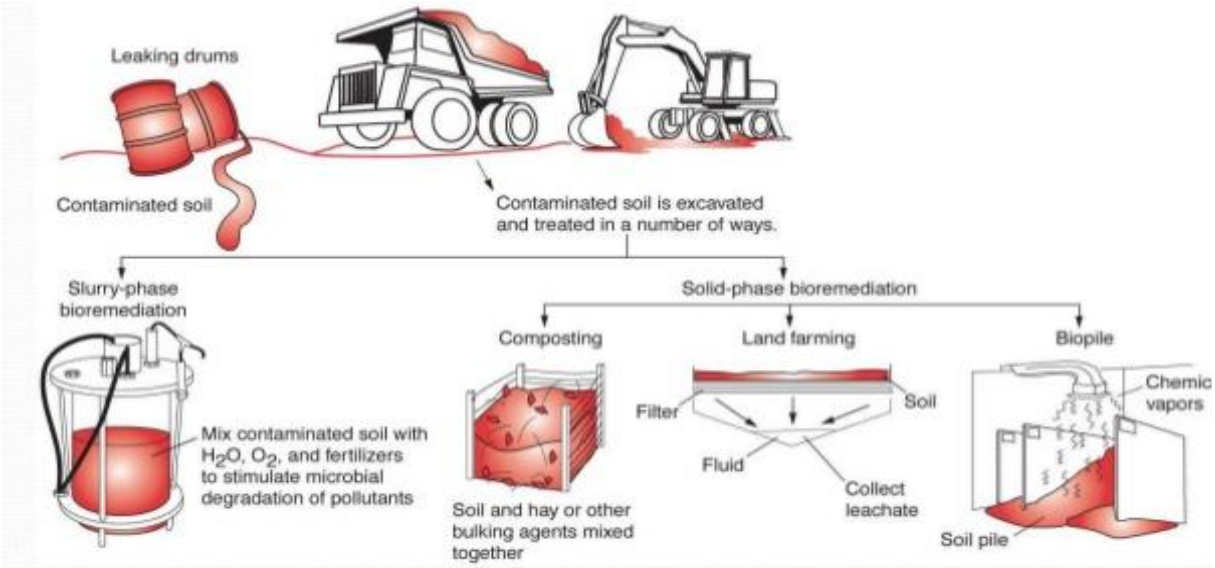


Fig 2.14 Methods of Ex-situ Bioremediation

Source: Azeem (2013) Bioremediation-of-contaminated-soils

Compaction

Waste compaction is done to compress the waste in a landfill to reduce volume and extend the lifespan of a landfill. A landfill compactor rolls over layers of flattened waste at least thrice to eliminate voids.

The remaining waste, which has no further use could include inert waste, non-recyclable plastics, textile waste, composite material for which recycling technology is yet to be invented. A combined study by SAARC, NEERI and the Royal Society has established that reliance on waste dumps is neither sustainable nor environmentally safe for fast-growing cities.

(Source: Challenges and opportunities associated with waste management in India. Sunil Kumar et al, Mar 2017. http://rsos.royalsocietypublishing.org/content/4/3/160764.)

Fig 2.15 Landfill Compactor

This film explains total waste management achieved by the industrial town of Nashik, Maharashtra.

(Watch Film: Nashik Waste Management, Dur: 6 min: https://www.youtube.com/watch?v=JXmDJtJ-mMw)

Landfill

In most cases disposal sites are located in environmentally sensitive, low-laying areas such as wetlands, forest edge or adjacent to bodies of water. They often do not have liners, fences, soil covers and compactors. When waste breaks down in landfills it creates methane – a greenhouse gas and leachate – a toxic liquid. Methane is 25 times more potent than carbon dioxide as a green house gas. Leachate is highly toxic. It pollutes the surrounding ground and can find its way into rivers and oceans. Each year the amount of waste we throw away increases by 3%. This means by 2025, the waste we produce will have doubled.

Engineered Landfill: An engineered landfill is an engineered system designed for safe, environmentally sound long-term waste disposal. Trash is deposited in the landfill and compacted. The landfill's liner as well as gas and leachate extraction system protects the surrounding land, air and water. Operating procedures include regular environmental monitoring. Residential and commercial waste is transported to a waste management landfill for permanent disposal. Much of this waste including food, paper, cardboard, is organic in nature. Bacteria digest this organic waste and produce methane gas and carbon dioxide as natural by-products. The methane gas is recovered via a series of wells drilled into the landfill. These wells are connected by a common pipe system that collects the gas and delivers it to a fuel conditioner. The gas is piped to an electricity generation plant, on- or off- site.

Though technically sound and a great improvement from waste dumps, yet landfills ~~are~~ is not the most sustainable method of disposing waste. Landfills need constant monitoring and are expensive to build. Hence they are not popular in India.

For any solid waste management enterprise, the aim should be to make garbage reaching the dumpsite to a bare minimum. As recycling and waste minimization gain attention, the amount of organic waste in landfill sites is bound to be low too. With only inert materials sent to a landfill, it will take several years to settle and very minimum methane will be generated.

Bioreactor Landfills: To better the system, bioreactor landfills are considered the future of landfill management. Instead of being secured waste repositories, landfills can be turned into waste treatment systems through bioremediation. The most important condition to promote waste decomposition is moisture content. Landfill leachates, gas condensates, waste water treatment sludge and storm water runoff can be added to maintain moisture. Leachate recirculation not only reduces leachate management cost, but also improves leachate quality. Bioreactor landfill process is still under development. Four types of technologies can be used: aerobic-anaerobic, anaerobic, aerobic and facultative. The process can be retrofitted to old landfills as well as to new ones. In India, we do not have many engineered landfills. The challenge is to stabilize our garbage dumps with minimal pollution.

Capping of Waste

The final act to be done in garbage disposal is capping. Caps do not destroy or remove contaminants. Instead, they isolate them and keep them in place to avoid the spread of contamination.

Therefore, just before capping, the waste heap needs to be bio-remedied. Various inoculums containing fungi and bacteria are added to the soil, which helps to capture or breakdown any toxic materials to leave the waste inert. The entire heap is compacted by heavy machinery benched and sloped and then covered with multiple layers of soil, silt, geo-textiles and finally topsoil. The gradient of the slopes should

be gentle. This artificial hill is then vegetated at first by fast growing tree species. As the vegetation flourishes, more indigenous tree species are planted till the entire area is naturalized. It takes around 15 years to re-wild? the dump yard. The process is similar to that of rehabilitating mining waste.

Waste dumps are big eyesores for nearly every city. Under the Swachh Bharat Abhiyan an effort is being made to cap legacy waste dumps. Legacy dumps are those waste dumps, from which most of the recyclables have been recovered and now no waste added. After a few years of stabilization, they need to be capped to prevent water pollution due to leachate draining out after the monsoons. This is a major operation.

Case Study: Jawaharnagar Legacy Waste Dump Capping project, Hyderabad

The Greater Hyderabad Municipal Corporation has undertaken one such mega project- The Jawaharnagar Legacy Waste Dump Capping project. The Jawaharnagar dump yard gathered a 70-80 metres high hillock of waste, amounting to 12 million tonnes, deposited between 2001 and 2012.

Since the inception of Integrated Municipal Solid Waste Management Project in January 2012, Greater Hyderabad Municipal Corporation has begun processing all its municipal waste. By October 2017, they became capable of processing 100 per cent of their entire 5,000 MT of garbage into manure and energy.

The entire waste is being segregated and compost is being generated, besides refused derived fuel (RDF). Of the waste, nearly 40 per cent is used for generating RDF, which is produced from various types of wastes, including municipal solid waste. About 20 per cent is used for generating compost and the rest is utilised for scientific landfill. Every day, nearly 350 tonnes of compost and 2,000 tonnes of RDF are generated at the plant in the yard.

Fig 2.16 Step 1- Compacting

Fig 2.17 Leachate Pollution

The Jawaharnagar Waste dump has two portions- the Legacy Dump admeasuring 130acres, where no garbage has been added since 2012, and a 170 acre section which is kept aside for waste management. The reclamation work on the dumpsite began in December 2016. By Dec 2017, 95% of the garbage profiling was completed.

GHMC aimed to arrest leachate discharge from the 12-million-tonne Legacy Dump into the surrounding lakes. Malkaram Lake was so highly polluted by leachate seeping from the legacy dump that the water turned black and the plant life in the lake was almost dead. During rains, the situation worsens as the overflowing lake pours its pollutants into other water bodies in its network, including Dammaiguda Cheurvu and Pedda Cheruvu.

Fig 2.18 Step 2- Terracing

Fig 2.19 Step 3- Capping, geotextile awaited

The Concessionaire, Hyderabad integrated Municipal Solid Waste Limited (HiMSW), a subsidiary of Ramky Enviro Engineers, had established a leachate pond, but it was overflowing into the nearby water bodies. Drainage pipes needed to be laid to pump out leachate emanating from wet garbage inside. These could control seepage from the wet garbage to a large extent, but not completely, thereby leaving the ground water at the dumpsite polluted. Leachate seepage occurs when the slime oozing out of the legacy dump is mixed with rainwater and flows out into lakes and other water bodies. Leachate already collected in small ponds around the dump yard still needs to be treated before it is let into Musi River.

Of the total 7.5 million litres of leachate only 2.4 lakh litres have been treated through the two treatment plants each of two kilo litre capacity per day. Ramky Enviro Engineers has been managing this dumpyard and the leachate issue since 2012.Capping the dump costs Rs. 147 crore. This is a non-revenue generating activity. The cost was borne by GHMC, HiSWM and Swachh Bharat Mission.

In March 2018 the gigantic task of capping the entire 14 million tonnes of garbage began. Nearly 4.5 lakh tonnes of soil was used to cover the garbage with a single layer. The GHMC deployed heavy machinery like excavators, bulldozers and compactors for the task. Every day, about 6,000 tonnes of soil, excavated from Nalla Cheruvu, Uppal, Cherlapally Lake and Cherlapally Jail Lake, was transferred to the dumping yard. Considering the distance, excavation from Nalla Cheruvu was stopped later. Heavy trucks and tippers made several trips, at times 1,000 to 1,500 trips a day, carrying the soil from the lakes. The soil was then levelled by the bulldozers and the rolling work was done by compactors. A total of 5.5 lakh tonnes of soil has been excavated from Kapra Lake and Nalla Cheruvu of Uppal for this purpose. The final layer will require an additional 6.5 lakh tonnes.

By June 2018, the first layer of history was levelled and a one-foot thick soil capping began. The residents of about 30 villages surrounding the dump yard heaved a sigh of relief. A channel was dug to circumvent the Malkaram Lake.

Though it is difficult to comprehend the 130 acre-yard being capped by soil, this is just the first layer and six more are to come, which is why this is one of India's largest capping work projects.
The 300 mm thick soil cover will be followed by a non-permeable geosynthetic clay liner, a flexible geocomposite membrane layer of HDPE, and a geo-drainage layer made of geotextile to provide storm water channels on the mound. Final topping will be of restoration soil with 450 mm thickness, one more soil layer of about 1.5 feet thickness and finally the vegetative layer, on which plants will be grown. Gas vents will be provided in the dump to collect and fire Methane and such other gases produced within.

In Oct, 2018 Municipal Administration and Urban Development assured that the capping work at Jawaharnagar Dumpyard were progressing at brisk pace. The entire 7 layers are expected to be laid by April 2019.

Due to water contamination, the GHMC is supplying drinking water through tankers to residents of 14 villages, including Cheriyal, Dammaiguda and Nagaram, surrounding the Jawaharnagar yard at a cost of Rs 2.5 crore this year. This apart, as a permanent measure, the municipal corporation has deposited Rs 4.61 crore with the Hyderabad Metropolitan Water Supply and Sewerage Board for laying pipelines to these villages. The project of laying pipelines is under way.

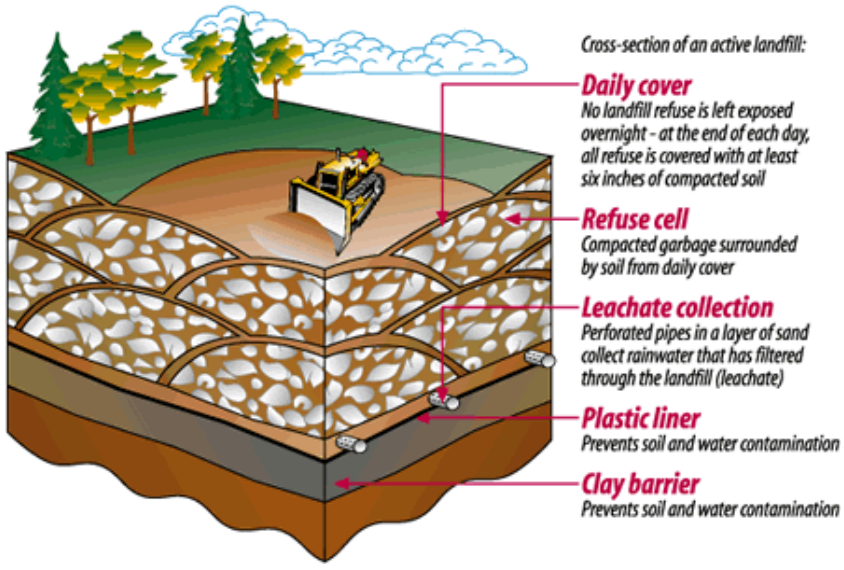


Fig 2.20 Cross section of an active landfill

This case study explains all the components and processes required for successful capping of waste. It also gives an insight into the vision, political will, expertise, cooperation between public and private sector, labour, finance and effort required to handle the problems of solid waste. In the near future there will be much demand for this exercise across different cities in India.

Summary

Waste Management needs societal support, manpower, equipment and technical expertise. The intention is to safely transport the waste from the source to a common area, remove as much re-usable, recyclable, compostable components and energy out of it and reduce its volume before safe disposal. The waste dumps must be carefully managed to prevent pollution, before being scientifically capped with good soil and put to alternative use.

Self- Assessment Test

1. Explain logistics and waste management
2. Discuss on Equipment, transport, RFID and cloud based waste management
3. Discuss on waste segregation. Compare 2-bin and 3-bin models
4. Explain on compaction, W to E landfills and dangers involved.

Explain why transfer stations are needed.

2. If you are a solid waste collection manager of a small town, what equipment will you need for operating effectively?
3. Briefly explain the steps in waste management.
4. What are the social aspects to be considered for a successful waste management programme?

Films

1. Waste Picker's life and livelihood. Duration: 11 min. https://www.youtube.com/watch?v=aLda8O2ySMc)
2. New life for waste flowers, Duration 6 min. https://www.youtube.com/watch?v=Boogipm_9Qg&feature=youtu.
3. Film: Sabarimala temple a shining example of 'Swacch Bharat Abhiyan': PM Modi - ANI News Duration 2 min. https://www.youtube.com/watch?v=8HEyBZ1LpHY
4. Indore waste collection: Duration: 8 min https://www.youtube.com/watch?v=V98Pbum1wQA
5. Tour of London's (Ontario) recycling Centre. https://www.youtube.com/watch?v=c2Tr-U0nALM
6. Street sweeping RAVO 5 series sweeper, Duration 4 min https://www.youtube.com/watch?v=3p1M1C2gYsg
7. Sarthak Indore: Plastic Waste Management project -Movie made by UNDP Duration 2min. https://www.youtube.com/watch?v=7NwpQUw9gIs
8. Importing garbage for energy is good business for Sweden, Duration: 4 min. https://vimeo.com/103801887
9. Nashik Waste Management, Duration: 6 min: https://www.youtube.com/watch?v=JXmDJtJ-mMw
10. Sanquelim Reclamation Mines - Vedanta Sesa Goa Initiative, Duration 9 min, https://www.youtube.com/watch?v=5zJtHnEXLUM

Chapter 3
Waste Processing - Composting, Recycling and Reusing

Objectives

- To know the components of solid waste that can be recycled
- To understand the simple methods of composting and its benefits

Structure

3.1 Composting –Types and Processes
3.2 General Process of Recycling
3.3 Precautions for Recycling –Aluminium, Glass
3.4 Precautions while Recycling of Plastics
3.5 Precautions while Recycling paper
3.6 Re-use

To Do Activities

1. Begin with a small practical exercise of setting up a compost pit. It could be in the ground or in suitable containers. This project can be expanded as the course progresses.
2. Explain the Waste Management Hierarchy. Discuss in class what level they observe themselves and their neighbourhood. What steps would be ideal.
3. Classroom teaching of Aerobic, anaerobic composting, vermicomposting, pipe composting. Ask students to explore the Krishi Vikas Kendras and other NGOs/ businesses selling microbe mix for quick composting. Encourage them to experiment with their compost pit. Let them practice composting leaf litter, too.
4. Visit to any agency involved with composting of Municipal Solid Waste to observe open windrow composting, mechanical composting and the different steps involved in the composting business etc.
5. Watch videos of preparing biodiesel from waste cooking oil.
6. Run an experiment to prepare biodiesel, if possible. Source waste oil from the College Canteen
7. Make students interview one or two recyclers, or waste collectors. The student can report their findings in a class seminar.
8. Prepare a composting pit for leaf litter collected from your campus, modelled on “amrit matti’.
9. Set up a composting pipe and use it at the college for kitchen waste. What are the practical difficulties with the system? How can it be overcome?
10. Collect plastics from the campus. Segregate them as per categories. Take guidance from a plastic recycler/ scrap dealer. Understand the difficulties faced when the recycling codes are absent.
11. Create hand-made paper out of beverage cartons.
12. Make your own biogas plant https://www.instructables.com/id/Bio-gas-plant-using-kitchen-waste/
13. Make your own biodiesel with waste cooking oil.
14. Discuss on what topics each student is interested in, scope out possibilities of career development, research or internship opportunities.

Introduction

Segregated waste is a valuable resource. Once the waste has been segregated into different categories, it moves for processing, sometimes in situ, at other times to a different location. This component of waste management generates revenue. Value extraction can be materials, energy or nutrients and this can provide a livelihood for many people.

At least eighty per cent of waste generated by an average person is recyclable. If not properly recycled, majority of it ends up in landfills. This amounts to one and a half ton per person every year- equivalent to the weight of a small car.

Fig 3.1 Hierarchy of Waste Management

This Waste Management hierarchy prioritizes source reduction and reuse as the first step, which students will have studied in Course 1. Therefore, this chapter will begin at the second step of the waste management hierarchy, which is composting and recycling.

3.1 Composting- Types and Processes

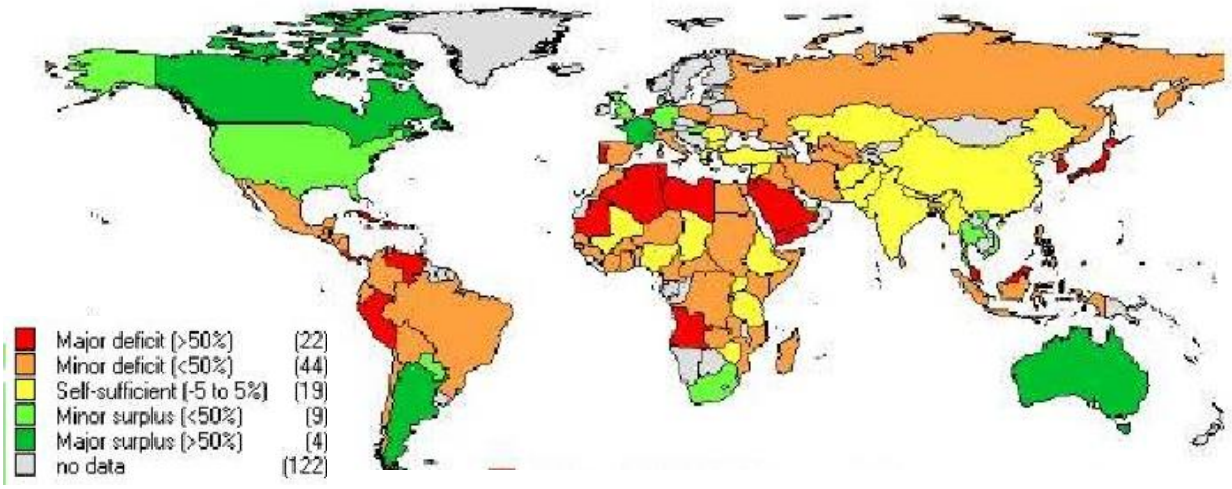
Food waste is a major component of solid waste. According to the United Nations Development Programme, up to forty per cent of the food produced in India is wasted. According to the Ministry of Agriculture, Rs. 50,000 crore worth of food produced is wasted every year in the country. India's food waste equals the total food consumption of UK.

Much of municipal waste including kitchen waste, food waste from hotels and leaf litter and plant trimmings is compostable. Fruits and vegetables have the highest wastage rates of any food - with roots and tubers not far behind. This is because these items are perishable. Almost a third of the world's cereals are lost or wasted each year. The rate stands at twenty per cent for meat and dairy, and thirty five per cent for fish. Studies have found that households throw away food for a variety of reasons, including preparing too much food and not using items in time.

It is important to distinguish between food loss and waste:

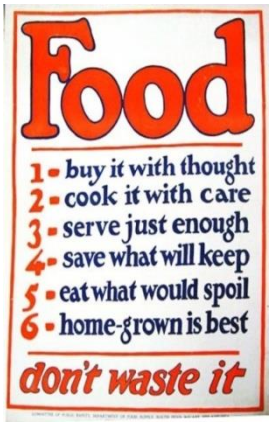
- Food loss: Occurs between production and retail
- Food waste: Occurs between consumption and retail

Food Waste and Global Hunger



Around two million people across the world are malnourished. This is due to insufficient food, low income, inadequate food distribution and land degradation. On the one hand, one-third of the world cropland has been abandoned due to erosion, while on the other hand the world population is set to double in 2050. With land shortage, water shortage, pollution rising dependence on petroleum to run intensive farming, we are facing a global food security threat. The rich and the emerging countries have a meat-based diet, which requires much more land and water to support than a vegetarian diet. However, the greatest disaster is the wastage of food during storage and wasteful consumption,

To combat this, besides better storage of perishables, cold-storage logistics, better warehousing, another trend is gaining popularity- that of **recycling food**. Food waste collectives take food from food outlets and supermarkets, food which is still good to eat, but past its sell-by date and provide it to the hungry. Food redistribution events bring together donors of surplus foods with organizations that provide food to the needy.



It is advised to individuals and institutions to avoid waste by following this mantra:

- ✓ Plan ahead
- ✓ Buy what you need
- ✓ Buy local foods (less preservatives, less transport, therefore lower carbon footprint)
- ✓ Choose to be vegetarian
- ✓ Store Correctly
- ✓ Cook the right amount
- ✓ Eat it all, or store leftovers for the next immediate meal
- ✓ Recycle what you cannot eat.

All food waste has the potential to be composted. Nutrient extraction requires the use of bacteria, fungi and soil fauna. Depending on the functioning of the bacteria, the composting process can be aerobic, anaerobic or facultative.

To ensure that the wet waste does not get contaminated by heavy metals and other pollutants, it is essential to collect wet waste separately. Hence, a 2-bin culture is followed.

Aerobic Composting at Source

Micro-organisms in the compost heap, called Aerobes need oxygen to help them grow, multiply and decompose the water materials.

Composting can easily be done in households in either pits or bins created for composting. The composted waste can be directly used for gardening.

Composting organisms require 4 four conditions to create compost:

- ✓ Carbon from brown organic matter like dried leaves, sawdust, straw, paper
- ✓ Nitrogen that comes from fruit and vegetable waste, coffee grounds
- ✓ Oxygen which comes from air
- ✓ Water in the right amounts

Oils, grease, meat, bones, fish, fats, dairy products should not be added to the compost pit. They add to the smell and can attract pests.

Composting is an aerobic process, during which organic waste is biologically degraded by micro-organisms, bacteria, fungi and actinomycetes to humus-like material. The end product should not contain pathogens or viable seeds, and it should be stable and suitable for use as a soil amendment. Many factors such as oxygen content, moisture, composition of the feed, pH and temperature affect the composting process and ultimately the end product. Food waste in itself has a low pH and contains high quantities of carbohydrates that form organic acids upon degradation. The low initial pH limits microbial activity and delays the increase in temperature.

Studies have revealed that major bacterial groups in the beginning of the composting process are mesophilic organic acid producing bacteria such as Lactobacillus spp. and Acetobacter spp. Later, at the thermophilic stage, gram-positive bacteria such as Bacillus spp. and actinobacteria, become dominant. The most efficient composting process is achieved by mixed communities of bacteria and fungi. Immature compost can also be a health-risk for people/workers handling the compost.

Composting at Home

Stack composter or 'khamba', is a set of three earthen pots with a lid and air vents. It can be kept in a balcony, or a terrace, but away from direct rain and danger of being toppled over. They come in attractive colours to suit the decor of homes. The lowest container is filled halfway with dry leaves or coconut fibre. The top two bins are lines with newspaper. Daily kitchen waste is added and a layer of dry mix of soil and old compost is added. When the pot fills, a layer of microbes (available in market) are added. Humidity is adjusted by sprinkling water. The second pot is put to use. The cycle continues, using the bottom pit for the final decomposition. A contraption of this kind costs Rs.3000 or so and serves a nuclear family well. The compost can be used for home gardens or neighbourhood trees.

Fig 3.2 : Stack Composter

Farmers successfully applying Municipal Waste to Crops

Problem

Farmers across India realize that plants absorb only twenty percent of added Urea, while rest of the eighty percent is leached into soil, causing nitrate pollution in well water.

Solution

Kuilapalyam village in T.N. uses coir pith to do very low-cost of city waste composting under shady trees.

Method

Villagers bring garbage from Pondicherry at the rate of Rs 20/- per cart-load and pile it into platforms (20'x20'x4') under the tamarind-trees near their village huts. Only segregated "wet waste" without any plastic contamination can be used for this technology. This pile is covered with 6" of coir – pith purchased from Pondicherry at Rs 50 per cart-load. The coir pith acts as an insulating blanket that locks in heat, moisture and odour. It also keeps out flies and animals, hides the ugliness of heaps and protects compost from rain. Composting is accelerated by sprinkling the fresh garbage heaps in layers with water containing five percent fresh cowdung and dusting 5 Kilograms of Rock Phosphate per ton of garbage.

The temperature builds up very fast, reaching 70°C in 5-7 days. The high temperatures speed up the composting, kill weed seeds and kill germs that cause diseases like cholera, typhoid, hepatitis and worms. After a week, they turn the heap, placing the outer material in the centre of the new heap and the hot inner material on the outside of the new heap. Compost is ready in 4 weeks with 3-4 turnings. This heap is left undisturbed for several months until needed. By then, the rotten waste and the coir pith decompose completely and are applied to fields in the planting season.

Advantages

1. Composting is a pollution-abatement technology. City compost acts like a sponge, absorbing urea for later use. So, 1 bag of urea used with compost is equivalent to 5 bags.
2. This compost makes the crop very drought-resistant as the coir-pith helps to retain water for long.
3. Compost use makes soil porous, so roots are stronger. This strengthens the plant's natural resistance to pests and decay.
4. Farmers using compost find they need far less pesticides, saving input costs with less environmental pollution.
5. Fruit from compost-grown plants are larger, tastier, have better colour and shelf life and fetch better prices.
6. Compost use restores fertility to water-logged and saline soils. India has 22 million hectares of alkaline and saline barren soils awaiting rescue. Experiments at Kutch and by Bhoomi Sudhar Nigam of Uttar Pradesh have proved the benefits of using compost. Full yields are restored in 3 years to totally-barren soils. Soils deficient in micro-nutrient also benefit.

Precautions

Since no sieving is done, the wet waste must be plastic-free. Soil which contains plastic bags cannot absorb rain-water well. Seeds cannot germinate well. Plastics make the soil less fertile every year.

Recommendation

Encourage private composting efforts by:

>> Waste segregation at source. SJSRY schemes for collection of compostable waste and decentralised composting

>> Free delivery of garbage to the composting spot

>> Buy-back off-season compost for city gardens

>> Encourage banks to finance storage sheds for finished compost at the composters' site

>>Make co-marketing of city compost and chemical fertilizers compulsory. Creative solutions are needed for bulk storage, timely availability, affordability and ease of application

Anaerobic Composting at Source

Anaerobicdigestion is a series of processes by which microorganisms break down biodegradable material in the absence of oxygen. The process is used for industrial or domestic purposes to manage waste or to produce fuels. Much of the fermentation used industrially to produce food and drink products, as well as home fermentation uses anaerobic digestion.

When the breakdown of waste takes place in the absence of air, it is termed anaerobic. Biogas plants are the best example of anaerobic composting. Anaerobic digestion produces two main products: digestate and biogas. Digestate is produced both by acidogenesis and methanogenesis and each has different characteristics. The resultant cooking gas reduces the dependence on LPG. The major components of the bio-gas plant are a digester tank, an inlet for feeding the kitchen waste, gas holder tank, an outlet for the digested slurry and the gas delivery system for utilizing the biogas.

(Project: Make your own biogas plant https://www.instructables.com/id/Bio-gas-plant-using-kitchen-waste/)

Pipe Composters Allepuzha, Kerala

Allepuzha in Kerala encourages residents to treat their wet waste at source. Anaerobic pipe digesters and a community composting shed have been provided. This has put the responsibility of waste management on the citizens and the results are encouraging. (Watch Film on Pipe Composting , 3.2 min https://www.youtube.com/watch?v=JXOo313n88M)

Anaerobic digestion works well on hard-to-compost materials which have high fibre and low nutrition, such as cow-dung, by adjusting the nitrogen content. However, the addition of oil (5% v/v), caused the reactor failure, whereas, at 4.0 g VS L^{-1} d^{-1}, the reactor remained stable for 10 days before the accumulation of Volatile Fatty Acids, which resulted in low pH, and thus reduced the biogas and methane production.

Aerobic Composting: Open Windrow

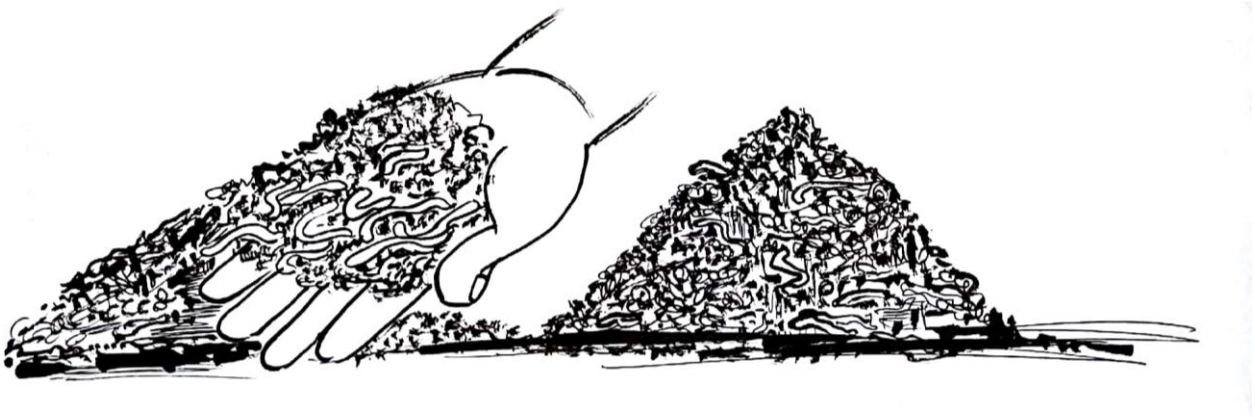
Most cities like Indore and Mangalore collect the wet waste to decompose them centrally. This is convenient for processing, monitoring, packing and selling the compost. The municipalities that collect wet waste in good volumes often choose open windrow method of composting, wherein garbage is piled in rows 1.5m high and 2.5 m wide. Moisture is maintained at 60 per cent. Heat builds up to 70°C. Thermophilic bacteria break down protein and other readily biodegradable organic matter. Facultative and obligate aerobic forms of bacteria, actinomycetes and fungi decompose cellulose and lignin. The pile is turned twice a week for aeration. If not, the actinomycetes and fungi make the outer layer grayish white. It takes 7-10 weeks for the compost to be readied.

Aerobic Composting of Garden Waste

Hyderabad city's GHMC has outsourced the composting of leaf litter to Ms. Poonam Bhide, who turns all the leaf litter into 'Amrut Matti'. Her method is to soak the leaf litter in water for 24 hours, add any fermented material (such as sour curd, liquefied toddy, underground soil or liquefied idli batter) and keep it covered for 15 days. Vegetable kitchen waste, garden soil, or jaggery is added in layers. The heap is turned once a week. It takes 2 months for the leaf litter to turn fit for use.

Mechanical Composting

Special machines (horizontal plug flow reactor, vertical continuous flow reactor or rotating drum) are available that can do the initial processing by turning food waste continuously to reduce particle size and allow aeration. Within two to five days the waste turns to humus. This humus needs only 1-2 weeks to stabilize when composted in the traditional way. This is a good method for large establishments to process their waste and hasten composting. Excel Industries of Ahmedabad treats around 300 tonnes of MSW per day through mechanical composting. Okhla, Delhi processes 200MT this way. To enrich the compost night soil, cow dung etc. are added to the refuse. Arrangements for draining of excess moisture



are provided at the base of the pit. Compost is stabilized in about 1 to 2 weeks. At the bottom of the pit, a layer of ash, ground limestone or loamy soil is placed – to neutralize acidity in the compost material and providing an alkaline medium for microorganisms. The pit is filled by alternate layers of refuse (laid in layers of depth 30 – 40 cm) and night soil or cow dung (laid over it in a thin layer). Material is turned every 5 days. The humus produced from mechanical composting can also be used for vermi-composting, which takes 2-3 months.

Carbon Capture by Soil, California

The Marin Carbon Project in California, which began in 2008, sought to improve the environment through the covering of cattle-grazing land with half an inch of compost and then observe the results for roughly the next decade. The study showed that if typical household compost were applied to just 5 percent of California's grazing lands, "the soil could capture a year's worth of greenhouse gas emissions from California's farm and forestry industries."

Advantages of Composting

i. Vast tracts of Indian soil are uncultivable. Application of surplus compost to these lands is a sure shot way to recover lost soil fertility. After this, the soils will be better able to sustain silviculture and agriculture.

ii. Municipalities sometimes have schemes for collecting the end-product i.e. compost by segregating, recycling and composting. A family of four can reduce their waste from 1,000 Kilograms to less than 100 Kilograms - a 90 percent reduction every year!

iii. Farmyard manure can fetch good money. Supplying composting bins, composting mix (inoculums mixtures of good bacteria for quick decomposing), selling or using compost to grow organic vegetables for sale are many ways of earning revenues out of bio-degradable waste.

How to Prepare Biodiesel from Waste Cooking Oils

Waste cooking oils are difficult to treat. They can slow down or completely stop the composting process. Tipping them down through drains causes grave water pollution and it is very expensive to clear blockages caused by fats and greases. Just one litre of cooking oil can pollute up to 1 million litres of drinking water.

A company in United Kingdom(UK) collects used Cooking Oil (UCO) from fish-frying industry, cafes, restaurants and food businesses and converts into biofuel, a low carbon alternative to diesel that lowers greenhouse gas emissions by over 70 percent

Indian Bioenergy is an Indian company located in Nandi Hills, Bengaluru, which collects waste cooking oil on a regular basis, on a scheduled basis at an agreed frequency, with a reminder. The company also supplies a barrel or container for storing waste oil, if needed. Used cooking oil is collected against a Waste Transfer Note which can be exchanged for biodiesel.

To know the details of how to make biodiesel, watch the following videos.

Watch Films on

- Biodiesel from Cooking oil- How To Make Biodiesel Using A Used Cooking Oil : Duration4 min. https://www.youtube.com/watch?v=qi1cqmvio5YHow to make biodiesel: Duration 9 min
- https://www.google.co.in/search?q=how+to+make+biodiesel+from+vegetable+oil+waste&rlz=1C1CHZL_enIN815IN815&oq=how+to+make+biodiesel+from+cooking+oil&aqs=chrome.4.69i59j0l5.8626j0j8&sourceid=chrome&ie=UTF-8#kpvalbx=1

3.2 General Process of Recycling

Packaging waste is an omnipresent content of garbage. The consumer pays up to 16% of the total product price on packaging alone. 15 million ‘single-use’ plastic bottles are used every day. Nearly half this amount ends up in landfills. Plastic can take up to 500 years to decompose. An average family throws away the equivalent of 6 trees a year. Recycling is defined as “Using waste as material to manufacture a new product.” Recycling involves altering the physical form of an object or material and making a new object from the altered material.

Recycling packaging waste can bring down the cost of packaging as recycling saves energy and resources. Glass, plastic, paper and metals are the main recyclable materials. One recycled tin can save enough energy to power a TV for 3 hours. One recycled plastic bottle saves enough energy to power a light bulb for 3 hours. The oil it takes to make one plastic bag could be used to fuel a car for 11 metres. A single recycled glass bottle saves enough energy to power a computer for 25 minutes. It takes 50 times more energy to make one battery than the energy produced by that battery.

Collection trucks bring recyclables to a recycling facility, where they are unloaded on a tipping floor. Often this is a single stream facility, since collecting different recyclable materials as individual streams can be logistically difficult. The single stream facility makes recycling easier for everyone in the community. In larger facilities, recyclables are placed on a conveyor belt, from which they are sorted by machine or hand into broad categories of paper, plastic, glass and metal.

1. Paper recyclables are separated into four categories: Old newspaper, corrugated boxes, mixed paper and office mix.
2. Plastics are sorted by colour and type. Air is blown into the mix to separate heavier and lighter plastics. Sometimes they are optically scanned for separation into types e.g. PET, HSPE, etc.
3. Glass is crushed into cullet, and then cleaned of debris and contaminants. Sometimes, glass may be sorted by colour before (or after) crushing or it may be shipped directly to the end-user without sorting.
   Cullet is loaded onto trucks for transport to customers. Glass cullet can be used for making new containers, consumer products, road bedding, sand blasting, counter-tops, etc. To make new containers, the cleaned cullet is mixed with soda ash, sand, feldspar and limestone at a glass plant. The mixture is heated at 1500^{o}C to mould new products. Using recycled glass reduces emissions, energy use, raw material and also extends the life of the plant equipment.
4. Metals: Magnets are used to separate steel from the rest of the stream. Steel is stored separately for baling. Aluminium is mechanically separated by eddy current (if it is the form of cans).
   Aluminium cans are crushed and baled separately. They are sent to the respective customers. At the aluminium plant, aluminium is melted and poured into ingot moulds or rolled into sheets to make new products such as window frames, cans, etc. At the steel mill, tin and steel are recovered through chemical and electrolysis baths. They are purified, melted and cast into ingots.

3.3 Precautions for Recycling

It is vital to keep the recycling stream clean. Education plays a key role in this to teach and remind staff and tenants how to maintain the recycling programmes. Training sessions, periodic talks, newsletters, events or competitions centred on recycling goals are essential.

Small mistakes can contaminate the recyclable stream, such as food wastes or liquids being discarded in the recyclable bins. Forbidden material include shredded paper, corrosive batteries, pizza boxes blotched with cheese and grease, plastic wrappers for food, unclean jam jars, broken glass, un-rinsed bottles, paper envelopes with plastic address-windows and newspapers that have been used for other purposes. Ordinarily, recyclable waste stream comes with 15-25 percent contamination. For proper recycling with least effort, the waste stream should have less than 1 percent contamination. Here, the model adopted by the zero-waste village of Kamikatsu in south western Japan, seems to be a sustainable solution.

If the recyclable waste stream is too contaminated, it runs the risk of not being recovered, but being completely trashed. Recyclers these days do not want items with mixed material such as paper and plastic, or cardboard and tape. It doesn't pay to tear the stuff apart. Such mixed recyclable waste is simply sent off to the landfill.

In many cases recycling does not generate enough money. Scrap value has dropped — especially for plastic. When oil prices tumbled, it became cheaper to make plastic bottles from all-new material than recycled matter.(Watch Film 4 How Sweden turns its waste into gold: Duration 20 min: https://www.youtube.com/watch?v=14r7f9khK70)

Aluminium

Aluminium cans must be rinsed out before sending. Recyclable aluminium has the code: 41-ALU. Aluminium Foil can also be recycled, if clean. Aluminium cans are 100 percent recyclable. This means every tin can you recycle ends up back on the shelves within 60 days.

Glass

Clear glass should be sent separate from coloured glass. Some recycling centres have three streams for-clear, green and brown glass. 70- GL is mixed or multi part glass. 71 GL is clear glass while 72 Gl stands for green glass. Mixing glass streams interferes with its uniform melting.

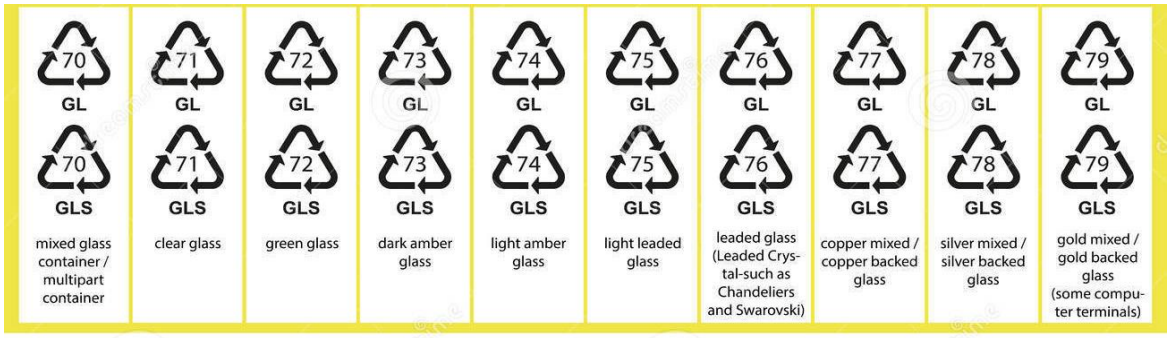


Fig 3.3 International Symbols for Glass Recycling

3.4 Precautions while Recycling Plastics

Threat of Plastics

As of 2018, about 380 million tonnes of plastic is produced worldwide each year. Less than 25 percent of this is recycled, the rest is incinerated or put into landfills and oceans. Leaching of chlorinated plastic can release harmful chemicals into the surrounding soil, which can then seep into groundwater and surface water bodies.

An estimated 1.15 to 2.41 million tonnes of plastic enters the oceans via rivers. The top 20 contributing rivers are mostly found in Asia and deliver around 67 percent of all plastics flowing into the oceans.

Plastics that reach the oceans degrade much slower than on land. It is estimated that a foam cup takes 50 years, a plastic beverage holder 400 years, a diaper 450 years and fishing line 600 years to degrade. Today there are 5 major gyres of plastic (marine debris particles) in the ocean, which resemble a diffuse soup of plastic floating in the waters. The Great Pacific garbage patch in the central North Pacific Ocean a.k.a. the Pacific trash vortex, is the largest of them –about 1.6 million sq. km. The carcasses of 90 percent of seabirds and marine turtles reveal plastic debris. Researchers suggest that by 2050 there could be more plastic than fish in the oceans by weight.

Plastic recycling is a complicated affair. The well-recognized “chasing arrows” symbol we see on plastic containers and products does not mean the product is recyclable. The number inside the triangle – 1 to 7- helps to identify the type of plastic used for the product, and not all plastics are recyclable or even reusable. It is important to understand the seven plastic codes. For example, water bottles that display 3 or 5 cannot be recycled in most areas.

#1 - PET (Polyethylene Terephthalate)

PET is one of the most commonly used plastics in consumer products, and is found in most water and soft drink bottles and some packaging. It is intended for single use applications; repeated use increases the risk of leaching and bacterial growth. PET plastic is difficult to decontaminate and proper cleaning requires harmful chemicals. Polyethylene terephthalates may leach carcinogens.

Products made of #1 (PET) plastic should be recycled but not reused. About 25 percent of PET bottles are recycled. The plastic is crushed and then shredded into small flakes which are then reprocessed to make new PET bottles, or spun into polyester fiber. This recycled fiber is used to make textiles such as fleece garments, carpets, stuffing for pillows and life jackets, and similar products. India has pledged to phase out single-use plastic by 2022.(Watch Film 5 How to turn plastic bottles into clothes. Duration 5.30 min: https://www.youtube.com/watch?v=zyF9MxlcItw)

#2 - HDPE (High-Density Polyethylene)

HDPE plastic is the stiff plastic used to make milk jugs, detergent and oil bottles, toys and some plastic bags. HDPE is the most commonly recycled plastic and is considered one of the safest forms of plastic. It is a relatively simple and cost-effective process to recycle HDPE plastic for secondary use.

HDPE plastic is very hard-wearing and does not break down under exposure to sunlight or extremes of heating or freezing. For this reason, HDPE is used to make picnic tables, plastic lumber, waste bins, park benches, bed liners for trucks and other products which require durability and weather-resistance.

#3 – PVC (Polyvinyl Chloride)

PVC is a soft, flexible plastic used to make clear plastic food wrapping, cooking oil bottles, teething rings, children's and pets' toys and blister packaging for myriad consumer products. It is commonly used as the sheathing material for computer cables and to make plastic pipes and parts for plumbing. Because PVC is relatively impervious to sunlight and weather, it is used to make window frames, garden hoses, arbors, raised beds and trellises.

PVC is dubbed the "poison plastic" because it contains numerous toxins which it can leach throughout its entire life cycle. Almost all products using PVC require virgin material for their construction; less than 1 percent of PVC material is recycled. Products made using PVC plastic are not recyclable. While some PVC products can be repurposed, PVC products should not be reused for applications with food or for children's use. The table below summarizes the use and dangers of each plastic category.

#4 – LDPE (Low-Density Polyethylene)

LDPE is often found in shrink wraps, dry cleaner garment bags, squeezable bottles and the type of plastic bags used to package bread. The plastic grocery bags used in most stores today are made using LDPE plastic. Some clothing and furniture stores also uses this type of plastic.

LDPE is considered less toxic than other plastics, and relatively safe for use. It is not commonly recycled, however, although this scenario is changing in many communities today as more plastic recycling programs gear up to handle this material. When recycled, LDPE plastic is used for plastic lumber, landscaping boards, garbage can liners and floor tiles. Products made using recycled LDPE are not as hard or rigid as those made using recycled HDPE plastic. Products made using LDPE plastic are reusable, but not always recyclable. You need to check with your local collection service to see if they are accepting LDPE plastic items for recycling.

Table 3.1 Recyclability and Dangers of Plastics by Category

Number	Type	Reusable	Recyclable	Cancer-ous	Avoid	Remarks
1- PETE **(Polyethylene terephthalate)**	One-time use. Mineral water bottles. Oil bottles	No	Yes	Yes	Yes	Leaching, bacterial growth
2- HDPE **(High density polyethylene)**	Stiff plastic e.g Shampoo bottles,	Yes	Yes	No	No	Safest
3- PVC **(Polyvinyl Chloride)**	Soft, flexible Eg. Blister packing, toys, garden hose	Yes but don't reuse for food or children	No	Yes	Yes	"Poison plastic" It leaches
4- LDPE **(Low density polyethylene)**	Shrink wrap, bread packets,	Yes	Yes Sometimes	No		Safe
5- PP **(Poly-propylene)**	Tough, light weight, heat resistant. eg diapers, bottle caps, rope, packing tape.	Yes	Yes	No		Not accepted in most recycling centres
6- PS **(Polystyrene)**	Cheap, Weak Lightweight, e.g. Styrofoam cups	No foam packing may be reused	Yes. But expensive, most organizations choose not to recycle	Yes	Yes	Leaches, Bad for reproductive organs
7-Others	BPA, Polycarbonate, LEXAN	No	Pla / Compostable plastics only can be recycled	No	Yes. Avoid for foods.	Leaching, Endocrine disruption
ABS **(acrylonitrile butadiene styrene)**	Hard, sturdy, durable plastics e.g. appliances, computers, and cell phones	No	Yes	No	No	Thermoplastics can be melted and re-moulded into new ABS materials. This cannot be done indefinitely like glass.

#5 – PP (Polypropylene)

Polypropylene plastic is tough and lightweight, and has excellent heat-resistance qualities. It serves as a barrier against moisture, grease and chemicals. PP is also commonly used for disposable diapers, pails, plastic bottle tops, margarine and yogurt containers, potato chip bags, straws, packing tape and rope. Polypropylene is recyclable through some curbside recycling programs but only about 3 percent of PP products are currently being recycled in the United States of America (USA). Recycled PP is used to make

landscaping border stripping, battery cases, brooms, bins and trays. However, #5 plastic is today becoming more accepted by recyclers. PP is considered safe for reuse.

#6 – PS (Polystyrene)

Polystyrene is an inexpensive, lightweight and easily-formed plastic with a wide variety of uses. It is most often used to make disposable styrofoam drinking cups, take-out "clamshell" food containers, egg cartons, plastic picnic cutlery, foam packaging, etc. Polystyrene is also widely used to make rigid foam insulation and underlay sheeting for laminate flooring used in home construction.

Because polystyrene is structurally weak and ultra-lightweight, it breaks up easily and is dispersed readily throughout the natural environment. Beaches all over the world have bits of polystyrene lapping at the shores, and an untold number of marine species have ingested this plastic with immeasurable consequences to their health.

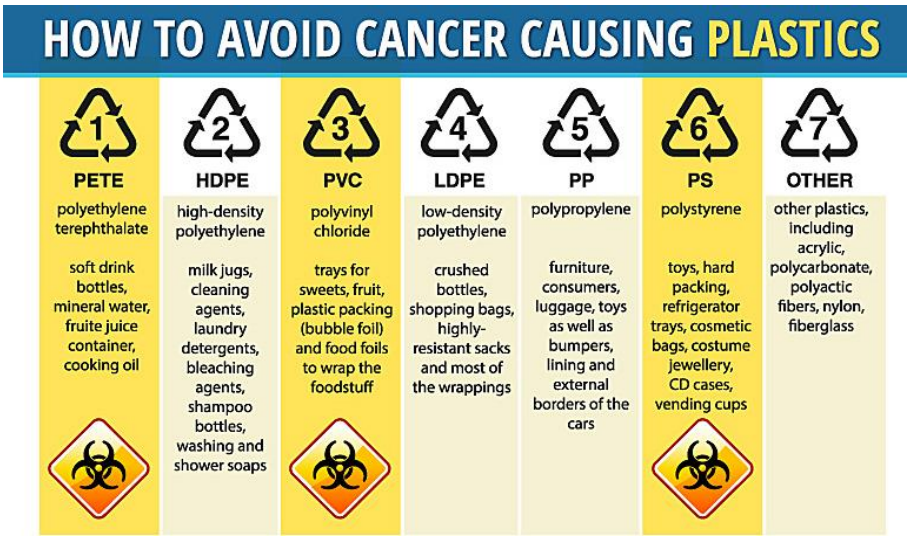


Fig: 3.4 International Symbols for Plastic Segregation

Polystyrene may leach styrene, a toxin that is possibly a carcinogen, into food products (especially when heated in a microwave). Chemicals present in polystyrene have been linked with reproductive system dysfunction. Recycling is not widely available for polystyrene products. Most curbside collection services will not accept EPS (encapsulated poly styrene), as this material accounts for about 35 percent of US landfill material. The reason is its light weight (>90 percent air). While the technology for recycling polystyrene is available, the market for recycling is small.

Styrofoam Densifier, Australia

PS foam is collected through curbside or depot programmes. The material goes through a densifier where it is compacted into blocks. The plastic blocks are remanufactured into decorative mouldings and high-end picture frames. The global market for post-consumer PS foam is 1,20,000 tonnes per year.

India is one of the signatory countries to the International EPS recycling agreement. We have a good scope in India to recycle this form of plastic. Several studies have found that the bacteria Pseudomonas putida is able to convert polystyrene to a more biodegradable plastic. The process of polystyrene depolymerization – converting polystyrene back to its styrene monomer – is also gaining ground.

#7 – Other (BPA, Polycarbonate and LEXAN)

The #7 category was designed as a catch-all for polycarbonate (PC) and "other" plastics, so reuse and recycling protocols are not standardized within this category. Of primary concern with #7 plastics,

however, is the potential for chemical leaching into food or drink products packaged in polycarbonate containers made using BPA (Bisphenol A). BPA is a xenoestrogen, a known endocrine disruptor.
7 plastics are used to make baby bottles, sippy cups, water cooler bottles and car parts. BPA is found in polycarbonate plastic food containers often marked on the bottom with the letters “PC” by the recycling label #7. Some polycarbonate water bottles are marketed as ‘non-leaching’ for minimizing plastic taste or odor, however there is still a possibility that trace amounts of BPA will migrate from these containers, particularly if used to heat liquids.

A new generation of compostable plastics, made from bio-based polymers like corn starch, is being developed to replace polycarbonates. These are also included in category #7, which can be confusing to the consumer. These compostable plastics have the initials “PLA” on the bottom near the recycling symbol. Some may also say “Compostable.”

#7 plastics are not for reuse unless they have the PLA compostable coding. When possible it is best to avoid #7 plastics, especially for children’s food. Plastics with the recycling labels #1, #2 and #4 on the bottom are safer choices and do not contain BPA. PLA coded plastics should be thrown in the compost and not the recycle bin since PLA compostable plastics are not recyclable.

The plastics industry has conformed to regulations by applying the required codes to consumer products, but it is up to individuals to read and understand the codes. By understanding these simple classifications, we can best use plastics to our advantage while minimizing the health and disposal issues that may otherwise arise.

(Watch Film: Central Coast Recycling https://www.youtube.com/watch?v=HBuOa-8PGoc)

3.5 Precautions while Recycling Paper

Wastepaper Recycling Plant, Aurangabad

(Watch film 7 MGM Aurangabad, Waste Paper recycling plant (Film in Marathi) Duration 19 min https://www.youtube.com/watch?v=9-316A4g0eg)
This film demonstrates how Mahatma Gandhi Mission, Aurangabad uses all old journals, assignments, papers to recycle in-house completely. First the papers are shredded by a shredder. This is weighed. 5 Kilograms of shredded paper is weighed and soaked in reclaimed water from the water recycling plant for 10 minutes. Shredded cardboard needs 24 hours to soak. Rosin and Alum solutions are added. The chemicals are diluted in water. A chart explaining the volume of rosin and alum to be used is displayed. For 5 Kilograms of paper, 150 grams of rosin is needed to bond the paper and 300 grams of alum powder for removing the ink from the shreds. The end product is turned into files and screen-printed. Hydro-pulper of 120 l capacity is loaded with the shredded paper for 10 minutes. I Kilogram of soaked cotton pulp is added along with the two solutions – rosine and alum. The final paper pulp is put in a univat to make paper board. 10 sheets are prepared separated by cloth layers. A screw press removes excess water and allowed to air dry. A calendaring machine flattens the paper 5 sheets at a time. Fresh paper is ready to craft into new file folders.

As many as 550 mills in India use waste paper as primary fibre source for paper, paperboard and newsprint production. This waste paper is sourced indigenously as well as through imports. The present recovery and utilisation of waste paper by paper mills in India is 3.0 million tonnes annually, which translates to a recovery of 27 per cent of the total paper and paperboard consumed, very low when compared to recovery rates in developed countries like Germany (73 per cent), Sweden (69 per cent), Japan (60 per cent), Western Europe (56 per cent), USA (49 per cent) and Italy (45 per cent).

For paper, the codes are 20-PAP for recyclable cardboard, 21-PAP for recyclable magazines, mail, catalogues, and other related paper products and 22 PAP is a general code for paper.
If there is no code, the paper can still be sent for recycling. However, some places do not accept magazines and periodicals. Their coloured ink interferes with the recycling process.

Due to inadequate availability of indigenous waste paper, Indian mills rely heavily on imported waste paper to meet the raw material demand. The import bill, in fact, has increased significantly over the years. India imports around 4.0 million tonnes of waste paper annually which is about 57 per cent of its requirements. The solution is in harnessing the post consumer paper, or waste paper, at home, since it is the most important renewable raw material source for the paper industry and can contribute considerably towards reduction in its imports. Its recycling is also crucial from the environmental perspective, as systematic collection and recycling of waste paper can significantly reduce the generation of municipal solid wastes. According to some estimates, one tonne of recycled paper saves approximately 17 trees, 2.5 barrels of oil, 4100 Kilowatt hours of electricity, 4 cubic meters of landfill and 31,780 litres of water.

Fig3.5 International Symbols for Paper Segregation

There are several grades of paper that cannot be sent for recycling:

1. Wax paper, plastic or foil-coated papers cannot be recycled, e.g. frozen food boxes, juice boxes, milk cartons.
2. Soiled/ unclean paper: paper contaminated with food waste, oils, used tissues etc carry viruses, bacteria and moulds (fungus).
3. Shredded paper: Shredding weakens the length of paper fibres. It is best to compost shredded paper along with nitrogen-rich decaying food to offset high nitrogen and add carbon.

3.6 Reuse

When the recyclables are simply broken or melted and shaped into new products, with and without recasting, it is called reusing. Plastics, glass, rubber tyres, etc can be reused. For example, plastics are melted to make synthetic marble with attractive patterns, tyres are shredded to make crumb rubble for roads (though this has been a cause of worry for environmentalists since the crumb rubber erodes from the road surface due to friction and escapes with rainwater runoff, thus causing water pollution), and

glass is melted to form countertops, etc. Plastic roads have gained much popularity in India to tackle #7 plastics.

Summary

Different organic matter is composted in different ways: locally, centrally, aerobically or anaerobically. Well composted waste becomes good soil conditioner and is capable of sequestering carbon. Poorly composted waste could cause health issues and aid in spreading seeds of invasive plant.
Plastics, paper, glass and metals can be recycled if segregated well. Those materials that cannot be recycled can sometimes be reused, such as for road-making.

Further Reading

Swachh Bharat Guidebook
https://swachhbharaturban.gov.in/writereaddata/Swachh_Bharat_Guidebook_v23.p df

Self-Assessment Test

1. Compare various methods of composting organic matter. Which method is most suitable for your lifestyle?
2. How is paper recycled?
3. Which are the types of plastics to be avoided?
4. Which is the best way to recycle old cooking oil?

Reference Book

- Swachh Bharat Guidebookhttps://swachhbharaturban.gov.in/writereaddata/Swachh_Bharat_Guidebook_v23.p df

Films

1. Pipe Composting: Duration 3.2 min https://www.youtube.com/watch?v=JXOo313n88M
2. Biodiesel from Cooking oil- How To Make Biodiesel Using A Used Cooking Oil : Duration4 min. https://www.youtube.com/watch?v=qi1cqmvio5Y
3. How to make biodiesel: Duration 9 min https://www.google.co.in/search?q=how+to+make+biodiesel+from+vegetable+oil+waste&rlz=1C1CHZL_enIN815IN815&oq=how+to+make+biodiesel+from+cooking+oil&aqs=chrome.4.69i59j0l5.8626j0j8&sourceid=chrome&ie=UTF-8#kpvalbx=1
4. How Sweden turns its waste into gold: Duration 20 min: https://www.youtube.com/watch?v=14r7f9khK70
5. How to turn plastic bottles into clothes. Duration 5.30 min: https://www.youtube.com/watch?v=zyF9MxlcItw
6. Central Coast Recycling https://www.youtube.com/watch?v=HBuOa-8PGoc
7. MGM Aurangabad, Waste Paper recycling plant (Film in Marathi) Duration 19 minhttps://www.youtube.com/watch?v=9-316A4g0eg

Chapter 4

Responsibility of Waste Management

Objectives

- To know the role of a producer in the handling of end-of-life waste
- To learn the concepts of extended producer responsibility, polluter pays principle and other sustainability issues
- To learn how the scrap trade and the informal recycling sector manage a large chunk of the recycling business while endangering lives
- To learn the concepts of carrying capacity, assimilative capacity and the importance of bioremediation to protect the environment

Structure

4.1 Responsibility of Waste Management
4.2 Polluter Pays Principle (PPP)
4.3 Assimilative Capacity
4.4 World Scenario in Scrap Trade
4.5 Extended Producer Responsibility (EPR)
4.6 Producer Responsibility Organisation (PRO)
4.7 Carrying Capacity
4.8 Precautionary Principle

To Do Activities

1 Discussion regarding who is responsible for waste- 5 minutes.
2 Collect soil samples. Using microbiological techniques, isolate different soil bacterial colonies.
3 Collect information on EPR and CSR activities of 5 reputed companies in India using their latest annual reports.
4 Explain scrap trade, its financial implications and health implications. Ask a student to read aloud the Mayapuri Radiological Accident in class.
5 Explain the precautionary principle to the class. Ask students to identify a few areas where the Precautionary Principle can be applied in real-life scenarios.
6 Discuss on what topics each student is interested in, scope out possibilities of career development, research or internship opportunities.
7 End the class with a 4 minute animated film by OECD regarding resource efficiency, as a precursor to the next chapter.

If anyone intentionally spoils the water of another ... let him not only pay damages, but purify the stream or cistern which contains the water.

-Plato, Greek Philosopher

4.1 Responsibility of Waste Management

Till now we have focussed on the steps in solid waste management and the extraction of resources from waste. It is human nature to push the 'dirty work' on to someone else. As the heaps of garbage grow, there is a growing debate on who should be held responsible for its generation and who should be made to clean it up.

There are several issues with this debate:

1. An assumption that the earth can tolerate waste.
2. The by-products of many processes do not have alternative use. The cost of treating them could be prohibitive, or at least takes away a substantial chunk from the profit margins.
3. Once distributed across the consumers, it is hard to retrieve.
4. Pollution could be from non-point sources, cumulative in nature and occurring over long time spans. Identifying a perpetrator is both difficult and sometimes technically unfeasible.
5. The polluter may be part of a production chain. For instance, packaging material is produced by one company and sold to the manufacturer of the goods that need packaging. It becomes waste only after reaching the consumer. Thus, there is ambiguity regarding whose responsibility it is.
6. The amount of compensation to be charged for restoration remains inadequate to repair the damage.

4.2 Polluter Pays Principle (PPP)

The Polluter Pays Principle is one of the oldest principles of environmental law and also one of the most intuitive. The first major reference to the PPP appeared 1972 in the OECD Guiding Principles Concerning International Economic Aspects of Environmental Policies. In 1992, it was adopted by the international community in Principle 16 of the Rio Declaration:

"Authorities should endeavour to promote the internalisation of environmental costs and the use of economic instruments, taking into account the approach that the polluter should, in principle, bear the cost of pollution."

But one big question remains – who should pay for causing pollution, and how much?

Poor households, informal sector firms and subsistence farmers cannot bear any additional charges for energy or for waste disposal. Small and medium-size firms which mainly serve the home market, find it difficult to pass on higher costs to the domestic end-users of their products. Many environmental problems are caused by an overexploitation of common pool resources, such as ground water.

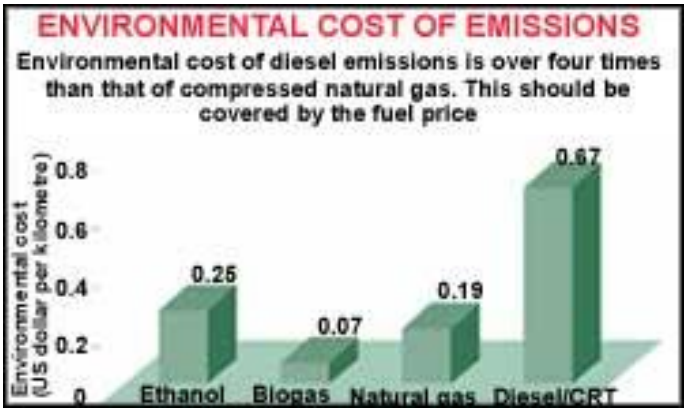


Fig 4.1 Polluter Pays Principle Suggests that the Customer Pays More for Using Polluting Fuels.
Source: Down to Earth, 7th June 2015

India's Stand on Polluter's Responsibility

Polluter Pays is an important principle for environmental law and governance in India.The Supreme Court of India has laid down the rule of absolute liability which essentially states that a person would be wholly responsible for any mishap caused by their "hazardous or inherently dangerous" enterprise. Court noted that the polluter would need to pay for cleaning up the damage as well as compensate those harmed by the pollution. However, under the public interest litigation route, courts in India have often also held the government liable for failing to curb the pollution and have directed them to pay for the costs of environmental damage. Ultimately, in the National Green Tribunal Act 2010, it was stated that the NGT would decide cases based on the polluter pays principle (among others)

PPP has also been applied more specifically to emissions of greenhouse gases which cause climate change. In this regard, PPP is implemented through a 'carbon price'. Many economists argue a carbon price should be global and uniform across countries and sectors so that polluters do not simply move operations to so-called 'pollution havens' – countries where a lack of environmental regulation allows them to continue to pollute without restrictions.

A Precautionary Principle is also stated in the Rio Declaration, which stipulates that, where there are "threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation." In other words, when an activity raises threats of harm to the environment or human health, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically.

To understand the importance of the Precautionary Principle, it is important to first understand the concept of assimilative capacity.

4.3 Assimilative Capacity

Assimilative capacity refers to the ability of the environment or a portion of the environment (such as a stream, lake, air mass, or soil layer) to carry waste material without adverse effects on the environment or on users of its resources. The assimilative capacity is dependent upon physical characteristics of the air, water and soil and varies from location to location.

Pollution occurs only when the assimilative capacity is exceeded. The Polluter Pays Principle allows the use of economic instruments, tradable pollution rights and environmental standards assuming that the environment has a certain assimilative capacity to absorb waste materials without long-term damage. This idea is based on the fact that some wastes, such as naturally occurring organic wastes decompose and break down in the environment if they are present within limits.

This approach is highly dependent on the ability of scientists to assess the impact of pollutants on the environment and to determine a safe level that will not irreversibly or severely damage the environment.

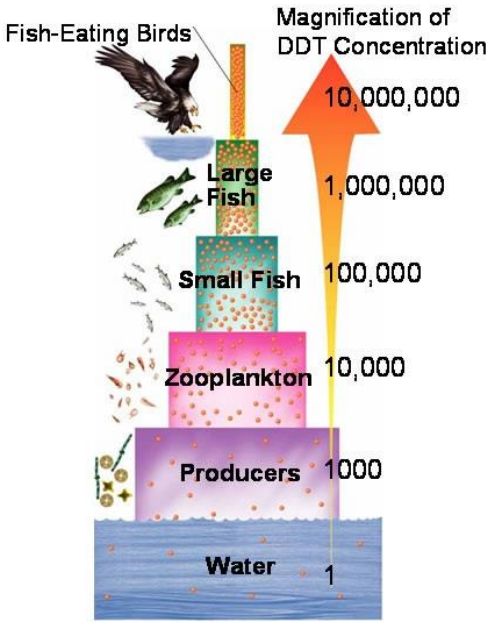


Fig 4.2 Diagrammatic Representation of Biomagnification

There are three hundred thousand chemicals being invented each year, and seventy thousand in daily use. Plants and animals and ecosystems interact with chemicals in such complex ways that assumptions about assimilative capacity and 'safe levels' of pollution or exposure bear little relation to reality. Materials that exist in extremely low concentrations in the environment and those which are synthetic remain in the environment without degrading. These toxins gradually accumulate in the tissues of organisms, a phenomenon referred to as bioaccumulation. They move through the food chain, increasing exponentially at every trophic level until their toxic effects start to show in the top-most member of the food chain. This is called biomagnification.

From the 1950s to the 1970s, populations of birds of prey in North America fell at an astounding rate. The peregrine falcon, the brown pelican and the bald eagle was mostly eliminated. The cause of this alarming situation was a highly toxic pesticide called DDT. DDT is a persistent toxicant that resists breaking down in the presence of environmental factors like sunlight, temperature and moisture. It was not DDT that damaged eggshells, but a DDT metabolite known as DDE. Biomagnification of DDE in the tissues of birds of prey affected their ability to lay normal eggs with thick shells. The shells broke during incubation, thus killing the offspring. North America has since banned the use of DDT. However, it continues to be used liberally in India.

In the late 1990s India lost nearly its entire population of three species of vultures to the bioaccumulation of diclofenac, a veterinary drug. Unlike DDT, which devastated populations of birds of prey, diclofenac does not accumulate in the tissues of livestock or birds. But for the vultures, it is poison. The drug caused visceral gout (kidney failure due to build-up of urates in the internal organs) in vultures. Feeding on carcasses of cattle treated with diclofenac killed the birds within days.

These two examples show that given the huge diversity of chemicals in use today and the limited nature of rudimentary tests for toxicity, persistence and bioaccumulation, it is not possible to accurately predict the assimilative capacity of the environment for them. There can be other damaging impacts, including altering salinity, physical smothering and thermal pollution. Therefore, one cannot safely say that the environment can absorb a certain level of wastes.

There are many substances with zero assimilative capacity including mercury, chromium, lead and cadmium. OSPAR, 1998 issued a list of chemicals with zero assimilative capacity that need priority action. These chemicals include Polychlorinated biphenyls (PCBs), Polyaromatic hydrocarbons (PAH), short chained chlorinated paraffins, mercury and organic mercury compounds, organic tin compounds, musk xylene, brominated flame retardants, certain phthalates, polychlorinated dibenzodioxides, penta chlorophenol, cadmium, lead and organic lead compounds, etc.

Conventional wastewater treatment methods cannot deliver zero discharge for persistent and bioaccumulative chemicals. Therefore, the assimilative capacity approach is not scientifically valid and a precautionary approach is required to progressively remove pollutants from the environment altogether through clean production techniques. To ensure a sustainable, sound and healthy ecosystem, the guiding principle is **the precautionary principle**. This implies continuously reducing discharges, emissions and losses of hazardous substances that are toxic, persistent and liable to bioaccumulate; with the ultimate aim to bring down concentrations in the environment close to zero for man-made synthetic substances. Zero-discharge policies already exist in some regions. They are scientifically defensible. They encourage waste minimization and avoidance rather than waste treatment and disposal.

4.4 World Scenario in Scrap Trade

The scrap market has become increasingly global in nature in recent decades. Figures from the United Nations Comtrade Database show that in 2015 alone, exports of all scrap commodities from reporting countries approached 180 million metric tons valued at more than $86 billion.

The free and fair trade of scrap commodities provides tremendous economic and environmental benefits stemming not only from scrap's attractiveness as a low-cost raw material input for manufacturers, but also due to the energy savings, reduced depletion of natural resources and reduction of material sent to landfills associated with scrap recycling.

According to research conducted by the US Environmental Protection Agency, recycling scrap metals can be quite beneficial to the environment. Using recycled scrap metal in place of virgin iron ore can yield:

- 75% savings in energy
- 90% savings in raw materials used
- 86% reduction in air pollution
- 40% reduction in water use
- 76% reduction in water pollution
- 97% reduction in mining wastes

Every ton of new steel made from scrap steel saves:

- 1,115 Kilograms of iron ore
- 625 Kilograms of coal
- 53 Kilograms of limestone

Energy savings from other metals include:

- Aluminium savings of 95% energy.

- Copper savings of 85% energy.
- Lead savings of 65% energy.
- Zinc savings of 60% energy.

Maintaining open markets for scrap is vital to ensure that recycling is economical and environmental benefits are fully realized.

Global scrap import network analysis of various trading countries with cumulative scrap trading amounts in excess of 2.5 MT from the period of 1990–2013. Larger nodes and thicker lines indicate dominance in the scrap trade between the respective countries.

The figures of steel scrap import in 2017 show Turkey as the top importer at 20,981 TMT (thousand metric tonnes), India ranks third with 5,365 TMT. Other major importers are South Korea, US, EU, Taiwan, China, Indonesia, Mexico and Belarus.

Besides metals, South East Asian countries including India, Bangladesh, Vietnam, Malaysia, Indonesia and China have been importing a wide range of scrap from the Western nations for recycling. This comes at a enormous cost to the importing nation in terms of environmental health and the health impacts on the workers. The Basel Action Network (BAN), perhaps the most notable critic of the industry's reliance on exports, argues that much of the current trade is not only ethically questionable, but it routinely breaks international law.

Several countries have begun banning scrap import. China was the first, as it started the 'Green Fence' policy in 2013 and the 'National Sword' campaign in 2016. In 2017 China banned the import of 24 types

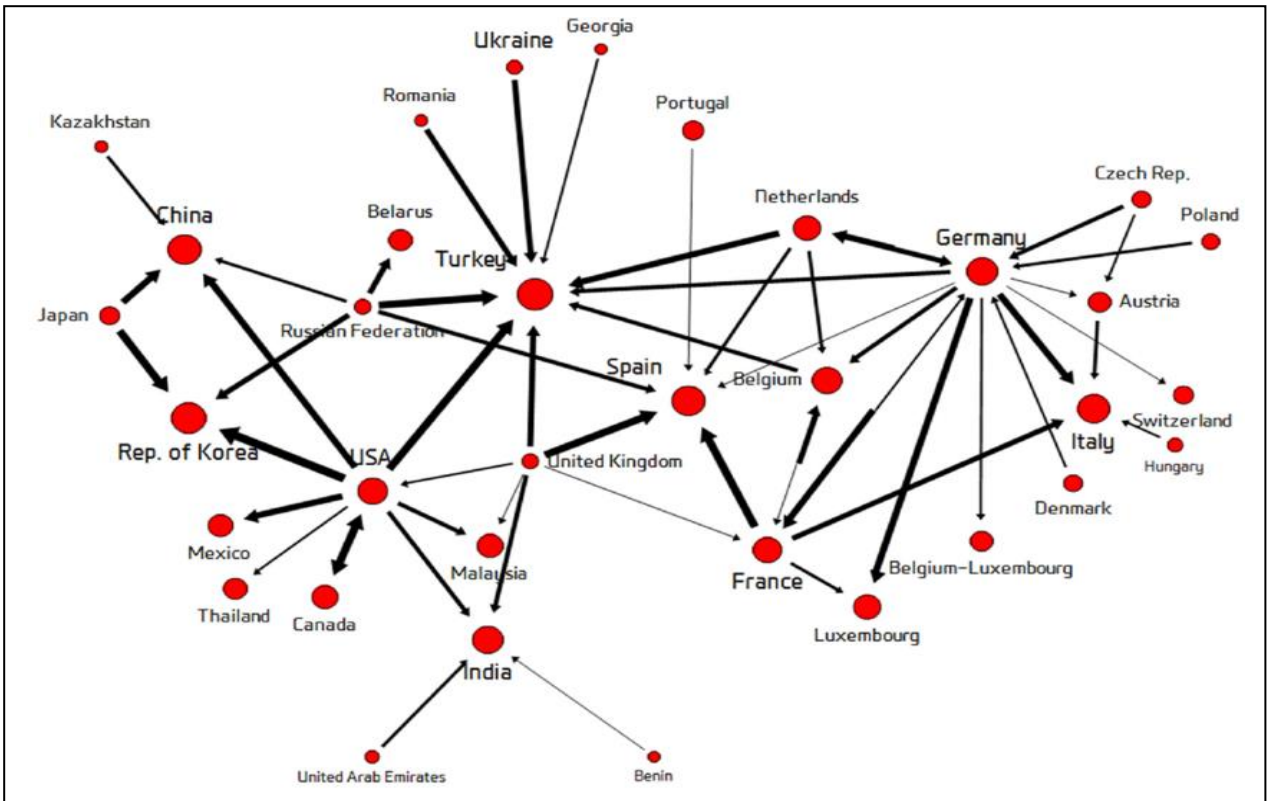


Fig 4.3 Illustration of Global Scrap Import Network AnalysisOf Various Trading Countries

of solid waste. By 2020 the country will ban the import of all scrap. Other nations like Vietnam, Malaysia and Indonesia are now starting to restrict the inflow of scrap which is being diverted away from China.

In January 2018, officials from India too were saying that the country did not want "foreign garbage" entering its borders, either — just like China did. As a result, businesses in the USA and Europe face higher tipping fee in landfills and higher recycling costs. The future for not only USA but all nations lies in adopting zero-waste strategies.

Mayapuri Radiological Accident

Mayapuri in New Delhi is the recycling hub for metal scraps and sale of salvage vehicle parts. It is arguably the biggest market for used automotive and industrial spare parts in India. Many traders from all over India come here to sell or purchase old auto parts. The safety of the scrap yards became a concern after the radiological accident which occurred in April 2010.

An AECL Gammacell 220 research irradiator owned by Delhi University since 1968, but unused since 1985, was sold at auction to a scrap metal dealer in Mayapuri. It was dismantled by workers unaware of the hazardous nature of the device. The cobalt-60 source was cut into eleven pieces. The smallest of the fragments was kept in a worker's wallet; two fragments were moved to a nearby shop, while the remaining eight remained in the scrap yard. Eight people were hospitalised in AIIMS as a result of radiation exposure, where one later died. The event was rated level 4 out of 7 on the International Nuclear Events Scale. All of the sources were recovered by mid-April and transported to the Narora Atomic Power Station, where it was claimed that all radioactive material originally contained within the device was accounted for. The material remains in the custody of the Department of Atomic Energy.

Mayapuri is not equipped with radiation detectors, despite it being a common practice in steel recycling factories in the US and in most of the European countries. The presence of toxic heavy metals and of harmful chemicals in the waste generated by scrapping activities presents a direct menace for the health of several thousands of people living in the area.

4.5 Extended Producer Responsibility (EPR)

Extended Producer Responsibility (EPR) is a policy approach under which producers are given a significant responsibility – financial and/or physical – for the treatment or disposal of post-consumer products. In the field of waste management, extended producer responsibility is a strategy designed to promote the integration of environmental costs associated with goods throughout their life cycles into the market price of the products.

For, far too long, manufacturers of consumer products have externalized the cost of disposing containers and packaging. Policymakers and manufacturers must get together to re-thinkdifferent models of responsibility for waste.

EPR is an environmental protection strategy with an

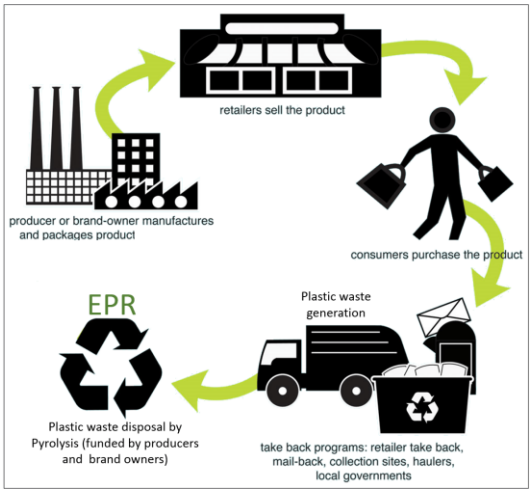


Fig 4.4 Diagrammatic Representation of Extended Producer Responsibility

objective to decrease total environmental impact of a product by making the manufacturer of the product responsible for the entire life-cycle of the product and especially for the take-back, recycling and final disposal.

EPR is designed to promote the integration of environmental costs associated with goods throughout their life cycles into the market price of the products. EPR legislation is a driving force behind the adoption of re-manufacturing initiatives.

It is important to understand that:

a. EPR is not Corporate Social responsibility, but part of sustainable business practice.
b. It is a product policy.
c. It is the next-generation policy that brings a shift from end-of-life to pollution prevention.
d. It formalizes waste sector by setting up financial cost standard and environmental standards.
e. It sets financial, physical and information responsibility.

Only when the producer takes responsibility of recovering and responsibly disposing his packaging waste, will he understand the problems associated with packaging wastes. This will cause a change in packaging material to more environment- friendly and recycling- friendly materials. EPR is focused on life cycle thinking, as it forces producers to remain accountable for their products past the factory gate – beyond the point of purchase and any warranty period.

In a recent move over 3 lakh British citizens have protested the hard-to-recycle packaging of a popular brand of chips co-owned by Pepsi-co by posting the empty snack packets to the manufacturer. The citizens are asking manufacturers to choose a more environmentally friendly packaging or else deal with their own waste. Such pressure can propel manufacturers towards choosing sustainable packaging. Prior to the advent of polypropylene, pioneering biscuit brand Parle-G and chocolate brand Cadbury Dairy milk came wrapped in packaging of wax paper, printed paper, cardboard and un-laminated aluminium foil, all of which were less harmful to the environment without compromising on product quality.

(Watch Film 1 on Resource Efficient Economy: Managing Natural Resources: Making more with less, Duration: 3.45 min https://www.youtube.com/watch?v=ZERrpFwETgs)

The Green Dot

PRO EUROPE (Packaging Recovery Organisation Europe) is the umbrella organization for European packaging and packaging waste recovery and recycling schemes intended to relieve industrial companies and commercial enterprises of their individual obligation to take back used products. The operations of PRO EUROPE fulfil these obligations on a nationwide basis on behalf of their member companies.

The aim is to ensure the recovery and recycling of packaging waste in the most economically efficient and ecologically sound manner.

In many countries this is done through the Green Dot trademark. The Green Dot (German: Der Grüne Punkt) is the license symbol of a European network of industry-funded systems for recycling the packaging materials of consumer goods.

Consumers who see the logo know that the manufacturer of the product contributes to the cost of recovery and recycling.

The system is financed by the Green Dot Licence Fee paid by the producers of the products. Fee varies by country and are based on the material used in packaging (e.g. paper, plastic, metal, wood, cardboard).

Each country also has different fee for joining the scheme and ongoing fixed and variable fee which take into account the cost of collection, sorting and recycling methods. This system encourages manufacturers to cut down on packaging as this saves them the cost of licence fee.

There are around 400 EPR schemes in operation across the world (as of 2001), most of which are mandatory. These include small consumer electronic equipment, packaging, tyres, end-of-life vehicles, lead-acid batteries, etc. A few voluntary EPR schemes are emerging, which target specific, hard-to-recycle packaging products – one example is Nestle's trial with Suez and Terracycle to take back Nescafe Dolce Gusto coffee pods from households in Berkshire. Pioneering examples of in-store take back include M&S' 'shwopping' initiative, Ikea's second life for furniture and light bulb recycling reverse vending schemes and Argos' trade-in service for unwanted gadgets. Once the item has been collected, if it is a product or component part, it may be ~~able to~~ refurbished and reused. Packaging is typically recycled and reprocessed into a secondary raw material, and taken back into the industrial manufacturing process.

Assessment of EPR systems is difficult because of lack of data, analytical difficulties, wide varieties of EPR systems limits comparison. Still, there is evidence that in some countries EPR has helped to:

a. shift some of the financial burden from municipalities and taxpayers to producers
b. decrease the share of waste destined for final disposal
c. increase rates of recycling in many OECD countries
d. prevent waste through eco- designs

There is scope for improvement in EPR in many countries by emulating the best performers. Setting targets, clear demarcation of responsibility, monitoring and audits, financial management, consumer acceptability and producer acceptability are the key determinants for the success of EPR.

There is also opportunity to make EPRs more effective by:

- increasing the level of ambition
- broadening the scope of products covered
- improving internalisation of environmental costs and transparency in EPR systems.

EPR in India

In India, Extended Producer Responsibility (EPR) is present in:

a. Lead acid batteries since 2000
b. Plastic waste rules since 2011
c. E-waste rules (mostly business to business) since 2011
d. Fluorescent mercury based lighting since 2016
e. MSW rules for packaging and sanitary pads since 2016.

4.43 million tons for waste is generated from the lead acid battery industry. There are around 450 authorised recyclers along with a large contingent of unorganized lead acid smelters. Around 70 percent of the plastic waste is recycled in the informal sector. There are 3,500 authorized recyclers. Of the 8.5 million tonnes of plastic consumed in India per annum, 6 million tonnes is sent as waste.
For e-waste, the producer of electrical and electronic equipment has been given the responsibility of managing such equipment after its 'end of life' i.e. once the consumer discards them. There are only 138 authorized recyclers for the 1.8 million tonnes of electronic waste generated in India annually. 95 percent of the e-waste is being handled by the informal sector. 18 of the 51 electronic brands studied by

Toxic links take minimal or no effort towards e-waste management. The monitoring of the implementation of e-waste rules in an effective way lies with the Central Pollution Control Board (CPCB).

8.79 million pieces of mercury florescent tubes are sold in India annually with nearly no recycling. The reasons for the dismal condition of recycling through EPR in India are as follows:

1. Recycling is considered isolated from the collection chain.
2. An informal sector for collection and recycling is rampant, despite the safety risks.
3. However, it is a tedious process for getting formalized into the recycling sector. It does not benefit the small unit owners and workers.

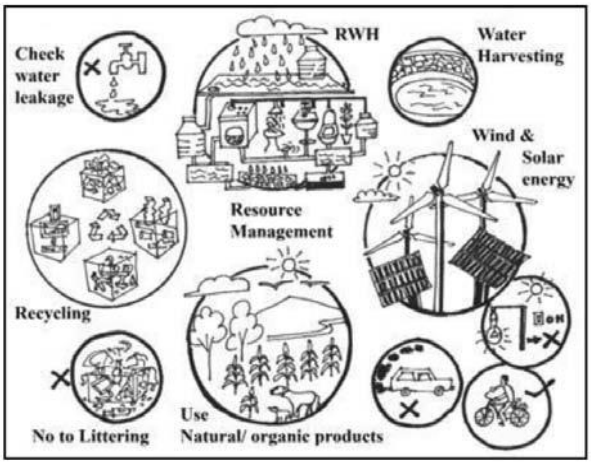
EPR vs CSR

Corporate Social Responsibility can sometimes be confused with Extended Producer Responsibility. Both CSR and EPR move the company towards sustainability, but in different ways.

While EPR is a product policy, bringing a fundamental shift from end-of-life to pollution prevention, CSR ensures full compliance to rules and regulations, protect the global environment and provide humanitarian support around the world.

CSR is the way a company interacts with its stakeholders and customers. CSR directly enhances the reputation of a company and strengthens its brand. CSR can be a strategic business management concept, charity work, sponsorships or philanthropy.

EPR formalizes waste sector by setting up financial cost standards and environmental standards, to create an environmentally sound waste management. On the other hand, CSR is the way through which a company achieves a balance of economic, environmental and social imperatives-the Triple-Bottom-Line approach**.**



4.6 Producer Responsibility Organisations (PRO)

Companies in India have now started taking help of third party organizations to help them with their EPR. The cost of reverse logistics and compliance are high for an individual producer. It is also time and energy intensive. Producer Responsibility Organisation (PRO) take back waste from open market, recycle or process, and file compliance on behalf of the producer. The producers only need to support the process financially.

This creates an opportunity for PROs to work with multiple producers.
Manufacturers pay service fee to PROs for enabling EPR compliance. The fee consists of:

1. Cost of reverse logistics
2. Cost of compliance

Initially PROs were tried only for e-waste.
PROs source waste from self-owned collection centres through the informal sector. Additionally, they also operate through franchisee-driven sourcing centres, which reduce transaction costs. In general, the obligation to recycle is transferred to a certified recycler. In few instances, these recyclers also operate as PROs by instituting their own collection channels.

Numerous Producer Responsibility Organisations (PROs) are now coming into the picture. CPCB has started registering PROs for plastic waste management**.** Companies too are warming up to the idea of PROs to deal with plastic waste**.** PepsiCo India committed to collecting and recycling PET plastic waste generated in Maharashtra. It partnered with Gem Enviro (PRO) to set up infrastructure for collection and recycling. The PET bottles would be recycled to manufacture thermal wear, furnishing fabrics and carpets.PET waste will be sourced through developed network of scrap dealers and contractors, who, in turn, work through informal ragpickers. Gem Enviro associated with Ganesha Ecosphere Ltd (GESL) as the collection and recycling partner. GESL sources raw material through a pan-India network of more than 20 collection centres. PET waste at collection centres are further sent for processing. This established network enables collection of about 225 tonnes of PET waste daily.

Waste collection model of PROs
Saahas Zero Waste (SZW), is another name in the field of reverse logistics, collecting plastics through extensive network of informal sector in Bengaluru, Gurugram, Chennai, Hyderabad, Surat, Bellary and Hubli.SZW has a strong collection model involving scrap dealers and informal sector of waste collectors who ensure collection of large quantity of tetra paks. Material recovery facilities (MRF) are the secondary aggregation and segregation point. Secondary segregation of paper, glass, metal and plastic is done at the MRF. Plastic is further segregated into 16 categories to increase sale value. SZW acts only as a collection partner and forwards the materials to Tetra Pak on reaching threshold (holding capacity of MRF). This model is a perfect example of strengthening existing value chain to ensure efficient sourcing of waste.
Waste Venture, a PRO operating from Hyderabad offers PRO solutions for a leading FMCG. The collection chain is driven by web app and on-call demand-based collection from residential and commercial establishments. This is further supported by nearly 30,000 informal waste collectors associated with the PRO. Waste Ventures created a database of these waste pickers, provided social identity, infrastructure and training on safe and hygienic way of handling waste. This ensured supply of quality raw material from these informal waste collectors at lower rates compared to an aggregator.

Challenges for the PRO:

1. PROs experience great challenges on the ground due to low level of source segregation.To make PROs effective, segregation at source needs to happen**.**Waste pickers collect high-value waste rather than low-value plastic with high volume. Indiscriminate scattering of products, some of which are not produced by a known brand, makes it even more challenging.

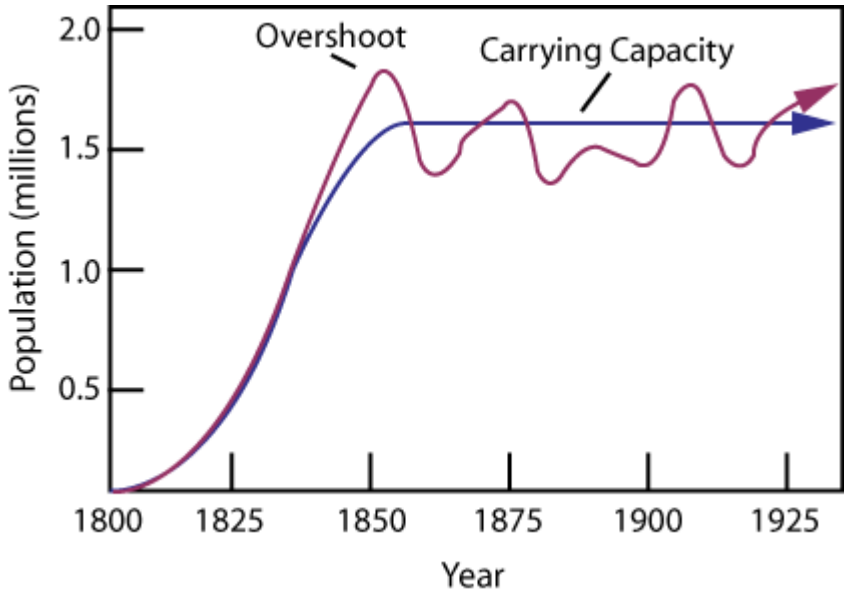


Fig 4.7 Carrying Capacity for a Particular Species (Humans in this Example)

Source:http://www.algebralab.org/practice/practice.aspx?file=Reading_CarryingCapacity.xml

2. Infrastructure deficit: The manufacturers are process-oriented entities with a formal structure. The Plastic Waste Management Rules specify that the manufacturer is to develop a mechanism to collect back the plastic waste in collaboration with the local bodies. The readiness of ULB to work in tandem with the manufacturers, considering the grassroots-level challenges and existing infrastructure deficit is not completely certain. A forced collaboration might not be required.

3. Monitoring and reporting structure: A strong monitoring and reporting structure is needed for both PROs and recyclers. A real-time assessment and mapping of supply by producer and state-wise consumption is required to determine the realistic and accountable EPR. Guidelines for registration as PRO and the roles of each stakeholder must be clearly drafted and enforced by the legislature.

4. PRO has to invest in a collection channel that would ensure continuous flow of high-quality source material. The optimal solution is to invest in the existing channel. The knowledge persisting in the informal sector is enormous and needs to be captured. Karo Sambhav, a Gurugram-based PRO, has created a strong network of informal sector. With this, the PROs can address the need for cost-effective collection of waste and safe disposal.

4.7 Carrying Capacity

Carrying capacity in an environment is the maximum population size of the species that the environment can sustain indefinitely, given the food, habitat, water and other necessities available in the environment. Carrying capacity may be seen as an equilibrium or balance. Overburdening the environment with overpopulation or excessive exploitation of resources makes the environment lose its balance, thereby causing widespread destruction until a new balance is achieved.

Carrying capacity is not a fixed number. Estimates put Earth's carrying capacity at anywhere between 2 billion and 40 billion people. At the present rate of consumption, 10 billion people are the uppermost

population limit where food is concerned. There are ~~current~~ly 7 billion people alive on Earth today. The carrying capacity changes according to a wide range of factors determined by our lifestyle.To sustain life it is important to keep in mind the carrying capacity of land. Many interventions have been done in the past to improve the carrying capacity of land. For instance, the Green Revolution in India brought with it high yielding crops and widespread use of pesticides, fertilizers and diversion of water for irrigating croplands. A few decades down the line, we are facing the repercussions of the Green Revolution with soil salinity due to over irrigation, rendering good farmlands barren. The agricultural runoff has caused mass contamination of soils and water, including groundwater. The quality of food available is rich in carbohydrates, high in yield, but dismally low in proteins because fertilizers only replenish macro nutrients like nitrogen, phosphorus and potassium but not the micronutrients which are essential for crop growth.

Carrying capacity of land depends on soil health. The health of soil is determined by the following characteristics:

Table 4.1 Characteristics of Healthy Soil

PHYSICAL	CHEMICAL	BIOLOGICAL
Aggregate and Structure	pH	Roots
Porosity	Soluble salts	Microorganisms
Compaction	Nutrient Holding Capacity	Microfauna
Surface Sealing	Sodium	Macrofauna
Water Availability	Nutrient Availability	Biological Activity
Water Movement	Toxins	Organic Matter

Proper waste management by the vast majority of citizens can help improve the carrying capacity of the environment in the following ways:

1. Wet (biodegradable) wastes can provide a solution to the food problem of India. By applying compost as a soil conditioner over vast tracts of barren land, an attempt can be made to improve the carrying capacity of the land.
2. Preventing the entry of toxic or potentially toxic material into landfills by moving them for recycling or reuse.
3. Reducing the requirement of resources- metals, petroleum oils, will bring down the requirement for mining.
4. Proper waste management prevent air pollution to a large extent.
5. Responsible behaviour of producers towards environment and communities can bring about change in products and technologies that are less harmful to the environment.

There are a few more important game changers that could bring us back from the brink of total environmental collapse. The important thing to remember is that the Earth has enough for every man's needs, but not for every man's greed. The degradation of Earth's carrying capacity for humans is associated with two integrated factors: (1) overpopulation and (2) the intensity of resource use and

pollution. It is in our hands to control these two factors, thereby ensuring continued life on this planet. We shall be reading more about sustainable lifestyles in the next chapter.

4.8 Precautionary Principle

Precautionary Principle is nothing but rephrasing of the adage, 'to be on the safe side' describes Often? we are not sure if our actions will have a negative impact. Keeping a reactive 'wait-and-see' approach can cause widespread environmental damage at times. Therefore, the principle is used by policy makers to justify their discretionary decisions in situations where there is the possibility of harm, especially when extensive scientific knowledge on the matter is lacking.

Article 3 of the UNFCCC contained the precautionary principle and made it one of the most popular legal concepts in international environmental law today. The Precautionary Principle is applied where scientific understanding of possible risks is yet incomplete, such as the risks of nano technology, genetically modified organisms and systemic insecticides. It is imposed to protect the human rights of those affected.

Guidelines in environmental decision making involve four central components of the precautionary principle:

- ✓ taking preventive action in the face of uncertainty;
- ✓ shifting the burden of proof to the proponents of an activity;
- ✓ exploring a wide range of alternatives to possibly harmful actions; and
- ✓ increasing public participation in decision making.

Disposal of Used Drugs

Bio-medical waste management is a specialized subject. However, there is one stream of biomedical waste that recurs in household waste and mixes with municipal solid waste, ultimately entering water bodies or landfills. This is unused and outdated medicines. There are a wide range of pharmaceutical drugs (chemicals) being used which have a hazardous effect on the environment.

There exists no post-market survey of the quantum of unused drugs. Nonetheless, there is an urgent need for constructive disposal of these chemicals, especially antibiotics which are the leading cause of drug-resistance in patients.

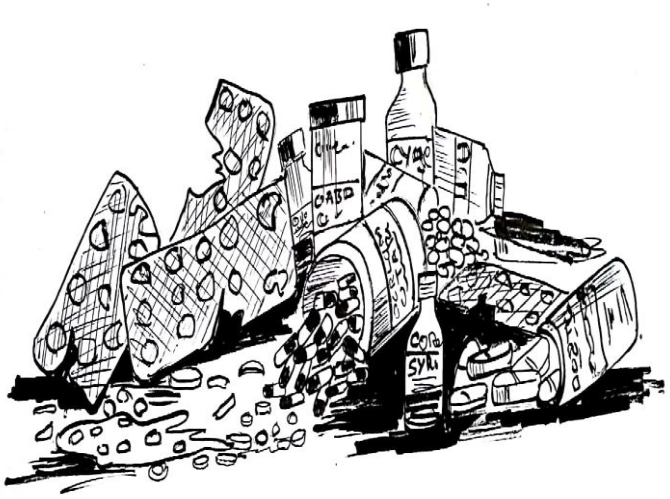
The Kerala State Drugs Control Department in alliance with the all Kerala Chemists and Druggists Association has recently launched an awareness programme under the Suchitwa Mission (Local Self Government Department, Govt of Kerala) wherein the public will be directed to deposit expired and unused drugs at kiosks. The medicines will be collected and moved to a pharmaceutical waste treatment plant (Ramky) in Mangalore. This is a good example of how the Precautionary Principle can work in India.

Summary

Waste Management is a common responsibility of the produces, consumers and the governments. To implement, it requires stringent laws in place. Policies of Extended Producer Responsibility, Polluter Pays and Precautionary Principle are the three most prominent mechanisms to enforce waste management. Pollution is not limited to its source, but spreads across borders and ecosystems. We explored the world scenario of scrap trade, which is a boon for economies and ecology, provided stringent norms are applied to prevent pollution and health hazards. Consequently, many South East Asian countries are reluctant to bear the burden of the deleterious effects of this trade. The assimilative capacity of the environment and also the carrying capacity of the ecosystem require a proper understanding. With heavy pollution affecting almost the entire globe, it is time for us to practice bioremediation to clean up persistent pollutants, practice zero-discharge policies and give a chance to nature to revive.

Self-Assessment Test

1. What is the purpose of Polluter Pays Principle?
2. Does the assimilative capacity of any part of the environment determine how much pollution is permissible? Explain.
3. What are the advantages and disadvantages of the international scrap trade?
4. What are the ways in which a polluter can take responsibility for his actions?



Video Film

1. Resource Efficient Economy: Managing Natural Resources: Making more with less, Duration: 3.45 min https://www.youtube.com/watch?v=ZERrpFwETgs

Chapter 5
Waste Reduction- Towards 'Zero-Waste'

Objectives

- To understand the concept of sustainable development
- To know how waste reduction can take place at different levels - individual, community and industry
- To identify areas that require innovation and transformation to achieve the goal of Zero-waste

Structure

5.1 Sustainable Living
5.2 Waste Reduction at Business (Producer) Level
5.3 Waste reduction at individual level: Zero-waste living
5.4 Waste Reduction at community level

To Do activities

1. Discuss on what is sustainability
2. Discuss- Is Zero- waste possible? How close can we reach it? Take a simple example of (say) preparing tea. How can the process be refined to near-zero waste?
3. Read and understand the case study of LCA of razor cartridges.
4. Discuss how each product they use in their daily life can be replaced by a low waste and healthier alternative. Divide students into small groups and facilitate students to understand zero-waste alternatives.
5. Screen film 3. Discuss the learning outcome of students from the film. Are they willing to create and use products as explained by the protagonist?
6. Prepare a list of all household hazardous consumables present in your individual homes. Identify sustainable and effective alternatives for each. Each student/ team should demonstrate the cleaning power of two alternative consumables.
7. Create paper bags with different qualities of paper. Test the bags for their ability to carry 1, 2 and 5 Kilograms of weight.
8. Conduct an e-waste collection drive at your college/ department. Identify the different varieties of gadgets collected. Send them to a certified e-waste handler in your town.
9. Think out of the box and bring out own ideas for replacing disposables. Is it possible to scale up an idea to a business level? Explore with the student(s) and support in every possible way.
10. Discuss on what topics each student is interested in, scope out possibilities of career development, research or internship opportunities.

"Sustainability is the possibility that humans and other forms of life on Earth will flourish forever."

-Prof John Ehrenfeld

Dealing with waste conscientiously as a waste manager, makes one realize that it would be best to bring down the volume of waste wherever possible. Be it an individual, a small business, SME, society as a whole or a large enterprise, the goal remains to sustain a healthy, comfortable and profitable business

for as long as possible. Less the wastage, lesser is the burden of taking care of it. Let us explore what sustainability implies in terms of waste generation.

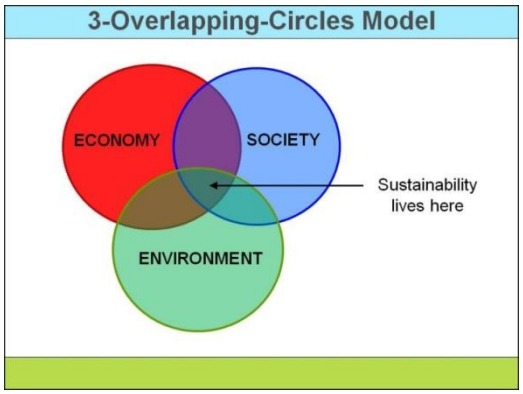
5.1 Sustainable Living

Sustainable living is a lifestyle that attempts to reduce an individual's or society's use of the Earth's natural resources and personal resources. Practitioners of sustainable living often attempt to reduce their carbon footprint by altering methods of transportation, energy consumption and diet.

Understanding Sustainable Development

"Sustainable Development – development that meets the needs of the present without compromising the ability of future generations to meet their own needs."

-The Brundtland Commission on Sustainable Development, 1987



Sustainability aims to protect our natural environment, human and ecological health, while driving innovation and not compromising our way of life. Sustainability is the capacity to endure. In ecology, it describes how biological systems remain diverse and productive over time. Long-lived and healthy wetlands and forests are examples of sustainable biological systems.

Today's lifestyles are unsustainable. It is estimated that we use about 40 percent more resources every year than we can put back. Sustainability has become a challenge due to:

---Over-population
---Intense use of resources
---Pollution.

Sustainability is the process of maintaining change in a balanced fashion, in which the exploitation of resources, the direction of investments, the orientation of technological development and institutional change are all in harmony and enhance both current and future potential to meet human needs and aspirations.

The World Summit on Social Development, 2005 defined the three pillars of sustainability as:

--- Economic Development
---Social Development
---Environment Protection

Sustainability should be self-driven, motivated by a personal and professional ethos. However, in reality businesses and other organisations require incentives to adhere to sustainability guidelines beyond their normal legislative requirements.

We must encourage and foster incentives for the average person to do their bit where and when they can. Economic development should give people what they need without compromising quality of life, especially in the developing world and reducing the financial burden and "red tapism" of doing the right thing.

Social Development includes maintaining access to basic resources without compromising the quality of life. The health of people should be protected from pollution through awareness as well as legislation.

Education teaches people about the effects of environmental protection and warns of the dangers if we cannot achieve our goals. It encourages people to participate in environmental sustainability. Societies should have sustainable housing that is built from sustainable material. These points fall under the ambit of social development.
The concept of nature having certain rights - that people have stewardship of the world and the importance of putting people at the forefront of solving global issues is the third pillar. We must study how to protect ecosystems, air quality, integrity and sustainability of our resources, with focus on the elements that place stress on the environment. Installing renewable power sources should be incentivized. Developing technology and biotechnology to drive our greener future and protecting the environment of the future from potential damage that technological advances could bring. Businesses must be regulated to prevent pollution and to keep their own carbon emissions low.
There are 17 Sustainable Development goals.

Sustainability and Zero-Waste

Economic well-being, environmental protection and social well-being are the three pillars of Sustainability. A zero- waste strategy implies an improvement in material flow, using far fewer raw materials and sending no waste material to landfills. This has direct implications for sustainability. Less raw material use amounts to protecting the environment and reducing costs. Less waste to landfill implies decreasing pollution. Zero-waste requires restructuring of the production and the distribution system. However, zero waste is an ideal, not a target. We can reach towards it, but achieving it totally is impossible.

Waste reduction needs to be at 3 levels: consumer, producer and community.

5.2 Waste Reduction at Business (Producer) Level

Reduce Waste in the Manufacturing Process

i. Reduce defects
ii. Avoid over production
iii. Avoid excess processing

In India, it is very commonplace to see factory outlets selling defective pieces of clothing, electronics and other products at cost-to-cost rates. These items are factory rejects - items which have been rejected by the customer or exporter for some minor mistakes, such as clothing with logos on the wrong place, slightly chipped crockery, etc. There are also certain factory defects, which are glaring mistakes that need to be taken back by the producer, for example several cars are sometimes recalled by the manufacturer after their sale if a glaring problem is observed in one of its parts. In all, creating a defective product reduces profitability and causes additional financial burden to the manufacturer. Hence, reducing defects makes good business and environmental sense.

In today's era, economies of scale are being used to produce goods far in excess of the demand. For instance, a small scale bakery may produce 50 loaves of bread in one batch. But a large scale production line will create 1000 loaves of bread per batch. So, create 1,200 loaves??, the production line will be forced to prepare 800 extra. This is over-production. If not sold, the waste created will be to the tune of a few hundreds vis-a-vis production by the small bakery, which may have far less wastage. A demand needs to be artificially created in several ways to compensate for over-production, such as replacement of spare parts instead of repairs, heavy advertising, competitive marketing, discount sales, launching

new products in quick succession, using sub-standard or environmentally damaging materials, etc. These feed hyper-consumerism, which leads to excessive waste generation.

Excessive processing is work effort that adds very little or sometimes no value to the end result. Over-processing is one of the seven wastes in 'Lean manufacturing'. For instance, painting areas that are not visible to the consumer, or likely to corrode, running the clothes dryer for longer, even after the water has drained off completely, removing all nutrients and fibre from whole wheat flour and then fortifying it with iron and vitamin B12- in short, a waste of energy, time, resources and effort.

Therefore, by preventing defects, overproduction and excessive refining, the business house can move towards a leaner production line. The second step would be responsible production is 'reverse logistics'.

C. Reverse Logistics

Reverse logistics is a process whereby companies can become more environmentally efficient through recycling, reusing, and reducing the amount of materials used. A more holistic view of reverse logistics includes reduction of materials in the forward system in such a way that fewer materials flow back, reuse of materials is possible and recycling is facilitated.

Traditionally, if a product is moved from its point of consumption to its point of origin, it is reverse logistics. Thinking in advance about long term can save money and time, reduce operational challenges, and minimize environmental and/or other long-term damages. A simplest example would be the old milk bottles made of glass. Dairy farmers would leave bottles of fresh milk at the customer's doorstep. Simultaneously, they would pick up the previous day's empty milk bottle, to be cleaned, pasteurised and reused the following day. Hence, they did not have to buy new bottles regularly to package their milk. The van which went for delivery returned with empty ones in the same trip.

Reverse logistics work in the developing world depends heavily on third-party provider due to shortage of legislation, awareness and infrastructure. It is characterized by low value addition due to the low reprocessing involved, e.g. from recycled electronics, paper, scrap, plastics, automobiles and food waste. Reverse logistics in emerging economies. Reverse logistics has not received the desired attention in developing countries and is generally carried out by the unorganized sector for recyclables like paper, plastics and metal. Professional collection, sorting and transportation of end-of-life products are much needed in emerging markets.

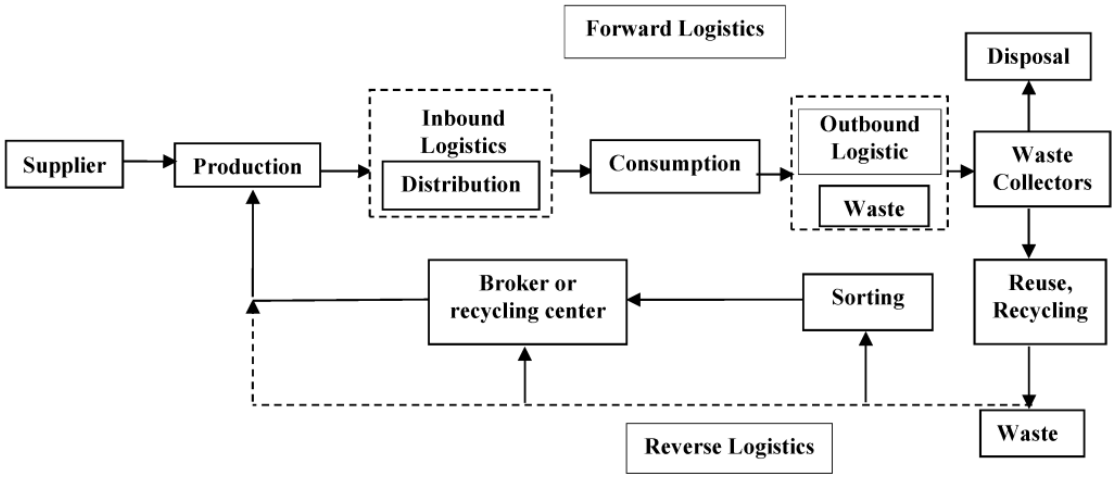


Fig 5.1 How Reverse Logistics Improves Efficiency in Material Use

A well-managed reverse logistics program can result in:

- ✓ significant cost savings in procurement- collected material can be reused or added to the raw material
- ✓ Responsible disposal- this can significantly reduce carbon footprint, reducing materials going to landfills, ensuring safe disposal (in case of hazardous wastes, like batteries)
- ✓ inventory holding and
- ✓ transportation.

Reverse logistics may be carried out by the original product manufacturers or by third-party reverse logistics providers. For example, using scrap metals saves energy and reduces metal to be mined. Companies like UPS and Apple collect the older models of their devices from customers. The usable parts from old machines are reused, while the non-usable material is responsibly??

With increased industrialization and globalization, reverse logistics is bound to gain momentum in coming years in the developing countries which will not only lead to economic gains but also protect the environment.

D. Life Cycle Analysis

With waste reduction and reverse logistics, much of the wastage can be reduced. However, there is need for technological advancements that will improve products, making them environment friendly at every stage of their existence. This demands a rigorous life cycle analysis.

Life-cycle assessment (LCA, also known as life-cycle analysis, eco-balance and cradle-to-grave analysis) is a technique to assess environmental impacts associated with all the stages of a product's life from raw material extraction through materials processing, manufacture, distribution, use, repair and maintenance.

LCA is a technique to assess the environmental aspects and potential impacts associated with a product, process or service. This assessment is exceptionally useful as it shows the designer what areas are the most impactful during the product's life cycle. For example, the designer might think that the manufacturing stage would be the most impactful, when in reality it could be the raw material extraction or its use phase. LCA can also help to compare newly redesigned products with the original, acting as a benchmark to ensure the design changes are actually positive for the environment. LCA is therefore used in new product research and development, when environmental footprint is important to the future marketing or cost structure of a product.

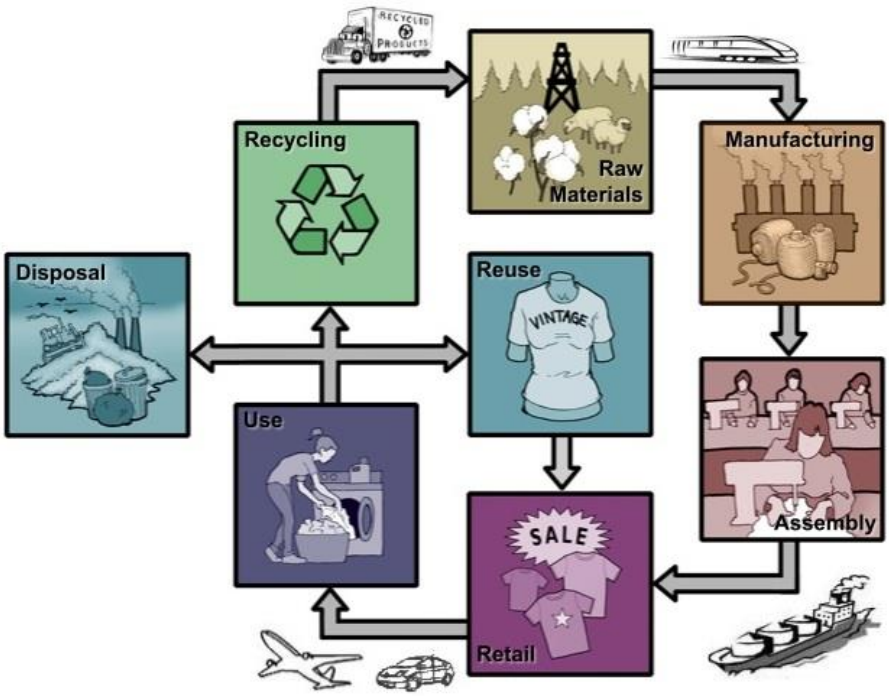


Fig 5.2 Life Cycle Analysis of Textile

LCA is not an exact science, unless it is done by the manufacturer himself. Athird party reviewer without access to all process details is bound to make certain assumptions. The Eco-Indicator method is a tool developed to help designers conduct a simplified LCA study.

Step 1. Gather all required information
Step 2. Analyse the product, identify areas that need improvement and which ones work well.
Step 3. Create alternative concepts which are more eco-friendly
Step4. A single score (Eco-Indicator point) is generated for all the impacts of the product.
Step 5. Improve the design
Step 6. Assess the new design to check if the impact is lower.

Methodology
1. Establish the purpose of the Eco-Indicator calculations. State the assumptions made.
2. Define the life-cycle.
3. Quantify the materials and processes.
4. Complete the form.
5. Interpret and analyse the results.

An example of LCA using Eco-indicator for razors is illustrated here, which compares the conventional double-edged safety razor with the modern cartridge based razor. As can be seen from Fig. 2 and 3, the results show that the double edged conventional razor is better with a score of 15.70 mPt. Whereas the cartridge razor got 115.06 mPt, primarily because of the 17 spot welds done in each cartridge. This is the part which is hardest to make. In landfilling or incinerating this part, the large amount of energy and material value used in creating it is lost. The biggest impact during the manufacturing of the razors was the cartridge. A new cartridge design can help the entire manufacturing process cheaper and energy efficient.

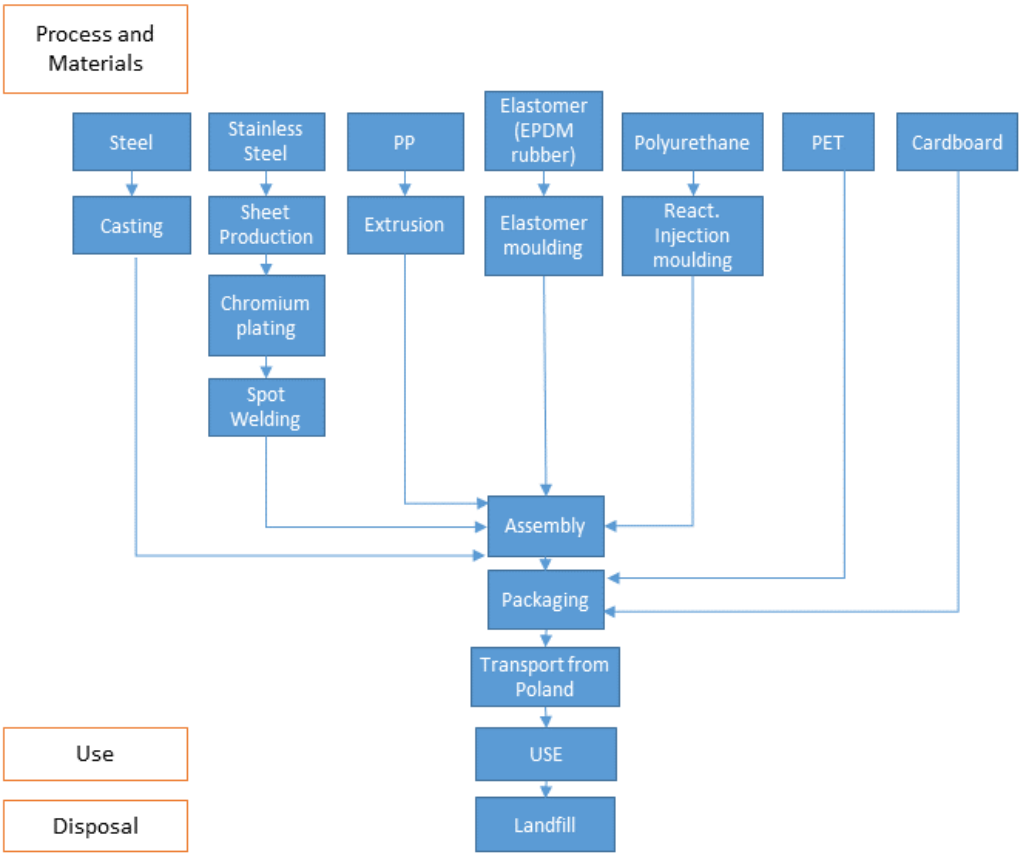


Fig 5.3 Product Life Cycle of a Cartridge Based Razor

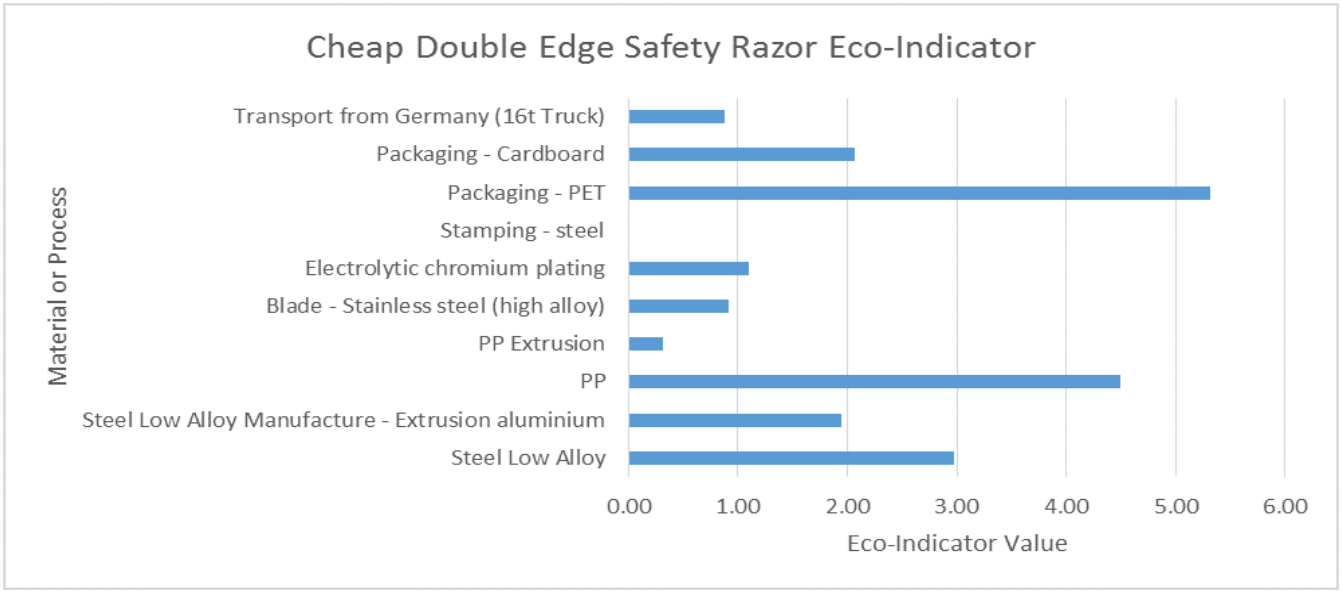


Fig 5.4 Eco-Indicators of Safest Razor

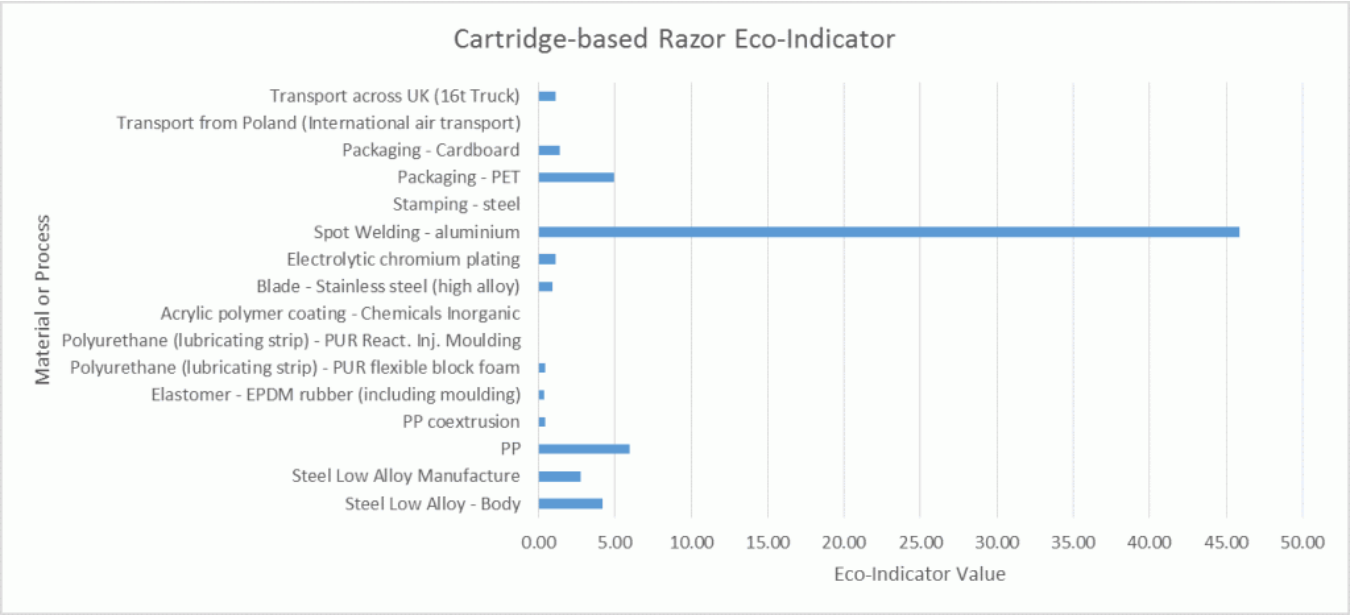


Fig 5.5 Eco-Indicator of Cartridge based razor

Preventive Maintenance

We have all heard of the adage 'a stitch in time saves nine'. Preventive maintenance is maintenance that is regularly performed on a piece of equipment to lessen the likelihood of it failing. It is performed while the equipment is still working so that it does not break down unexpectedly. It is planned maintenance that ensures any required resource is available. The maintenance is scheduled based on a time or usage trigger. Preventive maintenance involves the systematic inspection of equipment where potential problems are detected and corrected in order to prevent equipment failure before it happens.

It is simpler than predictive maintenance since monitoring strategies do not need to be planned, but more complex than run-to-failure maintenance that encourages use and throw practices. Preventive maintenance is suitable for assets with critical operational functions, whose chance of failures can be prevented with regular maintenance and those that have an increased risk of failure with time or use. A good example of preventive maintenance is servicing your vehicle every 1000 Kilometres.

Unplanned maintenance costs 3-9 times more than preventive maintenance, in terms of lost production, high cost for parts replacement and loss of time responding to emergency and diagnosing the faults. Preventive maintenance, on the other hand can be coincided with production downtime and minimizes repair time. Preventive maintenance includes much more than simply performing routine maintenance on equipment. It also involves maintaining accurate records of every inspection and servicing, as well as knowing the lifespan of each part to understand the replacement frequency. These records can help maintenance technicians anticipate the appropriate time to change parts and can also help diagnose problems when they occur. Preventive maintenance software helps collect and organize this information so it is readily available for maintenance technicians. Maintenance frequency should be optimized for best results.

5.3 Waste Reduction at Individual (Consumer) Level: Zero-waste living

Citizens across the globe are opting for a zero-waste lifestyle. The golden rule of zero-waste living is the 5R's:

1. Refuse
2. Reduce
3. Reuse
4. Recycle
5. Repurpose

Waste Prevention

- Responsible purchasing is an important step in preventing waste generation.
- Wherever possible, say no to plastic bags, wraps and packaging.
- Drive less or share rides to reduce plastic dust from tyres.
- Support a circular economy, where the product and packaging are recaptured by the producing company and some or all of the components are reused.
- Support organisations that are trying to stop plastic at source or cleaning up existing pollution.

Trick to Zero-Waste Living

"Anything I buy I want to get the maximum use out of it." This is the trick to zero waste living.
It is a change in mindset to recognise that everything you buy has been paid for in good money. Stop looking at it as waste and visualise it as hard-earned cash.
Living a zero waste lifestyle is a process .Tackle one area at a time where you feel you can make the most difference.
Some areas to work upon:

Food waste: Be more organised when you shop. Before you go shopping make a list of what is required for the week. Do not deviate from it. Feed left-over food to pets. If not, compost it.
>> Containers: All containers such as aluminium cans are automatically washed and recycled. Avoid plastic wherever possible but if you do have to buy them, they should be repurposed for anything from keeping food fresh in the fridge to portioning food ready for the freezer.
>> Plastic bags: Keep plastic shopping bags collected from shopping trips in your vehicle, so that it can be reused the next time you shop. Packaging can be repurposed for bin liners.
>> Dishcloths: Avoid single-use napkins and wipes. Re-wash dishcloths for the washing up. When they get threadbare, use them to clean the bathroom and toilet.
>> Food packaging: The recent trend is to use a cardboard foam material to cushion fruit then wrap it in thin plastic. Instead, buy loose fruit and vegetables and carry them in your own bags.

Bathroom: There are several products, such as bamboo toothbrushes that can help cut down on waste.
>> Avoid disposable razors
>> Buy products in bulk to reduce packaging, only when you run out
>> Buy solid alternatives to shampoo, conditioner and soap. These last longer.
>> Read labels and buy the products with the least number of chemicals.
>> Avoid products containing micro-beads. These contribute to microplastic pollution and endanger wildlife.
>> Create your own cleaning solutions and use an old spray bottle. A simple mixture of white vinegar and baking soda is just as effective. Lemon juice adds a lovely scent. Use newspaper to get rid of streaks on windows.
>>Make products multitask. There is no need to buy different products for different jobs. The cleaner for the bathroom works just as well in the kitchen.
Clothes: The global use of clothing amounts to 3 percent of all CO2 emissions. That includes production, shipping, washing and drying. To reduce clothing waste, buy fewer products of better quality so they'll last longer. Mend higher-quality items instead of just throwing them out.
Monitor your progress: Keep track of your zero-waste living progress and work out your carbon footprint estimate.

Sustainable Solutions

1. Avoid the fast fashion trap: Fashion/ clothing industry is one of the top polluters in the world. Buy durable clothing, use to the maximum, re-fashion the garment for further use (rough-use clothes, cropped clothes or night wear) and finally turn them into cloth bags, dishcloths, foot mats, etc.
   (Watch Film How fast fashion adds to the world's clothing problem, Duration 22 min
   https://www.youtube.com/watch?v=elU32XNj8PM)
2. Avoid hyperconsumerism: Hyperconsumerism is becoming a large issue for families and the environment. Though the film shows America, a similar trend is developing in urban middle class homes in India. To bring down the quantum of waste, we need to reduce this trend.
   (Watch Film A cluttered life: Middle class abundance. Duration 19 min.
   https://www.youtube.com/watch?v=3AhSNsBs2Y0)
3. Preventive Maintenance: Buy durable items and take care of them with timely maintenance and servicing. Make optimum use of all equipment. Over-use can cause breakdown, underuse can cause malfunction (e.g. rusting) and encourage trashing.
4. Purchase refurbished items: It saves money, gives longevity to goods and protects the environment.
5. Identify source reduction opportunities. Seek alternatives. Explore and revive traditional ways of doing things.

5.4 Waste Reduction at Community Level

When communities decide to work together, they can bring in tremendous change. This needs education, motivation, political will, stewardship and enthusiasm.

India's Zero-Waste Model Cities, Organizations and Villages

There are several cities and towns that have dramatically changed their attitude towards waste management. Swachh Bharat Mission was instrumental in fast-tracking this change. A few note-worthy examples are given below.

1. Alleppey, Kerala:

Biogas plants, both portable and fixed, were set up in 40,000 households in 52 wards with a 75 percent subsidy provided by the government. The pipe composting system is convenient to use. In addition, centralized aerobic composting units have been set up and are run entirely by the people. This has resulted in Alleppey closing down all its waste dumping sites and made the town a zero-waste role model.

2. Mysuru, Karnataka:

Proper waste segregation at source by the citizens of Mysuru makes the job of the municipality easier to further separate the dry waste into 24 categories in a decentralized manner and send the cleaned waste streams directly to recyclers.

3. Gerethang village, Sikkim:

600 households in Gerethang gram panchayat passed a resolution to not to use disposable paper, plastic or styrofoam plates, cups and spoons, nor sell them in their shops in May 2013.

4. Sikkim:

Sikkim is India's fully organic state, by banning procurement and use of chemical fertilizers and pesticides as early as 2003 in the state. It eliminated subsidy to farmers for procuring chemical pesticide. Further, in 2014 the use of chemicals in agriculture became a criminal offence. Organic farming was introduced in the school curriculum as a separate compulsory subject. Compulsory training on organic farming and its advantages was introduced as part of capacity building. As a result, the soil has recovered from pesticide pollution and 1,90,000 acres of cultivable land has been certified organic. Health, tourism and wildlife are flourishing. Today Sikkim produces 65 percent of all of India's 1.24 million tonnes of organic produce.

5. The Better India, Bengaluru, Karnataka:

This is a media company that runs stories of public interest on social media. Zero-waste was achieved within two months with the help of Hasiru Dala, a waste pickers' welfare association and One Hop Organics Pvt. Ltd., a waste management company. They are composting their wet waste. The most important step was proper segregation monitored by office staff. Electronic waste is being sent once every 3 months for recycling. The office has changed its purchase policy by replacing tissue paper with cloth towels, curbing tea bags in the pantry and storing drinking water in glass bottles.

Community Level Action for Waste Reduction

Waste reduction at community level can take waste management to the next level. Communities should consider the following action points:

1. Goal Setting: Each individual, institute, community, business or city must set a goal for waste reduction. For example, a goal to reduce per capita waste generation by 50 percent in 3 years. This requires proper waste reporting and tracking to quantify changes in waste generation.
2. Identify waste diversion opportunities: By reducing waste, we reduce waste management costs.
3. Innovations: Governments and private agencies as well as communities should experiment with new, innovative methods of reusing hard-to-recycle material, such as e-waste or developing state-level policies to address contamination.
4. Speak up against household hazardous waste: Only when the community boycotts products that generate household hazardous waste will the business and governments listen. Media will publicize the issue and the producers will be forced to make eco-friendly products.
5. Make packaging recyclable: The waste stream has rapidly changed to more plastic and less paper. This is a very complicated issue. Local, state and central governments along with the private sector, must ensure that we have sustainable recycling programs.

Innovative Products to Replace Disposables

1. Bengaluru based 'Earthware' company is South India's first manufacturing company that makes food containers out of bagasse (fibre from sugarcane, bamboo, wheat, cellulose). The containers include cups, bowls, cutlery and lunch boxes that are water-resistant, shatter-proof, compostable (within 90 days) and micro-wave safe.

2. Bakey's , an all-women enterprise in Hyderabad, uses a mix of jowar (sorghum millet), rice and wheat flour to manufacture edible spoons of different sizes as well as chopsticks. The spoons are available in three flavours- plain, sweet and spicy. Over 1.5 million people worldwide are switching to edible cutlery. Edible cutlery can be consumed by humans as well as animals without fear. If thrown away, it quickly decomposes.

3. Bumpadum Cloth Diaper: Bumpadum is an enterprise started by concerned mothers, who wanted a better option than disposable diapers. This is a Make-in-India company, with a virtual community of young mothers who choose to use re-usable cloth diapers in attractive prints. The diapers are adjustable, with inserts made of organic cotton, silk, hemp, bamboo fibres and waterproof fabric like PUL (polyurethane laminate). Bumpadums can be bought new (from the website) as well as 'pre-loved' (from social media handles) to suit every mother's needs.

Reuse of Scrap Tyres

This is an example of how best to use hard-to-use scrap material. The applications of scrap tire-derived recycled material are increasing in civil engineering because of their potential economic and environmental gains. Tire chips of 20 mm x 10 mm are mixed with sand (40-50 percent by volume) to create STC. This STC is 20 percent lighter and has better strength parameters and compressibility than conventional retaining wall material and thus can be used for geo engineering applications.

Summary

Waste reduction is possible at individual, business and community levels. Hyper-consumerism and a lack of life-cycle analysis are making us inadvertently waste resources. Reverse logistics, life cycle analysis, preventive maintenance, waste prevention and goal setting can help businesses become zero-waste. Communities have worked together to manage wastes. They can take it further by preventing waste. Sustainable living is possible with a few lifestyle changes. This is not only beneficial to the people and the planet but also profitable for businesses.

Self-assessment Questions

1. Discuss on preventive maintenance.

2. Explain the concept of waste reduction, and reverse logistics.
3. Write a note on sustainability.
4. How can wastage be reduced during production?
5. What is life cycle analysis?
6. Enlist the changes you can make in your personal life to achieve a zero-waste lifestyle. How challenging will it be? How long do you think it will take?
7. Explain with an example how reverse logistics can be applied to any production process.
8. Which are the areas that individuals need community support to achieve a zero-waste lifestyle?

Films

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Course 4 Water Security

PG Diploma in
Waste Management & Environmental Hygiene

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Foreword

Water is the primary medium through which climate change impacts people, ecosystems and economies. Therefore water resources management should be an early focus for adaptation to climate change. Water is not only part of the problem but also an important part of the solution. Achieving and sustaining water security that is harnessing water's productive potential and limiting its destructive potential is a primary focus area for action. Countries that have not achieved water security will face the heat of climate change. Sustainability is also an issue for those countries with who enjoy water security. A focus on water security is a sound early adaptation strategy for strengthening systems and capacity for longer-term climate risk management.

Many societies will want to continue to invest in water management to move beyond water security and take fuller advantage of the economic, social and environmental benefits that can be derived from wiser water use. A water secure world will need investment in the three**Is**: Information, Institutions, and Infrastructure to store, transport and treat water.

Many pioneers in the field are doing immense work towards reaching a sustainable world. From floods to droughts, water-related disasters pose a significant threat to economies, infrastructure, and lives in both the developed and developing worlds. Water-related disasters account for almost 90% of all natural hazards, resulting in billions of dollars in damages and affecting millions of people each year. The significance of this is that with climate change the effects associated with water-related hazards will increase in intensity and frequency in both currently vulnerable areas as well as historically resilient areas.

This course on Water Security is suitable for students of all streams - Commerce, Humanities, Science, Management, Journalism, Mass Media, Healthcare services (B Pharm, Social Work), Education, and Engineering. The extent of environmental damage and the innovations in combating the issues require scientific understanding of the subject.

The subject has vast possibilities and several interlinking themes. There is extensive scope to explore and experience different aspects of sanitation, pollution, environmental hygiene and waste management during classroom learning, practical experiments in field and laboratory, internship and dissertation. There is a sea of opportunity in this field of waste management and environmental hygiene, and an urgent need of skilled as well as dedicated workers to make our country clean and green.

Nature has interlinked realms. Similarly, subjects dealt in this course cannot be compartmentalized. They necessarily have to merge with one another. It is therefore important that students try to make these linkages in their minds rather than treating subjects in isolation. Students can make the most of this learning opportunity as they prepare to launch their careers in a field that holds great premise.

Dr. W G Prasanna Kumar

Chairman, MGNCRE

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The sincerity with which the course curriculum was completed and published can be assessed from the fact that a prior National Consultation Workshop was held with several subject matter experts and academicians across the country, to review the contents of the course material.

The workshop was held to familiarize Central, State and Private Universities, local and social bodies with the contents of the curriculum and to discuss and share feedback on ways to improve the course curriculum. The workshop also focused on building industry–academia partnerships in Waste Management and Environmental Hygiene through an intellectual interaction. The findings and inputs of the consultation were subsequently incorporated in the course material.

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Objectives

- To orient in reducing the use of water and improving the quality of waste water
- To employ advanced methods for waste water treatment
- To appreciate the importance of water quality monitoring
- To adopt sampling techniques and laboratory techniques of water quality analysis

Rationale

Waste management and environmental hygiene is the need of the hour and needs to be addressed across all sectors and communities. The course on Waste Management and Environmental Hygiene gives the student an overview of waste management including collection, transfer, transport, and disposal along with methods of processing, basic disposal facilities, disposal options, recycling, project management and GIS applications, reclamation and remediation, entrepreneurship and job opportunities in waste sector. In addition, this course provides the student with relevant information about waste markets, recycling trends, cost and affordability of waste management practices, and incentive based concepts. This course is therefore essential for the students who wish to pursue a career in waste sector as moving ahead, waste management will become an infrastructural necessity.

Competency

The course will be taught and implemented with the objective to develop required skills sets in the students so that they are able to acquire following competency: Plan segregation, collection, transportation, recycling and disposal of wastes, know recycling trends and available waste markets, acquire skill development and know the scope and entrepreneurship opportunities in the waste management sector.

Methodology

The theory will be taught and practicality of the course will be addressed through questionnaires, self-assessment and dissertation. The course will be through class room lectures, guest lectures, field visits, audio – video learning mode, brainstorming sessions, seminars and Q&A. A lecture series will strengthen students' understanding of waste management which will help in acquiring different learning outcomes in rational andtheory to practice approach. Competency that will be gained as part of course outcome includes - understanding, learning, applying and implementing skills, knowing career prospects in waste management sector, and internship and placement opportunities in.

Topics Covered

- Water Issues
- Wastewater Management
- Alternative Technologies for Sewage Treatment
- Solutions for Clean Water
- Testing of Water
- BOD, COD
- Waste Water, Soil and Solid waste

Water Security – An Introduction

Availability of clean water is one of the limiting factors in the growth of any population. With climate changes, over-exploitation of ground water, rampant water pollution, ever-increasing per capita water use and rising human population, fresh water is undoubtedly the fastest depleting natural resource. Besides the threat of desertification and perennial rivers turning seasonal, there is also a threat of war and radiation pollution looming over water bodies.

This course deals with all aspects of water. The first chapter focuses on the availability and global distribution of water, the causes of water pollution, their types, and consequences. The second chapter throws light on the present scenario of waste water and the conventional methods to manage it, primarily sewage treatment plants. The third chapter explores alternative technologies, and advanced treatment methods, so that water treatment can be made more effective, cheaper and de-centralized. Each method has its pros and cons, which are discussed.

It is best to keep clean sources of water safe and unpolluted. The third chapter highlights some ancient technologies and civil engineering feats that secured water even under adverse conditions. These techniques can be revived and reproduced across the sub-continent to good effect. Some success stories are highlighted in the chapter that bring this point to the fore. Rainwater harvesting, riparian buffers along rivers, the need to decommission old dams to allow rivers to flow freely, and managing watershed in rural as well as urban settings are important ways to safeguard precious fresh water.

The last chapter is wholly dedicated to monitoring techniques, giving a clue to the types of water analysis. This is especially relevant to students of commerce and humanities, who may have missed such experiments during their graduation. It is crucial to understand why the analysis needs to be done, the proper techniques of water sampling, and the need to monitor water bodies. Consuming contaminated or polluted water can bring forth several health issues. Water-borne diseases are briefly touched upon. Besides water sampling, the chapter gives a brief overview of soil testing and explains how waste is tested for its potential to leach. This is particularly important to prevent irreversible ground water contamination.

Safety and reliability are key factors for water security. Even terrorism poses threat to wastewater systems as bring increased attention to issues of security. Landslides, land subsidence, droughts, population growth, deteriorating water quality, floods and other hydrological effects of global change contribute to the growing concern of water security. Hence a holistic approach is required which actively integrates social, cultural and economic perspectives along with scientific and technical solutions.

Chapter 1
Water Security

Objectives

- To understand water scarcity due to inequitable distribution of water and poor environmental management
- To know how water pollution heightens water scarcity

Structure

1.1 Overview of Water Security
1.2 Inequitable Global Distribution of Water
1.3 Water Quality
1.4 Consequences of Water Pollution
1.5 Causes of Water Pollution
1.6 Types of Water Pollution
1.7 Biohazard, Radiation hazard and Security threat

To Do Activities

- Have an open discussion regarding fresh water availability
- Screen film H2Woe
- Watch film on superbugs. Case study analysis of Patancheru.
- Discussion what topics each student is interested in, scope out possibilities of career development, research or internship opportunities.
- Make notes, add to the study topics of interest
- Collect five stories from local newspapers regarding types of water pollution in your area. Read and discuss in the class. If possible, visit the sites for ground-truthing. You may bring back water samples for testing.
- Test various samples of polluted water for oil pollution, micro plastics, surfactant pollution, odour etc. Take all due precautions while sampling.

1.1 Overview of Water Security

Water security is defined as, "the reliable availability of an acceptable quantity and quality of water for health, livelihoods and production, coupled with an acceptable level of water-related risks". It is also concerned with the responsibility for water and integrating water resources management across all sectors—finance, planning, agriculture, energy, tourism, industry, education and health.

Water Issue

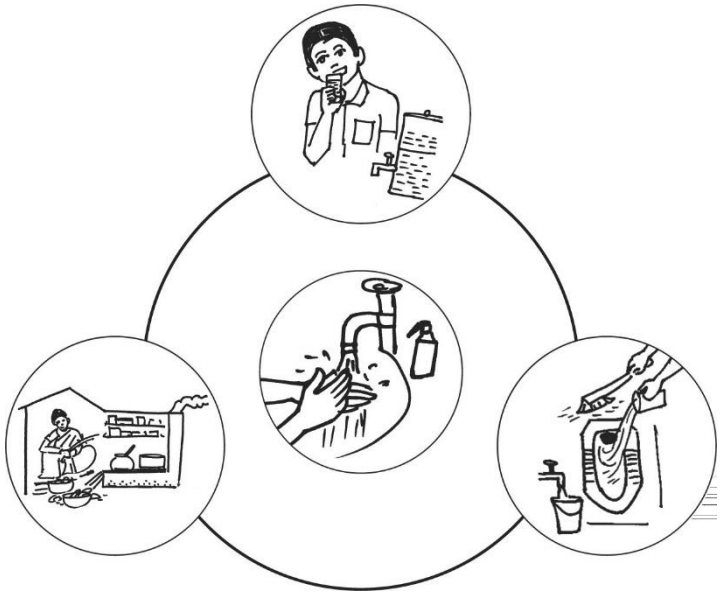
Main factors that contribute to this issue include poor management of resources, lack of government regulations and man-made waste which leadsto water scarcity. It involves water stress, water shortage or deficit, and water crisis. Some of the major reasons for water scarcity are:

1. Inefficient use of water for agriculture
2. Reduction in traditional water recharging areas
3. Sewage and wastewater drainage into traditional water bodies

Release of chemicals and effluents into rivers, streams and ponds would also cause water scarcity because of water pollution.

How do we curb water pollution and solve water scarcity?

1.2 Inequitable Global Distribution of Water



Water is the elixir of life. We, humans need more water for our daily needs than any other terrestrial creature. Where is this water supplied from? Roughly speaking, 97.5 % of water on this earth is in the oceans and therefore saline. Of the 2.5 % fresh water we have, 1.97% is permanently frozen. Of the balance 0.053%, 0.03 % is on the surface and 0.5% is present as ground water. Human population of the world stands around 7.7 billion, of which 1.35 billion are Indians. The most basic requirement we have is of 2 litres of clean drinking water per capita per day, for drinking alone. A person can comfortably live on an average of 40l per day. As per WHO, in extreme emergencies, we need a minimum of 15 litres per day to survive (for basic hygiene needs and basic food hygiene). However, an average urban Indian uses 250 litres of water per capita per day, an average Indian uses 150 litres (or two bathtubs full per day). Per capita water consumption in America is about 400 L, in Canada about 329 L, in China about 178 L. These figures are rising.

India is a water surplus nation. The gross mismanagement of fresh water and the extreme pollution of rivers is the cause of India's water woes. The distribution of water across India itself is not in any way equitable. As one can see in the film link, there are families surviving on less than 1 litre of water per day. Today much of rural India is suffering from failing agriculture, spending a large part of the day in strenuously seeking clean drinking water and the paucity of water is driving many a citizen to the point of suicide. The story of inequity does not end with personal use. Our water needs are not limited to domestic purposes alone. Of the fresh drinking water supplied through a network of dams and canals, roughly 68% is sent for irrigation, nearly 30% goes for industrial use and domestic purposes garner barely 2% of all the usable water.

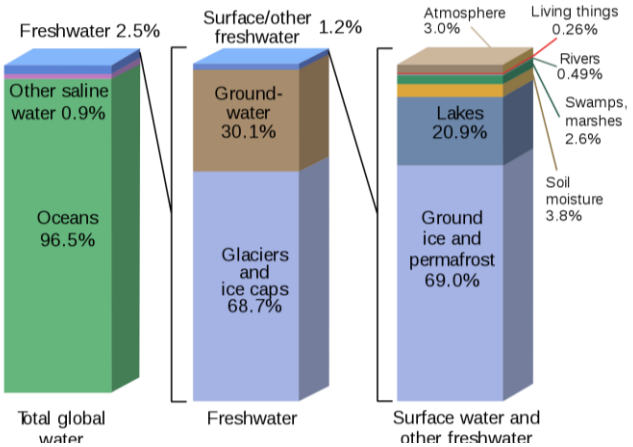
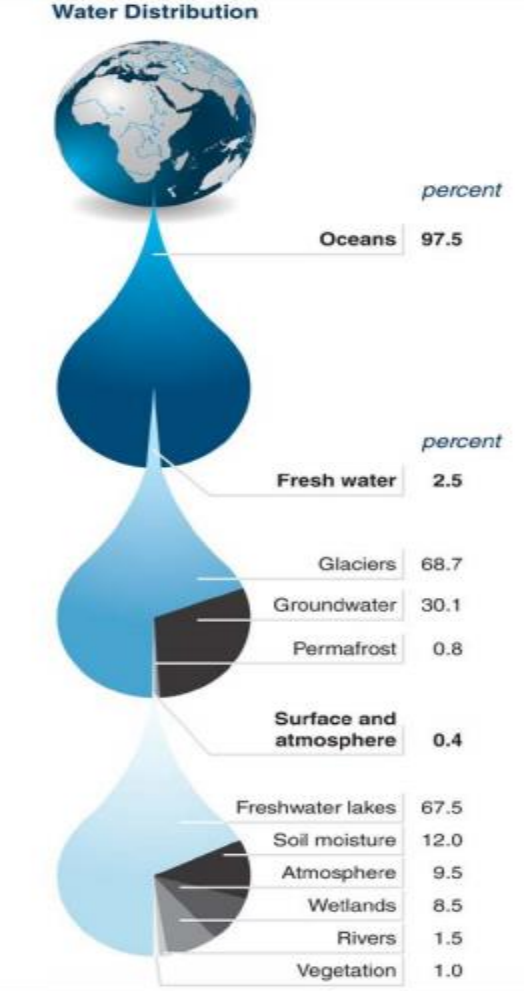


Fig 1.1 Distribution of Water on the Earth[1]

[1]Igor Shiklomanov, Peter H Gleick, 1993, 'Water in Crisis: A guide to the World's Fresh Water Resources

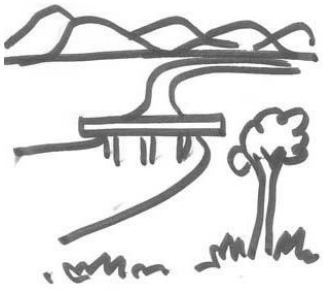
This inherent inequitable water distribution leads to many geo-political issues. Scarcity of water has a direct impact on health and prosperity. Without enough water, crops cannot be grown, which leads to hunger and poverty. This in turn leads to sickness and strife. An offshoot of this problem is the effect on education. When children spend much of their day fetching water from far off places, and regularly fall ill, it severely affects their attendance at school.

(Watch Film1-India's water crisis: H2WOE - India's water crisis- A warning to the world https://www.youtube.com/watch?v=H0hk_5Plv5U)



The Earth's Water – Source: Office of the DIrector of National Intelligence – Global Water Security)

Conflict Over Water



One billion people do not have access to safe water—problems that will likely increase as the world population grows from 6.8 billion people now to about 9.0 billion by 2050. This problem will be especially acute in countries with high population growth rates that share a major source of freshwater with other countries.

Major underlying reasons for conflicts over water include:

- low rainfall, inadequate water supply, and dependency on one major water source;
- high population growth and rapid urbanization;
- modernization and industrialization; and
- a history of armed combat and poor relations between countries and among groups within countries.

Water scarcity alone, is rarely the cause of armed conflict over water. Sociopolitical tensions; disputes over dams, reservoirs, and other large-scale projects; and disputes concerning environmental and resource issues tend to trigger such conflicts.

If the conflict turns violent, it will have disastrous health consequences for individuals and populations, including:

- death, injury, illness,
- long-term physical and mental impairment,
- destruction of the health-supporting infrastructure of society,
- breakdown of water supply systems,
- forced migration- that further decreases access to freshwater, and
- diversion of financial and human resources- making it difficult to maintain, rebuild or improve access to freshwater.

1.3 Water Quality

Water quality refers to the chemical, physical, biological, and radiological characteristics of water. It is a measure of the condition of water relative to the requirements of one or more biotic species and to any human need or purpose. The issue of water availability is closely linked with water quality. Water quality testing is an important part of environmental monitoring. When water quality is poor, it affects not only aquatic life but the surrounding ecosystem as well. Physical properties of water quality include temperature and turbidity. Chemical characteristics involve parameters such as pH and dissolved oxygen.

1.4 Consequences of Water Pollution

Pollution of water refers to as contamination of water bodies mostly due to human activities. The pollutants can be highly nutrient rich substances or toxic chemicals that change the quality of the water in terms of its pH, turbidity, colour, temperature and chemical composition. Pollutants could be solids, liquids and even gases.

Water is a universal solvent. It readily accepts a large variety of substances into it. It is also capable of hosting a wide variety of organisms within it, which together form aquatic ecosystems of varying species compositions. Ecosystems are capable of absorbing pollutants to a certain limit, and processing them to render them harmless. This is known as the assimilation capacity of the water body or ecosystem.

However, dumping pollutants beyond the assimilating capacity render the water body unusable. It causes fish kill, teratogenetic changes (birth defects) in frogs, makes the water bodies eutrophied (containing excessive nutrients) which cause an algal bloom, which in turn causes dissolved oxygen to get consumed quickly, leaving anoxic zones. Eventually, a clean water body is turned into a stinking, black, cess pool. The direct economic cost of water pollution is the cost we incur to clean the water and re-use it. Indirect economic costs come in terms of health care and loss of food security.

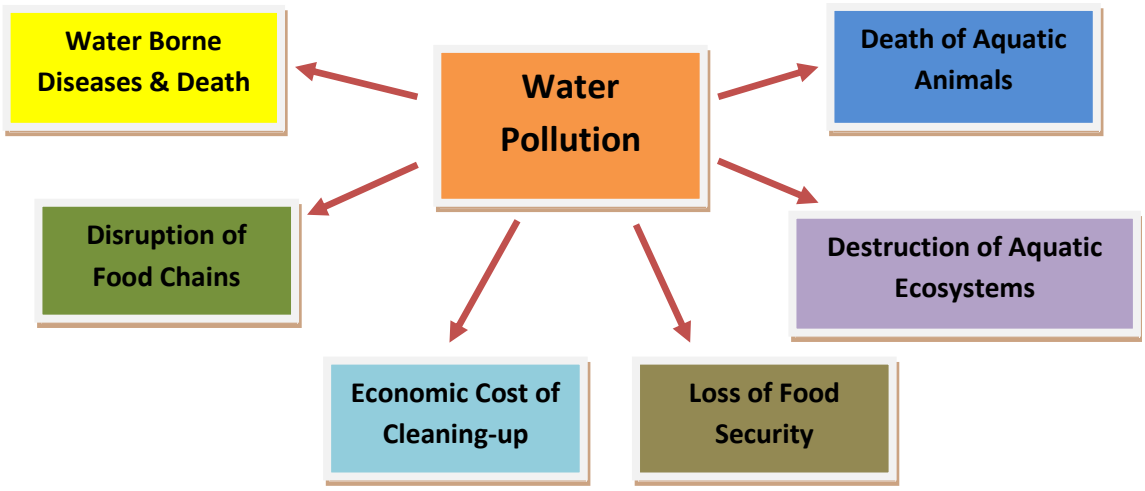


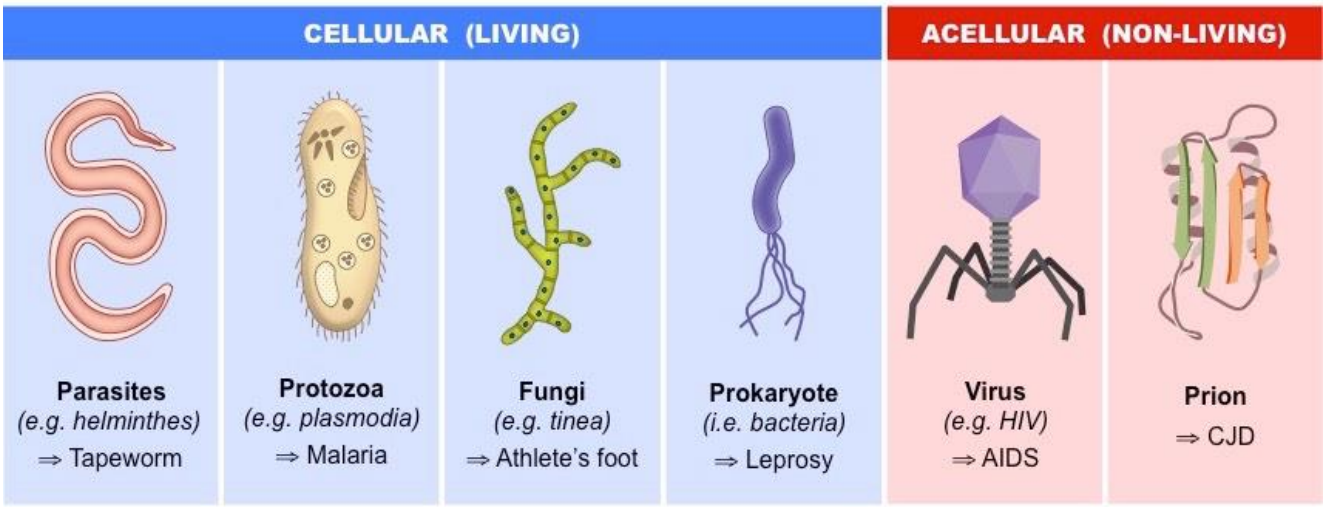
Fig 1.2 Consequences of Water Pollution

Water-Borne Diseases

Water-borne diarrheal diseases alone result in annual deaths of about2,00,00 children below four years of age in India, according to a study published in the Lancet medical journal in 2014.Main types of infectious agents are:

- **Bacteria** –Bacteria are very simple microscopic organisms. Some types of bacteria are essential to human life, playing a part in the digestive system. Many others provide beneficial services to us, such as decomposing wastes. However, pathogenic bacteria are responsible for many diseases, including tuberculosis, pneumonia and several waterborne diseases such as typhoid and cholera.
- **Viruses** – Viruses are not living organisms themselves but are infectious agents able to invade cells and cause them to manufacture more virus material. Polio, AIDS, influenza and rotavirus are examples of diseases caused by viral infections. More than 200 varieties of viruses cause common colds alone. But half of all colds are caused by rhinovirus. As we age, our exposure to many viruses make us immune to these viruses one by one, thereby preventing older people from catching colds and flu as often as younger people.
- **Protozoa-** Protozoa are the simplest members of the animal kingdom. They are microscopic, consists of a single cell and are found in water, soil and the sea. Some types are beneficial to humans, breaking down pollutants in water, but others are parasitic, causing diseases including malaria, amoebic dysentery and sleeping sickness.
- **Parasitic worms** (collectively known as helminths)– Helminths live inside the bodies of their human host, usually in the intestines. There are three main groups of parasitic worms including tapeworms, flukes and roundworms. Roundworms, also known as nematodes, include soil transmitted worms like Ascaris, hookworm and whipworm. Most worm infections are not fatal, but they do cause long-term debilitating illness including delay in growth, learning and education of children. Malnutrition and anaemia also occur. Lymphatic filariasis is caused by round worms transmitted through mosquitoes malaise; fever and chills, as well as enlarged painful lymph nodes. Chronic LF infection results in severe disfigurement and disability. It can cause hydrocele, or accumulation of fluid in the sac surrounding the testicles, and lymphedema, or elephantiasis, swelling of the legs and occasionally the genitals and female breasts.

Please note that all worms are not parasites. Most worms are harmless, and some worms are useful to us. For example, earthworms decompose dead plant matter and improve soil structure and fertility. They are known as farmers' friends. We are concerned only with parasitic worms in this case.



HELMINTH WORMS	PROTOZOA	FUNGUS	BACTERIA	VIRUS
Intestinal infection, elephantiasis	Malaria, sleeping sickness	Skin infection	Typhoid, TB, cholera, anthrax, pimples, peptic ulcers	Common cold, influenza, dengue, SARS, AIDS

Fig 1.3 Disease Causing Biological Agents

Death of Aquatic Animals and Destruction of Aquatic Ecosystems

Water pollution can cause loss of dissolved oxygen, or increase sedimentation, pH or temperature to such an extent to cause mass fish death, chocking of corals, interference with lifecycles of crustaceans, etc.

Disruption of Food Chains

Many species are sensitive to pollution and water conditions. As pollution rises, the vulnerable / sensitive species are the first to go extinct. Their space in the food chain is taken up by hardy species, many of whom are invasive. As a consequence, the species composition of the water body changes. This has direct impact on food chains and weakens the food web.

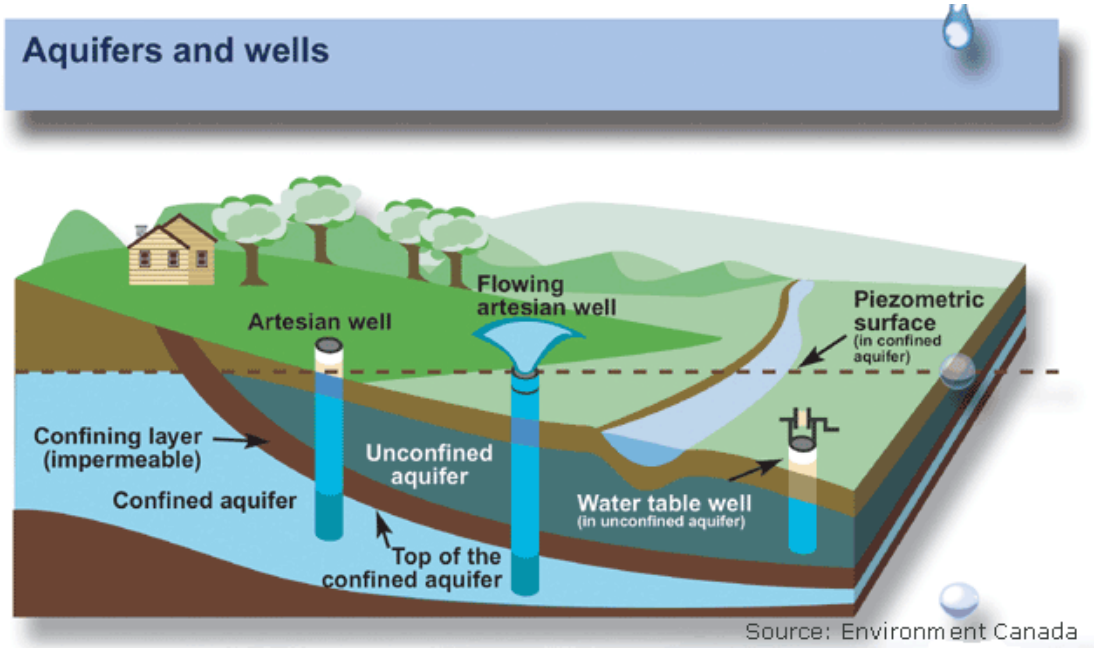
Loss of Food Security

Death of aquatic animals also put pressure on the communities depending on fish as a primary food source. With water quality deteriorating, increase in use of chemicals as well as increasing dependence on hard, ground water, the soil slowly becomes alkaline/ saline. Soil fertility is lost.

Economic Cost of Cleanup

Once a water body is disturbed and biodiversity is lost, due to any reason, the cost incurred to clean it up is massive and the chance of returning to its old natural self is remote. In case of severe water pollution, it can destroy ground water aquifers, which are impossible to restore.

An aquifer is an underground layer of water-bearing permeable rock, rock fractures or unconsolidated materials (gravel, sand, or silt). Groundwater can be extracted using a water well. The study of water flow in aquifers and the characterization of aquifers is called hydrogeology.



1.5 Causes of Water Pollution

The causes of water pollution lie on land- mostly human activities.

- Improper disposal of municipal solid waste
- Industrial effluents and Inadequate industrial treatment of wastes
- Improper practices in agricultural sector
- Reduction in water quantity in rivers& in plains
- Social and religious practices like dumping dead bodies in water, bathing, throwing waste in water
- Oil leaks from ships
- Acid rains
- Global warming

Improper Disposal of Municipal Solid Waste-It pollutes ground water resources as well as fresh water resources. It is essential to adopt some standard methods for disposal by the MunicipalAuthorities, so that such pollution problems can be mitigated.

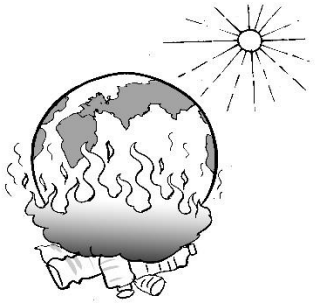
Industrial Waste and Inadequate Industrial Treatment of Waste: Several industries flout the law and let out their effluent in the cover of darkness or during heavy rainfall. Others treat their waste, but not adequately.

Improper Practices in Agricultural Sector: Overuse of chemical fertilizers and pesticides as well as over irrigation causes excess nutrients to run off to the nearest waterbody.

Reduction in Water Quantity in Rivers and Plains: Construction of too many dams and barrages and diversion of water suppresses the flow of water and prevents flushing of river system. Social and religious practices like dumping dead bodies in water, bathing, throwing floral offerings in water; Oil leaks from ships, boats, jet skis, oily runoff from roads, pollute the water.

Acid Rain: Air pollution is primarily due to burning of hydrocarbons, which increases the levels of NOx and Sox, which dissolve into precipitation and fall as acid rain.

Global Warming: Warming of ocean waters allow the escape of dissolved oxygen and carbon dioxide from the sea waters, thereby harming aquatic life and contributing to greenhouse gas effect.



1.6 Types of Water Pollution

1. Nutrient pollution
2. Oxygen depletion
3. Surface water pollution
4. Ground water pollution
5. Microbial contamination
6. Suspended matter
7. Total dissolve solids
8. Chemical water pollution
9. Oil spills
10. Thermal pollution
11. Micro-plastics

Domestic waste water, sewage and fertilizers in agricultural runoff as well as effluents from food processing industry are the main causes of **nutrient pollution**. Nutrient pollution eutrophies water bodies. Easily available food source increases putrefying bacteria, while the presence of nitrogen, carbon, phosphorus and other basic elements increase algal growth.

Algal blooms, i.e. rapid growth of algae, water weeds and microbes, their combined respiration drains the water, of all its dissolved oxygen. Moreover, they create a barrier at the surface of the water, preventing the natural exchange of gases between the water surface and the air above. These cause fish kills.

Oxygen Depletion: Anaerobic conditions set in due to OD. Anaerobic bacteria release foul smelling gases, hydrogen sulphide, ammonia and methane, which is also responsible for global warming. Sometimes at night when all dissolved oxygen is lost, the water body becomes anoxic and causes mass fish kill.

Hazardous chemicals from factories, agricultural runoff from fields during rains, pharmaceutical / bulk drug manufacturing units, and from the domestic use of chemicals like detergents, soaps, shampoos, cleaning agents, tooth paste, etc enter the water stream every day. This is **surface water pollution**.

When industrial effluents, pesticides, fertilizers, waste oils, detergents and other such pollutants seep into the ground from non-point sources, it causes **ground water pollution**. The extent of pollution is hard to assess, impossible to arrest and the effects are felt forever.

Improper disposal of **medical hazardous wastes** and small volumes of antibiotics entering the waste waters through rampant use of drugs, makes naturally occurring microbes evolve into super-bugs' resistant to all easily available antibiotics.

Microbial contamination of drinking water or usable water leads to outbreaks of disease. Sometimes purified, chlorinated water moving through pipes may also be subjected to microbial contamination, especially if the pipes are leaking.

Some pollutant particles are too large to dissolve. They remain suspended, especially when the waters are turbulent. Eventually they settle at the bottom of the water body as thick silt. Some of the suspended matter occurs naturally, but most of it is man-made, for example micro plastics. **Suspended matter pollution** hinders aquatic animals in their search for food. Today, it is known to cause the death of several marine creatures. Coral reefs are the most vulnerable to suspended matter pollution. Suspended water also decreases light in water, thus interfering with photosynthesis of submerged plants. The blanketing effect can cover habitats for nesting of certain aquatic species, such as migrating fish, leading to a decline of certain populations. It may also be harmful to creatures living on the floor of the water body. River silt which settles over farmlands become the most fertile alluvial soil. But, if the silt contains chemical residues and other pollutants, it can turn good agricultural soil unfit for use.

Minerals, salts, metals, cations or anions that readily dissolve in water, contribute to dissolved solid pollution. Total dissolved solids (TDS) are usually inorganic salts principally calcium, magnesium, potassium, sodium, bicarbonates, chlorides, and sulphates and also small amounts of organic matter. TDS is not visible to the naked eye. But it changes the hardness, pH and salinity and taste of water. Our growing dependence on ground water, which is very high in TDS, has made us believe that all TDS is bad. Naturally occurring mineral water contains TDS, which is good for our health and well being. In fact, TDS up to 500mg/L is permissible. High TDS renders water unusable for many industrial purposes.

Chemical water pollution refers to all the chemical pollutants let out by human activities which are alien to the natural aquatic environment. It includes solvents, pesticides, etc. Chemicals can seep into any water body or aquifer and disrupt the natural functioning of the ecosystem. This can lead to death due to toxicity, or if the toxins are in very low concentration, it can cause the system to gain resilience against those toxins.

Case Study on Phasing-out Copper Brake Pads, Canada

This is a case from Alameda County, Canada where County-supported research led to a State law for protecting San Francisco Bay. Copper from vehicle brake pads washes off roadways into waterways, where it can impact fish and other aquatic life. The results of 15 years of research propelled a law to be made that requires brake pad manufacturers to phase out the use of copper from their manufacturing. Preventing this important source of copper from reaching waterways, is more sustainable and cost effective than trying to remove copper from the water.

When water, used as a coolant by power plants and industries, is returned to the natural environment at a higher temperature, the sudden change in temperature decreases oxygen supply and affects ecosystem composition. This is **thermal pollution**. It can kill fish and frog eggs. Water temperature determines the gender of certain amphibians and reptiles. Thermal pollution disrupts this as well as other ecological activities in water.

Oil Pollution brings to mind the ghastly images of dead marine animals covered in thick layers of oil. This happens due to oil spills, which could be accidental (while shipping crude oil) or purposeful (during wars).Oil spills are long-lasting and their impact stays on for over 50 years. Yet, oil spills are responsible for only 8-10% of oil pollution across the world. Another cause of oil pollution is natural oil seep. Oil seeps also occur naturally when oil seeps out from the highly pressurized seafloor rocks. In such areas the oceanic bacteria have evolved to eat certain oil molecules.

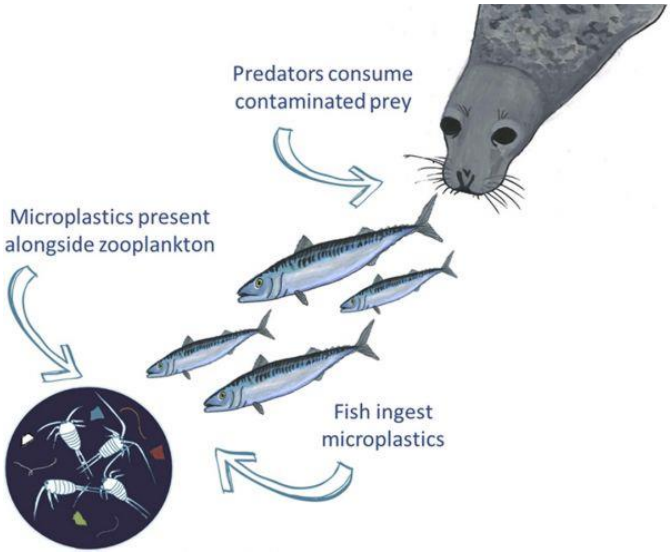


Fig 1.4 Microplastic Movement up the Food Chain[2]

However, the largest cause of oil pollution is **chronic oil pollution** that takes place by the dripping of petrol, diesel, lubricating oils from motor vehicles, boats, ships and machinery, which is responsible for 40- 60 % of oil pollution worldwide. When it rains, these hydrocarbons make their way from roads to the nearest water body. Recreational boats are a huge cause of small oil spills. In pursuit of recreation and leisure, tourism industry causes irreparable damage to the aquatic environment- both fresh and marine. Their Oil runoff is extremely difficult to track as it moves between water and sediments. Very few microscopes have been able to manage breaking down oil pollution. The impact of low, chronic oil exposure on wildlife is not known. Errors, unpreparedness, lack of education, careless attitude, cost-cutting mechanisms and pure negligence are the root causes of water pollution.

Micro plastic pollution is the most recent revelation. Microplastic pollution occurs due to single-use plastics (e.g. plastic bags and straws),synthetic fibres (e.g. polyester, nylon, acrylic, synthetic fur), dust from vehicle tyres, latex and acrylic paints, and micro beads in cosmetic products. These products are physically broken down into tiny pieces, but cannot be digested by microorganisms. Unlike other suspended solids, micro plastics remain suspended. Worldwide nearly 83% of water samples have been found to contain micro plastics. Microplastics are less than 5mm in size and can be as fine as 2.5 microns, which makes them easy to ingest and can also cross the walls of the digestive tract to reach other tissues and organs. Researchers estimate that we ingest roughly 3000 pieces of microplastic per year from water alone. Chemicals in plastic disrupt endocrine functions, affect hormone functions, cause infertility and lead to cancers. MIcroplastic accounts for 90% of plastic found in oceans. It harms all aquatic life from zooplankton and small fish to whales and sharks. Trophic transfer across the food chain is sending microplastic up the food chain. The effect of microplastic on aquatic life is an emerging field of research.

[2]Image source: PML, https://futurism.com/)

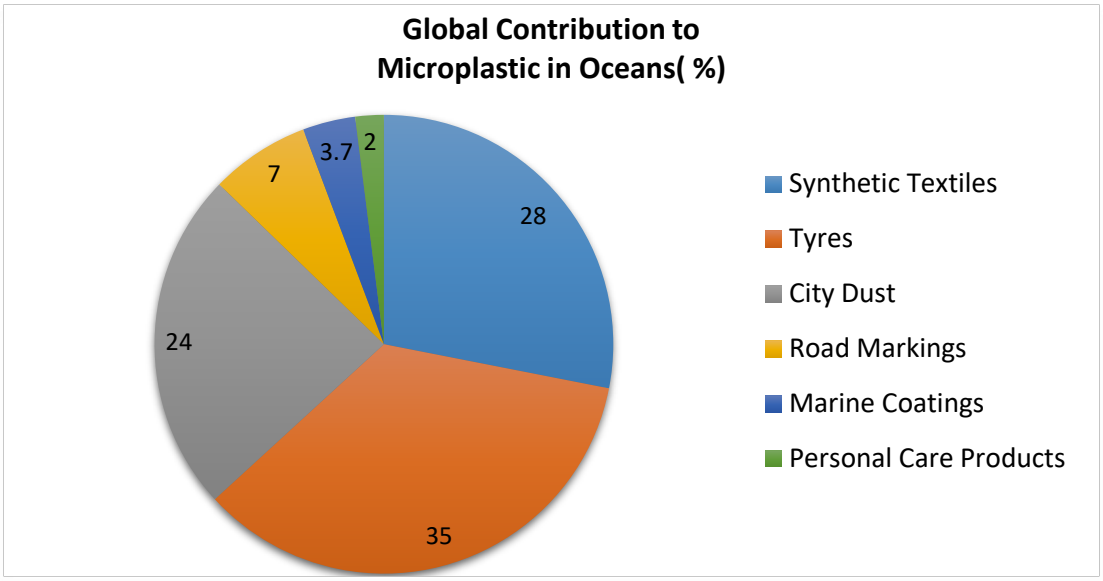


Fig 1.5 Sources of Microplastic Pollution in the World's Oceans

Case Study on Groundwater Pollution at Patancheru, Medak District, Telangana

First reported in 1990, the ground water pollution of this industrial estate on the outskirts of Hyderabad has far-reaching effects till date. Untreated effluent from over 100 bulk drug manufacturing units was being let out unt into the Nakkavagu canal and reaching the Patancheru Lake. The result was severe ground water pollution in 15 villages around the industrial area. Sultanpur, the village close to Patancheru suffered the worst with deaths due to brain tumours and extensive loss of livestock. Till date, despite efforts by the State Pollution Control Board, ciprofloxacin and cetrizine are found in ground water. Being a dry region of the Deccan plateau, most farmers and villagers need to depend on well water for their survival. Despite High Court orders for them to be supplied water from elsewhere, they are bound to depend on the polluted ground water, due to inadequate supply of municipal water.
However the guilty industries continue to run, after paying a fine to compensate for agricultural losses. Farmers in the area lament that even today, when it rains, the industries in the area release their chemical water allowing it to mix with storm water and pollute their fields and ground water.

Today, the Nakkavagu canal waters still run brownish red and the fish in the Patancheru Lake is inedible. Children swimming in ponds far from the industrial area suffer from rashes as the tanks are fed by polluted ground water. The people of the region suffer a multitude of diseases (congenital malformations, neoplasms, dermatitis, asthma, epilepsy, endocrinal and metabolic failures, asthma, arthritis and paralysis), the occurance rate of which are twice to 6 times higher than the control group. Inpite of National Green Tribunal's orders, the Health and Medical Department has not commenced as study on anti-microbial resistance, morbidity, epidemiology and genetic variation among the residents of the polluted industrial belt.

The problem persists instead of stopping the root cause, i.e. closing the polluting industries, the PCB and Municipal authorities are making a bid to clean-up the dirty water. Recentlyin Aug 2017, waters in Sangareddy tested positive for chemical pollution. Two industrial units were forced to shut down, but have resumed operations since.

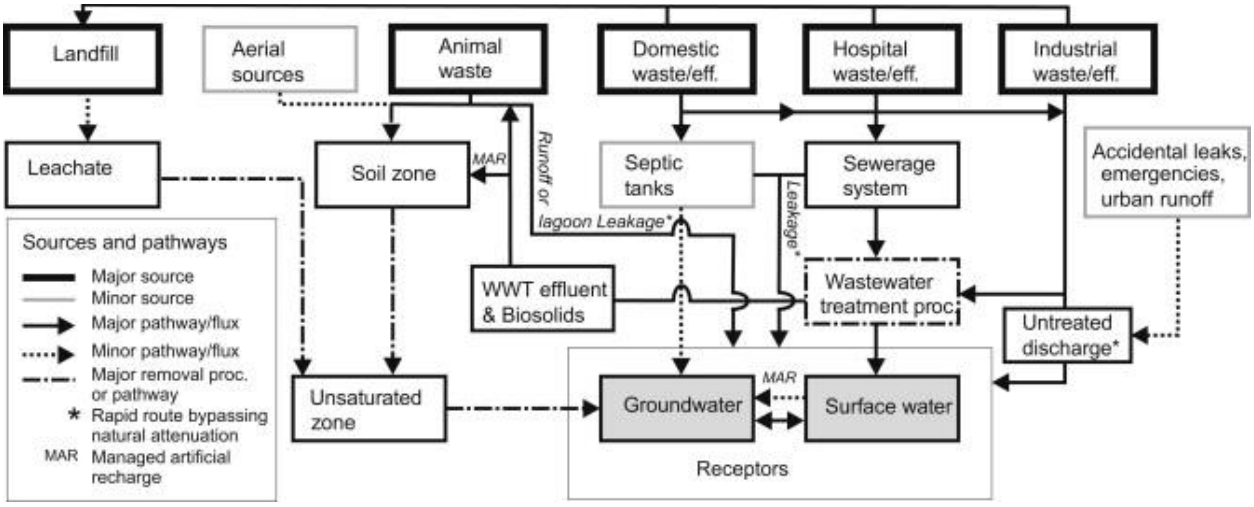


Fig 1.6Schematic Diagram of Groundwater Pollution[3]

1.7 Biohazard, Radiation, Security Threat

Besides the regular pollution issues discussed, there are a few situations that threaten our water security- primarily nuclear radiation, biochemical warfare and terrorist attacks.

Radiation Pollution

Radiation is generated through detonation of nuclear weapons as well as during electricity generation in nuclear power plants. The presence of radiation pollution is difficult to sense, but the effects are devastating- it causes cancer, genetic disorders and leads to death. There are no permissible limits to radiation pollution, because radiation pollution in the most limited way is harmful. Though radiation occurs due to many devices,it is mostly the high-energy radiation that causesradiation pollution and is a matter of concern.As of 2016, India had 21 nuclear reactors in operation at seven sites, having an installed capacity of 6680 MW. and producing a total of 30,292.91 GWh of electricity, 11 more reactors are under construction to generate an additional 8,100 MW.

It is not an accidentalrelease of radioactivity into the water, air or land at a nuclear power plant. It occurs as a routine operation. Low level waste includes laundry of the workers working at the power station while high level radiation could be irradiated spent fuel. There are over a hundred different radioactive isotopes produced in these reactors and atomic bombs, including Strontium-89, Strontium-90, Cesium-137, and Iodine-131. Each of these chemicals has a special biochemical action; iodine seeks out the thyroid gland, strontium clumps to the bone and teeth (like calcium), and cesium is distributed throughout the soft tissues. All are carcinogenic. Each decays at varying rates; for example, iodine-131 has a half-life of eight days, and remains in the body only a few weeks. Strontium-90 has a half-life of 28.7 years, and thus remains in bone and teeth for many years.These chemicals are different from “background” radiation found in nature in cosmic rays and the earth’s surface. Background radiation, while still harmful, contains no chemicals that specifically attack particular organs.

An example of radiation pollution is the release of around 10,000 litres of radioactive coolant from a ruptured steam generator tube in a nuclear power plant in America in the year 2000. It was caused by poor

[3]Lapworth et al. 2012, https://demeau-fp7.eu/toolbox/what-managed-aquifer-recharge/mar-and-emerging-pollutants

maintenance and lax oversight. A week later about 750 litres of radioactive water was released into the Hudson river. Such accidental leaks can go unreported by power plants. Seven years later, fish from the Hudson river were found having very high levels of Strontium – 90 in their flesh, from near the power plant as well as 20 km away from the plant. This toxic radionuclide is called the 'bone seeker' as it mimics calcium and can cause leukemia and bone cancer. Sr-90 has a half life of 28 years, so once it enters our bodies and locks into our bones, it keeps emitting radiation for 28 years! Mining industry could also cause release of radioactive material into the waterbodies.

This example shows that radiation pollution can, and does, travel through water and enters the food chain. As the number of nuclear power plants in India keeps rising, the threat of nuclear pollution also will keep increasing.

Biological Hazards and Superbugs

Swine flu, bird flu, HIV-Aids, re-emergence of polio, Nipah virus, Hepatitis-C, are biohazards one might have heard of. Biological hazards are frank and opportunistic pathogens, such as bacteria, viruses, fungi, protozoa or helminthes. They may get released into the water, or increase in number due to a hazardous event- an incident or a situation. Biological hazard may happen at any point or all over the water system- from catchment area to the consumer. The risk depends on the time frame, population exposed, the magnitude of harm, and its consequences. It is not practical or necessary to completely eliminate microorganisms from drinking water. However, the number of pathogens should be kept under acceptable levels. Contamination by pathogens originating from faecal matter- of human and animal origin- needs to be prevented. This is possible by avoiding back-flow of water after it is disinfected.

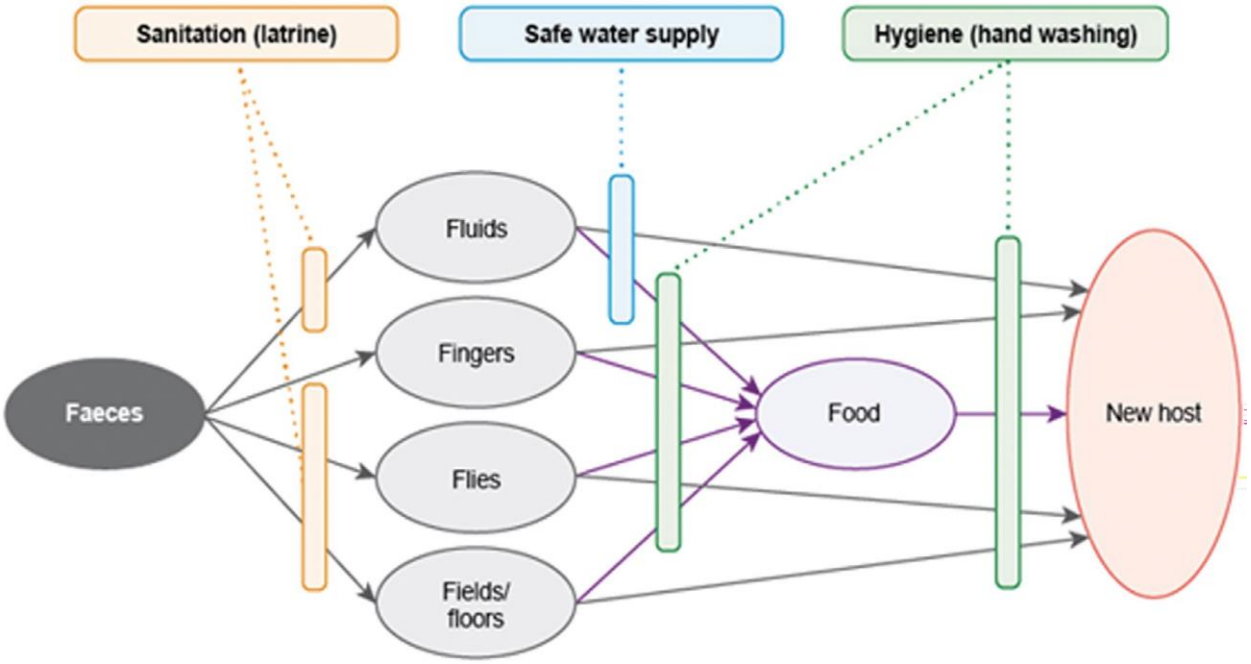
Emergence of 'superbugs' like MRSA bacteria (Methicilin resistant Staphylococcus aureus), E. coli related urinary tract infections, drug-resistent Salmonella, is increasing every year. Pharmaceutical pollution, improper hospital waste management and rampant use of antibiotics without medical prescription are some of the reasons why superbugs are on the rise.

Chemical Hazards

Chemical hazards too can compromise water security. Examples are chemicals from the catchment, such as nitrates, arsenic, fluoride and pesticides, chemicals from reservoir storage, such as algal toxins, cleaners, liner chemicals, lubricants, etc, or chemicals from the water treatment process, such as flocculants, pH adjusters, by-products of disinfectants and also chemicals from distribution systems, for instance copper lead, petroleum or cleaners . Physical biohazards could be sloughed off biofilm containing millions of bacteria, as well as sediments and re-suspended particulates with pathogens attached to them. .

To prevent such risks, a water safety plan team should be in place. They should study influencing factors such as variation in weather, accidental or deliberate contamination, waste water treatment practices, controlpractices at the source of pollution, water treatment practices, sanitation, hygiene, distribution and maintenance practices, receiving and storage practices as well as intended use of water.

(Watch film: Fighting superbugs in India, duration 10 min, https://www.youtube.com/watch?v=dCWiVx1ptf4)



Terrorism

There is a long history (dating back 2,500 years) of terrorist attacks on water systems, either as attacks to the water infrastructure or water purification systems, poisoning or disease causing means. The complexity of water supply arrangements, involving complex networks of millions of pipes make them difficult to monitor and leave the system vulnerable to attack. But this is poorly understood by the water managers and the public. It is difficult to accomplish poisoning of large water bodies effectively because of the dilution effect, filtration, and the disinfecting of water. The most likely scenario for an attack to inflict is to orchestrate a simple backflow contamination event - a pump is used to overcome the pressure gradient in the distribution system's pipes. After overcoming the pressure gradient, a contaminant is introduced, which gets siphoned into the flowing system. The introduction point can be anywhere in the system such as a fire hydrant, commercial building or residence.

The effect of such an attack on public perception and political response itself is the intent of terrorism, besides the aim to cause significant causalities. Terrorism means premeditated, politically motivated violence perpetrated against non-combatant targets by sub-national groups or clandestine agents, usually intended to influence an audience. Attacking a nation’s water supply is not without precedent. In July of 2015, five people linked to ISIS were arrested in Kosovo for allegedly planning to poison a reservoir. After the plot was discovered, the authorities in Kosovo cut off the water supply to thousands of people in the country’s capital in order to test the water for possible contaminants.

Lack of a centralized response is alarming. Due to the highly decentralized nature of the system, disparities in the level of protection, funding, and exchange of information between various water-supply companies are very high. There are insufficient funds to address risks ahead of time. In order to better respond to and address current threats such as cyber threats, updated and uniform physical security measures are required. The water supply sector requires a secure means of sharing information.

Solutions to Tackle Biohazards

Water Security, Preparedness, and Emergency Response (WSPER) team consisting of drinking water personnel, law enforcement, fire, and regulatory personnel is necessary in every municipality. Emergency Water Quality Sampling Kit (EWQSK) should be made available and proper training needs to be provided regarding its use. Effective communication to customers during a drinking water system crisis or emergency is just as critical to emergency response operations as the actual physical response. A poorly managed crisis can damage an organization's credibility and potentially expose that organization to costly litigation. Effectively communicating response actions, possible health effects and controlling rumors can be a powerful tool that can enhance emergency operations and create a more productive response. Vulnerability Assessment (VA) and Emergency Response Plan (ERP) for every reservoir and water supply system are essential.

Citizens and consumers have a big role to play in water security. Warning and education are important elements of providing for public safety. Public safety is a fundamental duty of the government and also the responsibility of citizens to take action not only to protect themselves but also to make society safer through their jobs and community activity.

Preventing conflict over water is important. Approaches include:

1. Reducing wastage, improving efficiency in using water.
2. Increasing availability of clean water, by reducing pollution
3. Improved watersheds
4. Better wastewater management
5. Maintain groundwater wells better
6. Expand use of grey water

These will be discussed in the subsequent chapters.

Another approach to conflict resolution is through prevention:

1. Laws and regulations at local, provincial, national and international level.
2. Proactive cooperation between nations
3. Mediation and arbitration

Internationally, there are more than 3800 unilateral, bilateral, or multilateral declarations or conventions concerning water, including 286 treaties.

- Public health workers also have a major role to play in preventing water related conflicts. They can:
- Raise awareness on access to freshwater
- Document water conflict and their adverse health impacts
- Promote water conservation, efficient use and prevention of contamination.
- Empower women, as they play a key role in water procurement, and make upto 70% contribution to food production in developing nations, yet they have little voice in water policy aspects.
- Promote proactive cooperation in water distribution.

Water security is therefore an important area that students of this course can specialize in.

Summary

We have learnt that the distribution of water is skewed across the world, with a bias towards urban areas. The looming threat of climate change and the ubiquitous water pollution have put the ecosystem and human existence in danger. Chemical, biological, terrorism related or radiation related threats to water system also need to be guarded against.

Self Assessment Questions

1. What are the major problems regarding availability of water?
2. What are the hurdles to meet the water requirements of the people?
3. Name a few causes of water pollution.
4. Discuss the different kinds of water pollution.

Video Links

1. India's water crisis: H2WOE - India's water crisis- A warning to the world https://www.youtube.com/watch?v=H0hk_5Plv5U
2. Fighting superbugs in India, duration 10 min, https://www.youtube.com/watch?v=dCWiVx1ptf4)

Chapter 2

Waste Water Management

Objectives

- To know how waste water is treated in a sewage treatment plant
- To learn how individuals and communities can contribute to less and better quality waste water generation

Structure

2.1 Individual responsibility towards waste water production
2.2 Community responsibility towards waste water disposal
2.3 Municipal responsibility for treating waste water
2.4 Conventional Waste water treatment: Sewage Treatment Plants
2.5 Issues facing present day STPs
2.6 Water Reclamation

To Do Activities

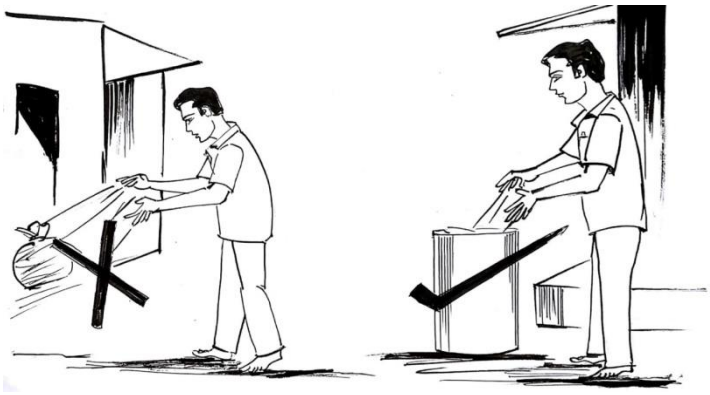
- Have an open discussion regarding waste water. How much water do we use each day? How much is let out through the drain? Do a simple exercise on the blackboard to calculate daily water consumption and waste water production.
- Do field work- survey the city in teams, photo-document malpractices and good practices in waste water release and drain silt removal practice.
- Screen Film on STP of Jaipur.
- Visit sewage treatment plant or CETP. Find out the issues the authorities are facing. Submit a report.
- Visit an STP/ ETP/ LTP to understand the process of waste water treatment.
- Discuss topics each student is interested in, scope out possibilities of career development, research or internship opportunities. Make students write their choices in their running list.

2.1 Individual Responsibility towards Waste Water Production

It will not be wrong to state that there are 1.35 billion point sources of water pollution in India. Every person who uses water pollutes it in the process. Whether we accept it or not, the same waste water returns to us, bringing with it a myriad of problems. It is advantageous to prevent water pollution at source. As an individual there are a few things that we can habituate ourselves to do which can reduce water pollution substantially.

Dos

1. Choose cleaning agents and cosmetics wisely to prevent exposure to harmful chemicals.
2. Install a water efficient toilet. In the meantime, put a brick or a one-liter full bottle in the standard toilet tank to reduce water use for flush.
3. Similarly, install water efficient plumbing and appliances.
4. Run the washing machine or dishwasher only when you have a full load. This conserves electricity and water.
5. Use the minimum amount of detergent and/or bleach when you are washing clothes or dishes. Use only phosphate free soaps and detergents. Soapnuts (Ritha or Sapindus sp.) and similar natural surfactants are an ideal alternative to detergents.



6. When constructing homes, plan for modern septic tanks that use bio-digester technology so that the water that exits is easier for the environment to handle. This is a one-time expense which will have long-term benefits.

Don’ts

1. Never pour oil, grease or fats down the sink. Discard it with solid waste.
2. Household chemicals or cleaning agents must never be poured down the sink or toilet.
3. Never flush pills, liquid or powder medications or drugs down the toilet.
4. Do not flush tissues, wrappers, dust cloths, sanitary pads, and other paper goods. They should be properly discarded in a waste basket even the fiber reinforced cleaning products like scrubbers, etc.
5. Avoid using a garbage disposal. This is a grinding machine attached to the bottom of a kitchen sink. It grinds up all kitchen waste including vegetable scraps and chicken bones, which then are flushed directly into drains. Though not popular in India, it is now being imported and could get popularized unless stopped.
6. Minimize or stop the use of pesticides, herbicides, fertilizers.
7. Do not dispose these chemicals, motor oil, or other automotive fluids into the sanitary sewer or storm sewer systems, as both of them end at the river.
8. Avoid water softeners and RO purifiers. They increase the TDS of the waste water, thereby spoiling sewage treatment plants. The waste water from them cannot be used in the gardens easily as it increases soil salinity and affects plants.

9. Never depend only on a local plumber to design and create a septic tank. Take expert advice for proper sanitation solutions.

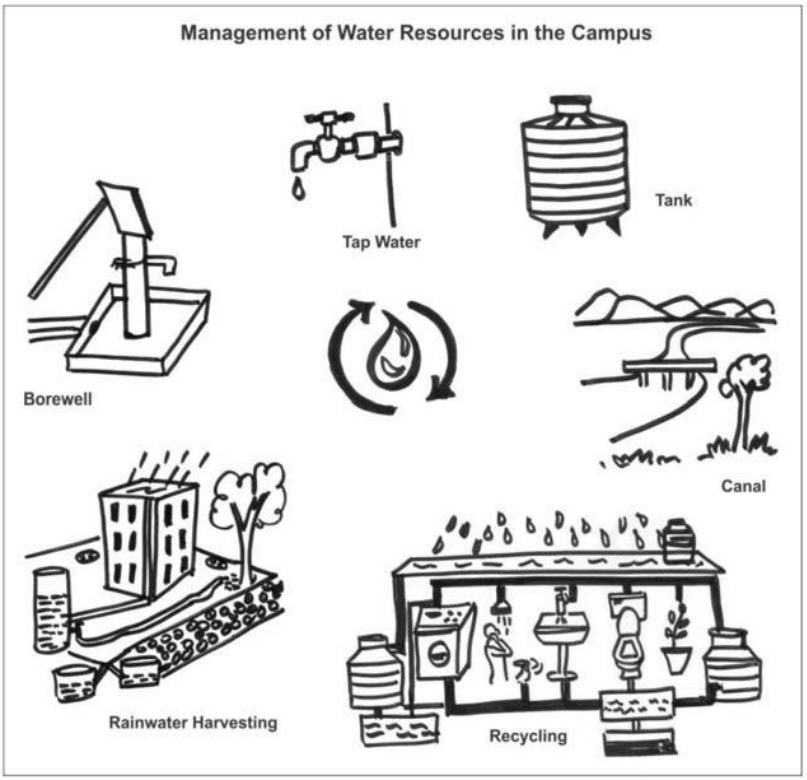
2.2 Community Responsibility towards Waste Water Disposal

In terms of domestic waste water, the biggest culprits are high-rise apartment buildings without a functional waste water treatment facility. They allow untreated sewage to exit directly into storm/ waste water drains. Communities should insist on first-level sewage treatment before letting out their waste water. If the treated water is of a quality suited for reuse in gardens, it should be used within the community. This way, the fresh water requirement can be reduced. Many cities, such as Bengaluru, have made wastewater treatment compulsory. This should be the case for entire India.

Every colony or residential society should take it up on its own accord without being pressurized by government bodies. By setting aside a small amount from the monthly maintenance collection for the maintenance of the waste water treatment plant one can to ensure its proper functioning. There are many modern, compact and efficient versions of wastewater treatment plants available in the market today. A few important ones will be discussed later.

It is often the case that the drains open into the nearest river or lake without being treated. As individual home owners, or residents of a colony, one needs to ensure that water from your toilets move through a properly constructed septic tank before being let out into the common sewers. Ensure that no solid waste enters the drainage through your premises. Under no circumstances should you allow waste water to pollute the groundwater or be let into storm water drains. Do not allow any member of the society to let out toxic or potentially toxic effluents into your drainage system as it will harm your sewage treatment plant and local water bodies.

If the community finds an individual or group polluting the waters, it should be reported to the pollution control board or civic body with evidence. The community elders should have a discussion with the polluting party and convince them that pre-treating their effluent is good for the entire community. Water is a common property- using clean water is everyone's right, keeping it clean is everyone's duty.



2.3 Municipal Responsibility of Treating Waste Water

Every municipality is responsible for the laying and maintenance of sewage lines as well as for the treatment of sewage in Sewage Treatment Plants. However, most municipalities are only able to treat a fraction of the sewage the town generates. Waste water collection takes place through a series of drains. The construction and maintenance of these drains is the responsibility of municipal authorities, house owners and business owners. Care needs to be taken that the drains are not damaged, cracked or leaking, to prevent contamination of soil and ground water.

2.4 Conventional Waste Water Treatment: Sewage Treatment Plants

(Watch film on “One Stop Shop Sewage Treatment Plant in India - Story from Jaipur”)

Effluent

The term ‘effluent’ is a directional word. It means fluid leaving a particular area- as opposed to influent, or fluid received by the area. As per US-EPA, effluent is "wastewater - treated or untreated - that flows out of a treatment plant, sewer, or industrial outfall”.Water that has been used for its purposeis wastewater. For instance, the water leaving a car wash station is wastewater.

For practical purposes, effluent water is waste water that contains solids up to 5 cm in size. This is normally considered to be water containing soap, laundry discharge, water from sinks, etc. Water with larger solids is called sewage water. Sewage is typically water and excrement.

Wastewater treatment processes are of the following types:

1. **Effluent Treatment Plants (ETP)** : ETPs remove high amount of organics, debris, dirt, grit, pollution, toxic, non toxic materials, polymers , chemical drugs by using evaporation and drying methods, and other auxiliary

techniques such as centrifuging, filtration, incineration for chemical processing and effluent treatment. ETPs are established in the industrial sectors like Pharmaceuticals, Chemicals, Leather industry and tanneries.

2. **Sewage Treatment Plants (STP)**: STPs deal with domestic wastewater- household sewage, domestic effluents and runoff. This material is often inadvertently contaminated with many toxic organic and inorganic compounds. Screens, grit removal, floating grease and oil removal, use of biological processes, sludge removal and disinfection are the stages in the sewage treatment process.

3. **Common and Combined Effluent Treatment Plants (CETP):** CETPs treat effluent from a cluster of compatible small scale industries that cannot afford ETPs. The Government and the individual factories together pay for the running of CETP.

Sewage Treatment Plants (STPs) use physical, chemical and biological methods to remove contaminants from household wastewater to produce 'treated wastewater' or treated effluent that is safer for the environment.

First, the wastewater passes through a grit chamber. Gravity sedimentation method of screening and de-gritting takes place to remove settleable solids. About half of the suspended solids and one-third of the BOD (biological oxygen demand) is removed in this first process. Then the water is sent for secondary treatment or activated sludge process where biological treatment methods are applied. Bacteria and protozoa present in the sewage are provided an aerobic environment and given a chance to consume the soluble organic contaminants such as sugars, fats, short chain carbon molecules, food waste and soaps. As the bacterial colonies consume the contaminants, they grow large in size till they settle to the bottom of the chamber, from where they are removed as sludge. Once the solid organic material has been removed, it can no longer place a demand on the dissolved oxygen in the water, and therefore the water is fit enough to be released into water bodies. Care needs to be taken that industrial wastewater is not mixed in the municipal sewage because the chemicals present in industrial effluents need a different physical treatment. The presence of harsh chemicals can affect the bacteria and protozoa that carry out the secondary treatment.

Three important terms that come across when discussing about waste water treatment and water pollution are DO, COD and BOD. DO is the Dissolved Oxygen present in water, also known as Total Oxygen Content (TOC). DO is higher at cooler temperatures and it escapes when the water is heated. COD is the chemical oxygen demand of water. It refers to the amount of dissolved oxygen required to oxidize all the chemicals in the water. BOD stands for Biological Oxygen Demand, which is the amount of dissolved oxygen required by microbes to consume/ break down the organic matter present in the water. DO or TOC in water should always be higher than COD to ensure the survival of aquatic animals. Water treatment is a 3-step process.

Table 2.1 Three Step Process of Water Treatment

Primary Treatment	Secondary Treatment	Tertiary Treatment
Removal of settleable and floating material	Degrades complex organic matter using bacteria, protozoa,	Removes the organisms that are used for secondary treatment, remaining inorganic
Eg. Leaves, grit, grease	e.g. human excreta, food waste, soaps and detergent	Nitrogen, Phosphorus, etc.
Screen chambers, grit chambers,	Supplying air for aerobic process, in suspended growth or fixed film activated sludge to allow bacteriato consume/ breakdown organic matter.	Activated sludge, Sand filters, biological nutrient removal, lagoons

		Expensive, often done only for water treatment, not wastewater in India. Compulsory for certain other nations.

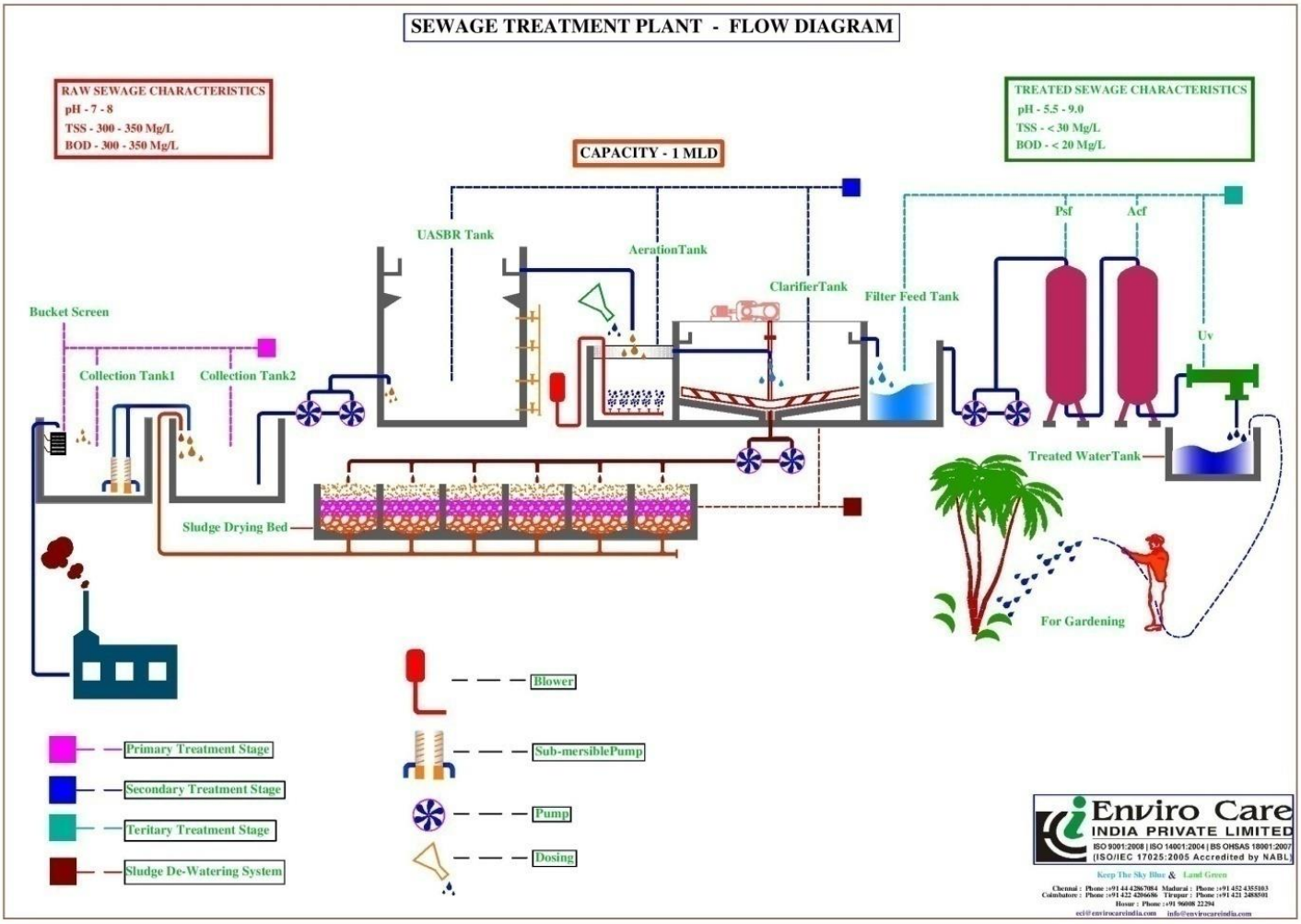


Fig 2.1 Sewage Treatment Plant- Flow Diagram

A fourth level treatment is needed for persistent chemicals in water, such as Poly Chlorinated Biphenyles (PCBs) from dyeing/ textile industries and pharmaceutical industries. When waste water cannot be treated biologically due to toxins or inhibitors, then membrane processes and mechanical steam compression vacuum evaporators etc are to be employed. The latter method compresses steam, super heats itand passes it through vacuum. The water is thus extracted and a pasty residue is left behind. The pasty residue is less voluminous to handle, yet cannot be allowed into the environment. This line of treatment is left to ETPs.

2.5 Issues Facing Present Day STPs

As per the Ministry of Environment, Forests and Climate Change (MoEFCC) nearly 70% of the Sewage treatment plants in India are not operational. However, the Central Pollution Control Board (CPCB) states that 522 of the 816 STPs in the country are functional. It is due to

1. High maintenance cost: Paucity of funds from state governments.
2. Erratic Power supply: STPs need continuous power to function properly.1 megawatt of power is needed for a 200 Million Liters per Day (MLD) facility. 60% of the energy is needed for the secondary (biological) treatment.
3. Outdated infrastructure: 10 to 15 year old STPs have undersized balancing tanks and out-dated clarifiers .This causes insufficient aeration and therefore failure of STP.
4. Inadequate treatment capacity: the volume of sewage keeps rising.
5. Lack of trained staff: understaffed STPs run by inexperienced workers causes STPs to disfunction. The core problem remains lack of funds.
6. Unavailability of land to construct new STPs.
7. Poor drainage plans: Directing sewage to the STP is a challenge in growing urban spaces that depend on decade old drainage systems.
8. Sludge Production: Disposal of residual sludge has been a quintessential problem in STPs.

As of 2015, 142 new STPs were under construction in India. The conventional cost of setting up an STP is Rs. 1 crore per million liters per day (MLD), which amounts to Rs. 300 crores for treating 300 MLD. Operational costs including power supply, generators and staff amounts to Rs. 70 lakhs to 2 crores per annum. One possible solution lies in running the STP on public-private –partnership (PPP), to reduce the burden on a single body. To solve the problem of power shortage, the 190 crore STP at Nagpur became the first to generate electricity using its own treated water. Anaerobic digestion of sludge to create biogas and compost is a welcome step in sludge management. Kormangala-Challaghatta STP in Bengaluru is producing 1 MW of energy from its biogas engine. The Yamuna Vihar STP in New Delhi produces around 18 lakh units of electricity per year, saving the Jal Board Rs. 1.5 crores.

Managing an STP is a demanding job especially during influent and seasonal changes. Staff at the facility should be adequately trained and certified to handle issues 24 x 7, from simple leaks to electrical and instrumentation issues. Automation of certain processes could be a possible solution to meet staffing needs. Government programmes like Swachh Bharat Mission, Namami Ganga and Atal Mission for Rejuvenation and Urban Transformation (AMRUT) are working towards installing improved STPs and handling the existing STPs scientifically and efficiently. With these many issues facing sewage treatment plants, it is a better proposition to decentralize wastewater treatment close to source. Changes in biological treatment processes can significantly reduce electricity consumption. Using fine screens in primary treatment, membrane technology for aeration, direct treatment of high concentration return streams are some of the operational mechanisms suggested.(Watch film on Flush to finish, Grandisland, Nebraska, USA)

Drain Silt

It is the Municipality's responsibility to maintain stormwater drains across the cities. If ignored, the drains can get silted. Non-removal of silt results in over-flowing drains that could lead to localized flooding and outbreak of diseases.

Stormwater drains are designed to move excess rainwater from paved roads, sidewalks and parking lots. Storm drains are usually fed by street gutters. It is often found that storm water drains are being used for carrying sewage to the nearest water body. Other materials that pollute the drains include solid debris, plastic and other trash, oil and grease, mineral deposits, cleaners and solvents, pesticides, tree roots, animal wastes, detergents and sediments. Regular street-

sweeping and monitoring of drains can prevent much of this issue. Storm water drains must be cleaned annually before the onset of monsoon. It is also important to ensure the presence of a grate and properly placed drain covers. Usually silt removal is a manual process that could take a few days. If the drain silt is not cleared immediately, it could find its way back into the drain in case of rain. The silt removing machine that replaces manual cleaning of storm water drains in the Salem Corporation (as reported in The Hindu, Jan 2018) limits has proven to be effective as about one tonne of waste was removed in 30 minutes that would normally take three days if carried out manually. The sewage is filtered while removing the silt. Plastic waste is too common in all of these drains. Previously, the community accepted drain silt to be put on the soil as a fertilizer. But with plastic waste increasing in drain silt, is making it difficult to dump. The waste material is dumped on the roadside, from where it is taken away for disposal.

2.6 Treatment of Leachate from Waste Dumps

Landfill leachate treatment is a major engineering challenge due to the high and variable concentrations of dissolved solids, dissolved and colloidal organics, heavy metals and xenobiotic organics. In older landfills and those with no membrane between the waste and the underlying ground, leachate is free to leave the waste and flow directly into the groundwater. In such cases, high concentrations of leachate are often found in nearby springs and flushes. As leachate first emerges it is black in colour, anoxic, and possibly effervescent, with dissolved and entrained gases. As it becomes oxygenated, it tends to turn brown or yellow because of the presence of iron salts in solution and in suspension. It also quickly develops a bacterial flora.

Specific leachate management practices, such as recirculation (bioreactor landfill) and blending landfill gas with leachate have an impact on the quality of leachate. This results in characteristics that vary greatly from site to site. Landfill leachate may be hauled or pumped to off-site wastewater treatment facilities for disposal. Some STPs do not accept leachate because of various reasons. Problems of leachate treatment:

1. Leachate is hard to treat with biological treatment due to high TDS (conductivity).
2. RO membranes have limitations of low recovery and fouling of membranes.
3. Leachate has very high ammoniacal nitrogen concentration; it is highly acidic, often anoxic and very large in volume.
4. In ageing landfills, pH returns to near- neutral, but the presence of a series of organic chemicals and their decomposition products make leachate difficult to treat.
5. Leachates can interfere with ultraviolet disinfection by strongly quenching UV light.
6. Leachate may also contain heavy metals and high ammonia concentration that may be inhibitary to the biological processes

On-site leachate treatment is an alternative solution. These treatment facilities are designed to fulfill the specific needs of individual landfill sites and allow discharge to a sanitary sewer or water body without any hauling or disposal costs. Leachate collection system consists of 4 components: liner, filter, pump and sump. In India, liners are mostly not present. However, leachate collection channels are prepared to carry the leachate to the sump. From the sump it is pumped into the treatment tank where it is mixed with chemical reagents to modify its pH, coagulate and settle solids and reduce the concentration of hazardous material. Only then it is sent to an off-site treatment facility. Technologies for landfill leachate treatment include:

1. Biological treatment: Activated Sludge Process (ASP), Sequencing Batch Reactors (SBR), Membrane Bi Reactors (MBR), aerobic lagoons and constructed wetlands, anoxic/aerobic processes (nitrification and denitrification)
2. Physical/chemical treatment: Oxidation, coagulation/flocculation, activated carbon, stripping, evaporation.
3. Technologies such as Reverse Osmosis (RO) filtration.

It is also a good initiative to apply leachate over the landfill site, a few times to help with the bio-remediation of the landfill. This takes place in a bioreactor landfill. New strides are being made in the use of treated leachate in silviculture. Care is taken to only apply as much treated leachate, that, the plant can utilize and evapo-transpire. Excess leachate could cause groundwater pollution.

Reuse of Water

Treated waste water can be let out into the environment. It can also be reused. This is called Water Reclamation. Treated waste water is ideal for gardening and irrigation. It is also good for flushing. However it needs to be tested before using in sprinklers or for washing cars. Treated water may also be suited for aquaculture. However, car washing needs water that is free of suspended solids as they might cause abrasion on the paint surface. Therefore it is essential to match the quality of reclaimed water to its potential use.

Summary

It is the responsibility of the consumer – every household and establishment- to reduce the volume of wastewater. Communities need to ensure that waste water is properly disposed of into the assigned sewage system. Disposal of solid waste, toxic effluents, etc must be strictly avoided while sewage lines should be well maintained. Waste water must never be let out outside the sewage system. Centralized Sewage Treatment Plants are expensive to run and manage. It is, therefore, advisable to decentralize wastewater treatment and reclaim the treated water for suitable use.

Self Assessment Questions

1. How does an STP work?
2. What is the responsibility of the community towards waste water?
3. How are municipalities in India coping with the shortfalls in running STPs in India?
4. What are the things to be kept in mind to prevent generating excessive wastewater?

Text Books

Metcalf and Eddy, Wastewater Engineering 4th Edition (Treatment and Reuse), 2002, Mcgraw Higher Ed.

Chapter 3
Alternative Technologies for Waste Water Treatment

Objectives

- To know advanced methods employed for waste water treatment
- To learn methods to disinfect water

Structure

3.1 Alternative technologies for waste water treatment
3.2 Summary of waste water treatment technologies
3.3 Biological Nutrient Removal Systems
3.4 Sludge Management
3.5 Disinfection

To Do Activities

- Explain waste water treatment methods for secondary and tertiary treatments.
- Visit nearest UASB/ RBC/ AOP
- Discuss Eco-STP. Will it be more successful than other STPs?
- Study various alternative waste water treatment facilities set up in hospitals, apartments or shopping malls. Identify the different technologies used and compare them for efficiency and cost effectiveness. How is the water being reclaimed at each location?
- Screen film on Nitrogen removal. Recap water pollution and effects of nitrogen pollution.
- Screen Film on Faecal Sludge Management. Discuss the Devanahalli case. Can this be replicated in other cities? What can be the issues?
- Conduct an experiment with any three types of water disinfection methods, using fresh water from a pond, well or stream. Check samples under the microscope before and after disinfection. Record your observations.
- Create a filtration mechanism to filter out suspended solids from water samples.

3.1 Alternative Technologies for Waste Water Treatment

It has been established in the previous chapter that STPs are expensive to construct and maintain. This brings forth two alternatives:

a. Make alterations to generate energy that can bring down the running cost of functioning STPs. Two important technologies in use are: sludge-to-energy technology, and biogas harvesting from sludge digesters.
b. Make alternative arrangements to treat wastewater locally without sending it to STPs. A few of these are also discussed in this chapter.

There are nearly one hundred methods of treating wastewater that can be used in different combinations to get the desired result. The choice of technology depends on the volume of waste water, quality, space availability, energy source, etc.

3.2 Summary of Waste Water Treatment Technologies

- Mechanical
  - Oxidation Pond
  - Extended Aeration
  - Sequencing Batch Reactor
  - Trickling Filter- SCP
- Aquatic (Lagoons)
  - Facultative
    - Free Water Surface
    - Sub Surface Flow
  - Aerated
    - Aquaculture
      - Water Hyacinth
      - Duckweed
    - Sand filters
      - Intermittent
      - Re-circulating
- Terrestrial
  - HCR
  - Slow-rate
  - Overland Flow
  - Rapid Infiltration
  - Subsurface Infiltration

This chapter explores a few alternative technologies for waste water treatment.

Upflow Anaerobic Sludge Bed (UASB) Reactors

UASBR are better for medium to high strength effluents (COD 1500mg/l). UASB is cheaper and combines waste water treatment with recovery and reuse. UASBR uses anaerobic process by forming a blanket of granular sludge which suspends in the tank. Wastewater flows upwards through the blanket and is processed (degraded) by the anaerobic microorganisms. The upward flow combined with the settling action of gravity suspends the blanket with the aid of flocculants. Normally referred to as UASB reactor is a form of anaerobic digester that is used in STPs (sewage treatment plant) and ETPs (effluent treatment plant).
The UASB concept has been successfully modified for treatment of liquid waste with high concentration of suspended solids like Abattoir waste waters as well as solid waste like Poultry droppings, Kitchen Waste, Vegetable Waste.For waste water, UASB can treat a maximum loading rate of 10-12.5 kg COD/m3 and reduce CC an

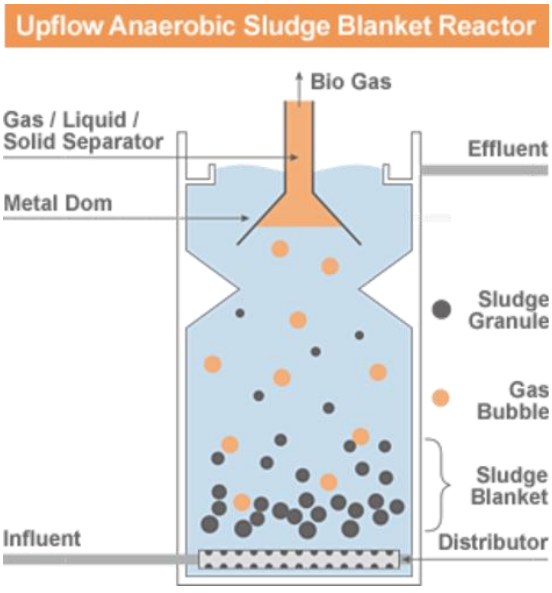


Fig 3.1 Upflow Anaerobic Sludge Blanket Reactor

Trickling Filter

A trickling filter, also called trickling biofilter, biofilter, biological filter and biological trickling filter, is a fixed bed, an attached growth process that operates under (mostly) aerobic conditions.

It is usually circular and between 10 m- 20macross and between 2 to 3 m deep. A circular wall, often of brick, contains a bed of filter media which in turn rests on a base of under-drains that allow liquid to pass downwards and air to pass upwards.

The fixed bed is made of any inert material of uniform size such as gravel, rocks, slag, polyurethane foam, sphagnum peat, ceramic, moss, pumice, coke, or plastic media. Mounted in the center, over the top of the filter media, is a spindle supporting two or more horizontal perforated pipes which extend to the edge of the media. Settled sewage is delivered to a reservoir at the centre of the spindle via a dosing mechanism.

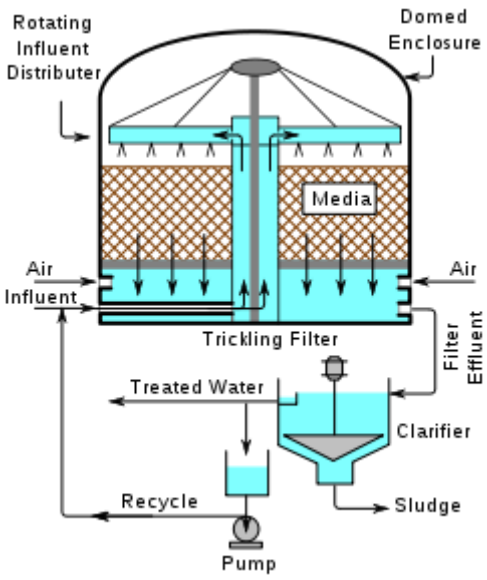


Fig 3.2Design of Trickling Filter

Fig 3.3 Aerial view of Trickling Filter

The perforations on the pipesallow an even flow of liquid over the whole area and are angled so that whenliquid flows from the pipes the whole assembly rotates around the central spindle. Aerobic conditions are maintained by splashing, diffusion, and either by forced-air flowing through the bed or natural convection of air if the filter medium is porous. Pre-settled wastewater is continuously 'trickled' or sprayed over the filter.

Sewage or other wastewater flows over this downward, allowing a layer of microbial slime (biofilm) to grow, covering the bed of media. This bio-film is a gelatinous matrix, several mm thick and contains many species of worms (annelids, round worms and insect larvae), bacteria(ciliates and amoeboid) protozoa, etc. Within the thickness of the biofilm both aerobic and anaerobic zones can exist supporting both oxidative and reductive biological processes. At certain times of year, especially in the spring, rapid growth of organisms in the film may cause the film to be too thick and it may slough off in patches leading to the "spring slough".Single trickling filters may be used for the treatment of small residential septic tank discharges and very small rural sewage treatment systems. Larger centralized sewage treatment plants typically use many trickling filters in parallel.

Table 3.1 Trickling Filter		
Advantages	**Disadvantages**	**Limitations**
Simple to operate	Low BOD removal	Needs consistent operating conditions
Resistance to shock loads,	High suspended solids	Not suited for highly chlorinated organics, aliphatics, amines and aromatic compounds.
Low sludge yield	Very little operational control	Heavy metals and non-biodegradable organics accumulate in the sludge.
Low power requirement		Hydrogen sulphide may be produced if anaerobic conditions set in, causing foul smell.

Corrective Measures

- If H_2S smell arises, immediate action is needed to resume aerobic conditions.
- Check for ventilation clogging
- Check for stoppages / clogging in under-drain system
- Increase recirculation rate
- Keep wastewater in filter. Do not allow onto grasses or exposed surfaces.
- Chlorination in limited dose in primary tank helps reduce odour. But residual chlorine can harm biofilm. So it should be handled carefully after the trickling filter is operational.
- Correct 'Ponding' that occur due to excess organic loading, small sized or non-uniform media, clogged under drains or debris in filter voids. Ponding decreases efficiency and causes odours.

Studies in Pakistan have proven that maize cobs serve as an economic, efficient and robust filter media which have better capability to sustain higher organic loadings and temperature fluctuations as compared to other conventional filter media. As the organic loadings increased, the removal (%) of BOD and COD decreased for the developed trickling filter. The removal (%) increased with an increase in temperature. The maximum removal (%) was achieved at an organic loading of 12-15 Kg BOD/COD/m3.d and a temperature range of 35-43°C.

Rotating Biological Contactors (RBC)

These are very effective filters where the biofilm is allowed to form on a series of large discs supported on a single shaft which rotates slowly through the wastewater. The RBC stacks are covered by a removable fiberglass housing that has access portals.

Table 3.2 Rotating Biological Contactor	
Advantages	**Disadvantages**
High contact time and high effluent quality (both BOD and nutrients)	Continuous electricity supply required (but uses less energy than trickling filters or activated sludge processes for comparable degradation rates)
High process stability- resistant to shock - hydraulic or organic loading	High investment as well as operation and maintenance costs
Process is relatively silent compared to dosing pumps for aeration	Requires permanent skilled technical labour for operation and maintenance
Short contact periods are required because of the large active surface	Must be protected against sunlight, wind and rain (especially against freezing in cold climates)
Low sludge production	Odour problems may occur
Low space requirement	
No risk of channeling	
Well drainable, excess sludge is collected in clarifier	

RBCs are compact (i.e. in densely populated urban settings) and they efficiently reduce organic matter, treat domestic black- or grey water and any other low- or high- strength biodegradable wastewater e.g. industrial wastewater from food processors or paper mills. They have been found to be particularly effective for decentralised applications (small to medium community or industry/institution),where electricity and skilled staff are available as well as urban areas where land requirements are low, but continuous and consequent energy supply as well as semi-skilled labour are available.

RBCs are high-technological and require skilled staff for construction as well as for operation. During operation, the system needs to be supervised by professional operators. Maintenance includes lubrication of moving parts, motors and bearings; replacing seals, motors, servicing bearings; and cleaning the attached-growth media (spray-washing of discs and purging of settled sludge). The discs may be also checked for debris accumulation, ponding and excessive or insufficient biomass accumulation.

The higher contact time in RBCs due to rotation allows up to 8 to 10 times higher levels of treatment than in trickling filters . It takes 6 to 12 weeks for the biofilm to establish for a good treatment. Rotation allows both optimum wetting and oxygen supply; RBCs are generally more reliable than other fixed-film processes. The disc is designed to allow large amounts of biofilm to attach, resulting in an improved stability and a reduced susceptibility to changes in hydraulic or organic loading compared to conventional activated sludge processes.

The performance of RBC systems depends on the design, the temperature, concentration of pollutants, rotating velocity and hydraulic retention time. RBCs can achieve Biological Oxygen Demand (BOD) reductions of 80 to 90 %.Nitrogen removal (mostly ammonia) by nitrification and denitrification is also high, because both aerobic nitrifying bacteria and anaerobic denitrifying bacteria can simultaneously live in the

attached biofilm. Some other microorganisms (called annamox) which can transform ammonia(NH3) in one single step to gaseous N2 under anaerobic conditions have also been discovered in biofilms growing on RBC. This has resulted in the development of innovative aerobic ammonia removal and wastewater treatment processes. Little is known about the removal of phosphorus in RBCs, but it can be presumed that large parts of the phosphorus present is either accumulated in the biofilm or in the settled and collected sludge. The collected sludge in the clarifier requires further treatment for stabilisation- anaerobic digestion, composting, constructed wetlands, ponds or drying. In small installations the accumulated sludge is directed back to the septic tank for storage and partial digestion. For discharge or reuse, a treatment unit allowing further pathogen removal should be considered. In any case (i.e. for operation and maintenance) direct contact with the biomass growing on the discs, the effluent or the sludge should be avoided.

Advanced Oxidation Process (AOP)

Solar energy can be used in two ways for waste water treatment. A traditional STP can be powered by photovoltaic cells. The other method is Advanced Oxidation Process (AOP).Hazardous organic waste, widely spread in water by industrial, military and domestic sources can be removed with AOPs efficiently. AOPs are a set of processes, involving the production of very reactive oxygen species, which are able to destroy a wide range of organic compounds. AOPs are driven by external energy sources such as electric power, ultraviolet radiation (UV) or solar light, so these processes are often more expensive than conventional biological wastewater treatment.

AOPs can be applied for the disinfection of water, air and for remediation of contaminated soils. AOPs are successful to transform toxic organic compounds (e.g. drugs, pesticides, endocrine disruptors, etc.) into biodegradable substances. Advanced oxidation generally uses strong oxidising agents like hydrogen peroxide (H_2O_2) or ozone (O_3), catalysts (iron ions, electrodes, metal oxides) and irradiation (UV light, solar light, ultrasounds) separately or in combination under mild conditions (low temperature and pressure). Among different available AOPs, those driven by light seem to be the most popular technologies for wastewater treatment. Solar AOPs are particularly attractive due to the abundance of solar light in regions where water scarcity is high and due to their relatively low costs and high efficiencies.

Types of Solar AOP

- Photolysis (UV + H2O2): surface or ground water can be disinfected by solar water disinfection by adding H_2O_2
- Photo-catalysis (light + catalyst): Dissolved arsenic can be removed by co-precipitation in the presence of iron.
- Photo-Fenton (solar light + Fenton (Fe2+ + H2O2)): suited for industrial wastewater with toxic compounds.

AOPs have a wide range of applications such as air (odour elimination, purification), soil (remediation) and water decontamination. Furthermore AOPs are successful to inactivate bacteria, viruses etc. AOPs are often used as pre-treatment combined with biologic treatment.

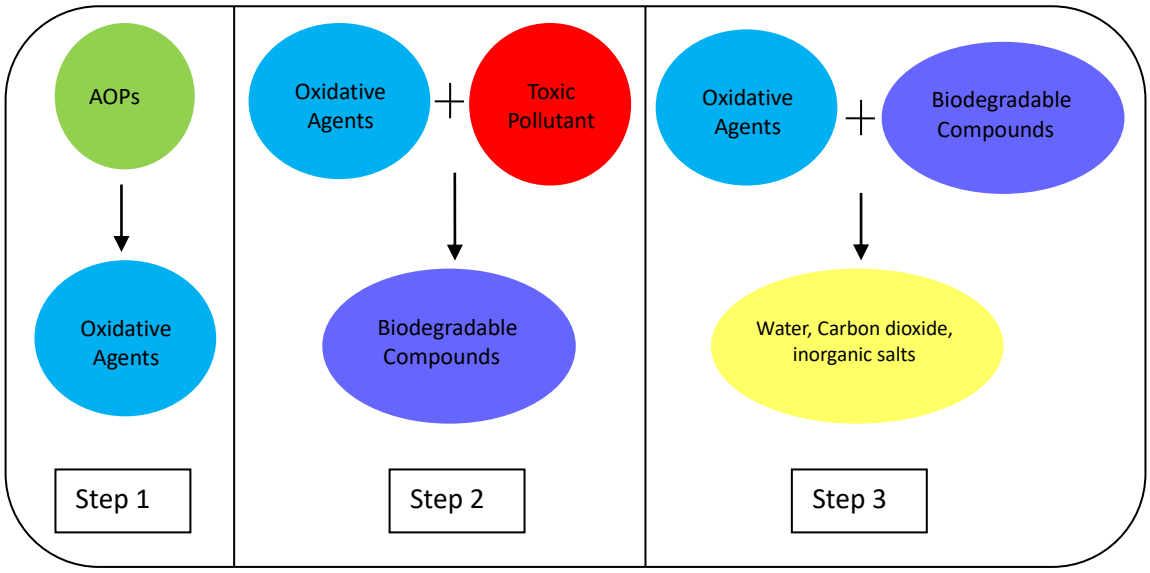


Fig 3.4 Main Steps Involved in an AOP'S Treatment of Wastewater Containing Toxic Organic Compounds (MAZILLE, 2011)

Table 3.3Advanced Oxidation Process

Advantages	Disadvantages
Highly efficient - destroys toxic organic compounds without pollution transfer to another phase.	Oxidation intermediates are potentially toxic.
Treats almost all organic pollutants.	Continuous supply of chemicals (ozone, H_2O_2, etc) is required.
Cheap to install	High operating costs due to the input of chemicals and energy required.
Adaptable to small scales in developing countries.	Engineers are required for the design and often also for operation.
Advanced oxidation can be used as quaternary treatment or a polishing step to remove micro-pollutants and for the disinfection of water.	The combination of several AOPs is an efficient way to increase pollutant removal and reduce costs. The technology is still emerging. There is scope for research.
Reliable if operating conditions are scaled taking into account wastewater content	

Since AOP is expensive, it should be applied judiciously, in any of the stages shown in the following illustration.

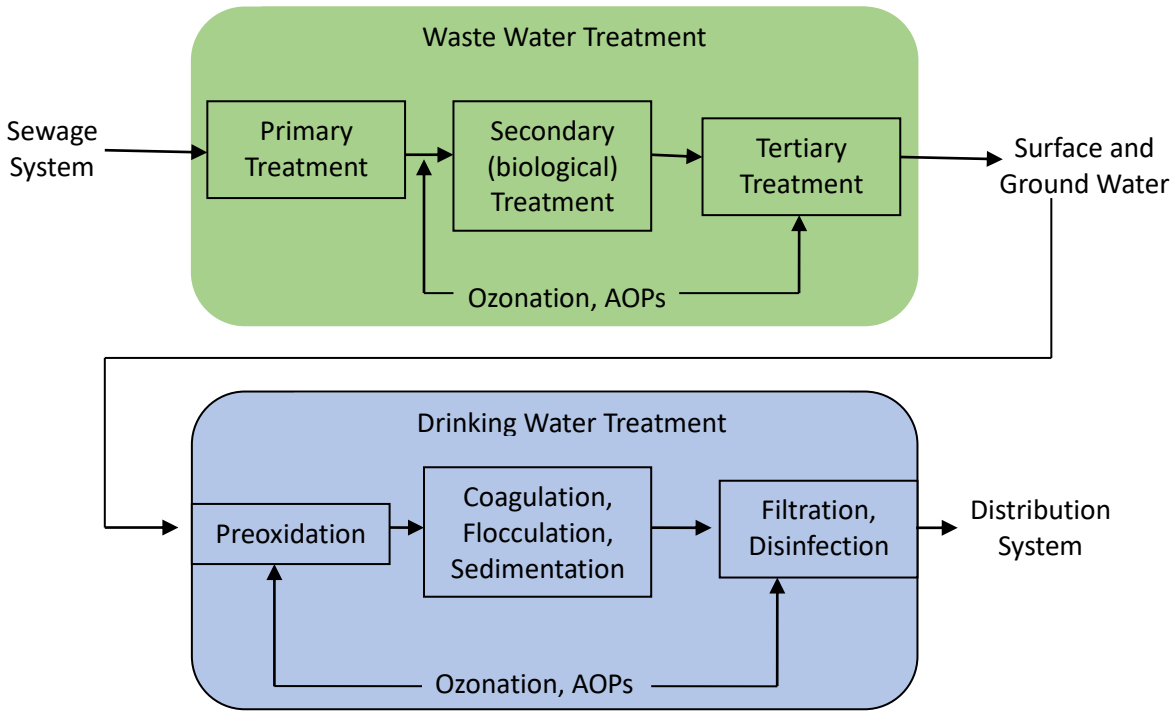


Fig 3.5 Possible Applications of Ozonation and AOPS in Wastewater and Drinking Water Treatment.(Petrovic et al., 2011)

Membrane Processes – Reverse Osmosis, Desalination, Ultrafiltration

In a membrane process, fluid is passed through a barrier. The separation occurs because of the pressure difference between the two membrane surfaces, keeping contaminants on one side of the membrane and fresh water on the other side. Used in drinking water for many years, membranes increasingly are being used in wastewater treatment as well. They can be used as pretreatment for reverse osmosis or in tertiary filtration. Membrane bioreactors are used as an integral part of wastewater treatment, creating high quality water for reuse.

There are growing restrictions on effluent discharge conditions, driven by total maximum daily loads (TMDL) and low effluent discharge requirements for nutrients such as phosphorus and nitrogen are becoming increasingly common. These conditions call for high levels of wastewater treatment, which membranes provide. Micro-constituents have gained worldwide attention. These compounds include pharmaceuticals and personal care products and endocrine-disrupting chemicals. The four critical design parameters to consider when incorporating membranes into treatment plant design are: flux, transmembrane pressure, permeability and recovery.

1. Flux is the filtration rate per square foot of membrane surface area. The higher the flux design rate, the less surface area you need and the lower cost of installation.
2. Permeability is basically the quantity of water per square foot of membrane surface area that 1 psi can treat. Another way to think of permeability is the flux divided by the TMP.
3. Recovery is the percentage of filter effluent vs. plant influent.
4. Other important design considerations include fluctuations in flow, temperature and feed quality. Cleaning requirements and replacement costs also need to be considered in the design.

Reverse Osmosis (RO)

The process of reverse osmosis is based on that of osmosis. Jean-Antoine Nollet, a French scientist and cleric, first observed osmosis in 1748 as the process cells use to transport water. Reverse Osmosis (RO) reverses the process. Pressure is used to force a pure solvent through a semi-permeable membrane. Water typically passes easily through membranes because its molecules are small. The pore size of a reverse osmosis filter is generally 0.0001 of a micron.Reverse osmosis is most often used for desalination of seawater and brackish water for potable and industrial applications, but also for wastewater treatment and water reuse. It can also be used to remove trace phosphates, calcium, heavy metals, and other substances. Nowadays, RO water filters are common in households dependant on ground water or hard water.

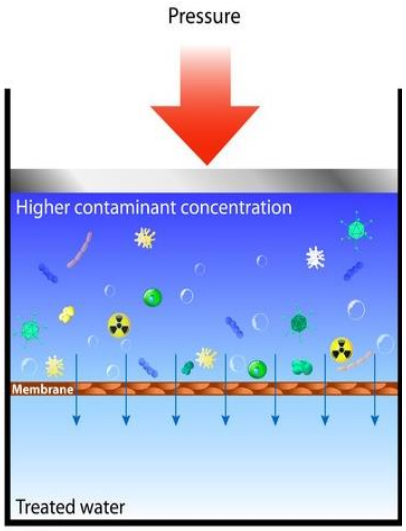


Fig 3.6 Working Principle of Reverse Osmosis

Ultrafiltration

Another membrane process is ultrafiltration. These membranes have a filter size of between roughly 0.1 and 0.01 microns. This allows for the retention of proteins, fatty acids, macromolecules, bacteria, and suspended solids in a liquid. In water treatment, the ultrafiltration process is able to remove bacteria, protozoa, and some viruses from the water. Often these processes can be used in combination to provide a comprehensive water treatment solution. Ultrafiltration is used in combination with reverse osmosis to create demineralized water for high-pressure boilers. The ultrafiltration process can also resolve issues with membrane fouling. The wastewater from mining operations is extremely high in total suspended solids and colloids. Ultrafiltration can remove these particles to prepare it for treatment with reverse osmosis. In some cases, the water is passed through reverse osmosis twice to reach the needed final specifications for full water treatment.

Drawbacks of Membrane Systems

All membrane processes are extremely useful, but they also have hidden ecological dangers.For instance, The RO water purifier at home lets out brine, with high Total Dissolved Solids (TDS). If the brine enters the STP, it will shut down the system as bacterial action will cease. The waste water will come out untreated. At the same time, the waste water cannot be used for toilets (stains ceramic), washing cars (damages paints and leaves salt stains) or watering the garden (affects soil salinity).With membrane filters it is essential to change the filters regularly to avoid biofilm formation. There are many monitoring systems and bio-film removal techniques which are being identified. Their efficiency will be known with time. Desalination plants using RO technology has been a boon for the Gulf and Middle Eastern countries. However the technology impacts seawater in several ways.

- ✓ It increases seawater temperature, salinity, water current and turbidity.
- ✓ It also harms the marine environment, causing fish to migrate while enhancing the presence of algae, nematods and tiny molluscs.

Alternative Methods of Desalination

Research and Technology modification is underway to avoid damage to marine life. Two examples are given in the boxes below.

Tamilnadu to Set up India's 1st Offshore Desalination Unit,
Cost an Estimated RS 2,000 crore!

A significant difference between this off-shore desalination plant as against the existing desalination plants in Nemmeli and Minjur is that it will move away from the traditional reverse osmosis (RO) technology to separate fresh water from seawater. Instead, the offshore plant will use the indigenously developed, environment-friendly technology of low-temperature thermal desalination (LTTD), which harnesses the temperature difference available between surface water and deep seawater.

Under this technology, the warmer surface seawater is made to evaporate at low pressures. The vapour obtained is then condensed using the colder deep sea water, thereby resulting in safe and potable drinking water. This technology is the answer to the pollution caused by the existing RO-based plants, which release chemicals and highly concentrated brine into the ocean during desalination. This brine later settles on the surface of the water body and disconnects oxygen causing oxygen deficiency in the ocean floor area, which threatens marine life.

Ocean scientists are meticulously researching if the proposed desalination plant could be powered by electricity using ocean thermal energy conversion (OTEC), then the existing practice of using diesel. If the use of OTEC for the plant becomes a reality, it could bring down operation costs to a great extent.

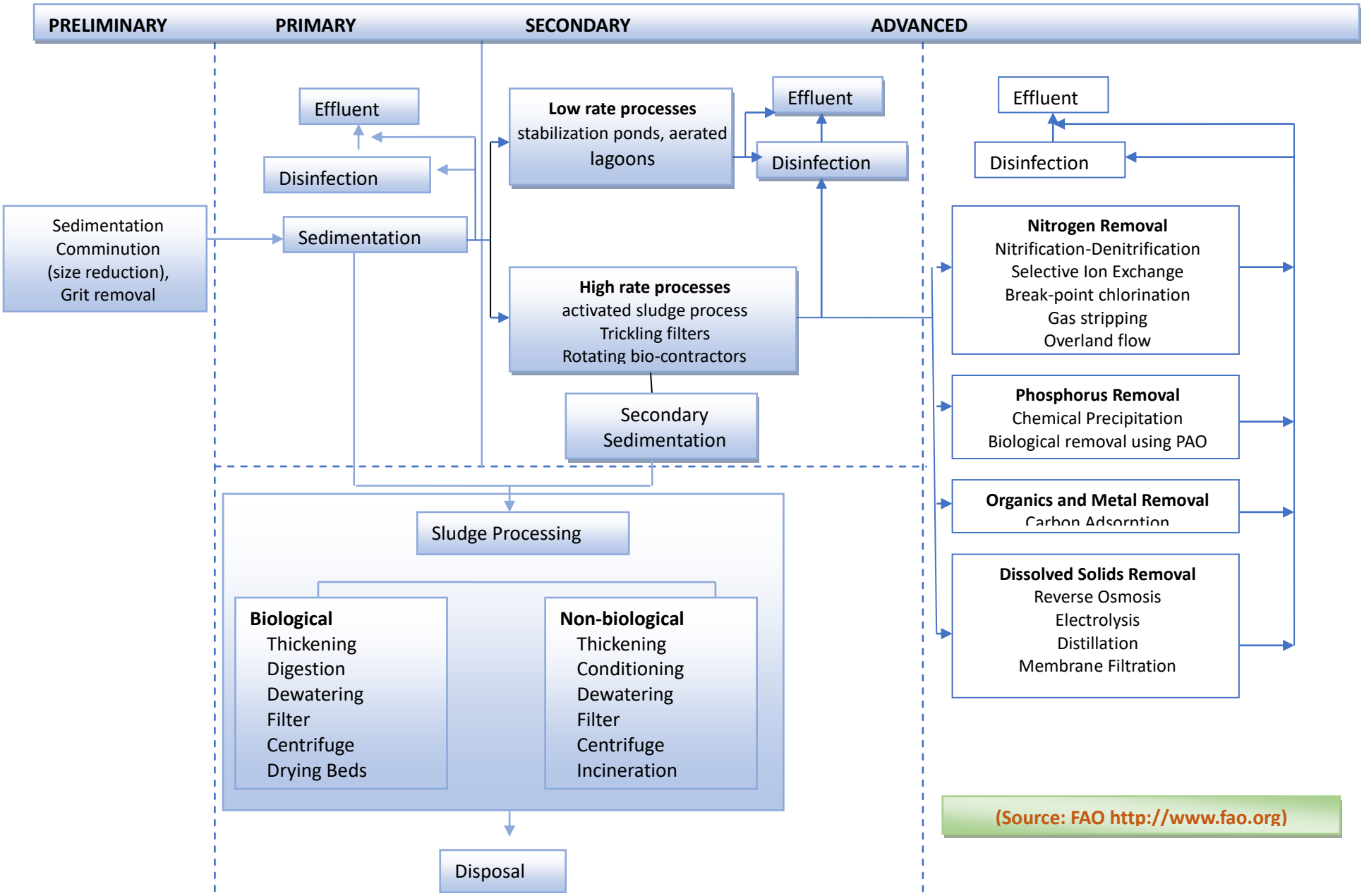
Cheap Method to Turn Salt Water into Drinkable Freshwater

Chaitanya Karamchedu from Portland, Oregon, is an Indo-American student who has found a cheap method to turn salt water into drinkable freshwater. His work has caught the attention of major technology firms and universities.

The real genesis of the idea was realizing that sea water is not fully saturated with salt. By experimenting with a highly absorbent polymer, the teen hit upon a less expensive method to remove salt from seawater and turn it into freshwater. "It's not bonding with water molecules, it's bonding to the salt!"

People have been looking at the problem from one view point, how do we break those bonds between salt and the water-- Chaitanya thought about it from a completely different angle. Instead of working on 10% of water that's bonded to the salt in the sea, Chaitanya looked at the 90% that was free. It is a breakthrough that is estimated to impact millions of lives if ever implemented on a mass scale. Karamchedu has also been named one of 300 semifinalists in the Regeneron Science Talent Search, one of the most prestigious competitions in the U.S. for high school seniors.

Fig 3.7 Steps in Waste Water Treatment



(Source: FAO http://www.fao.org)

Eco-STP

Eco STP treats water naturally without chemicals or electricity. There is no foul smell and the method is low cost. It is designed by ex-TERI scientist, Pravinjith, and marketed by Paradigm Environmental Strategies, Bengaluru. The method is modeled on a cow's stomach, using different chambers to treat the waste. The treated water is run through a plant bed consisting of Canna plants and Colocassia and the final water is used for toilet flushing and gardening. There is minimum maintenance involved. It mimics the processes of the natural world — using a combination of microorganisms, plants and gravel to clean sewage water and return clean water back to mother earth, completing the 'cradle to cradle' sustainable lifecycle.

Table 3.4 Comparison between Conventional STP and Eco-STP

Conventional STP	Eco STP
Aerobic	Nature- based, decentralized treatment system
Needs motor for aeration	No Motor needed
Power intensive- uses 40% of monthly electricity	No electricity needed
Less space needed	Takes twice the space of STP
Built above ground- eyesore	Built underground. Land can be developed.
Foul smell	No smell
	Installation cost 14 lakhs
High running cost- in lakhs per year	Running cost Rs.2 5 per month per family
Weekly sludge removal	Sludge removal once in 2 years. 

The team has already successfully used the STP in Aishwarya Amaze Apartments, Bengaluru. The response from the residents was overwhelmingly positive."We have been using the DTS ecoSTP by Ecoparadigm for the last six years and we are very happy."Another success story for the ecoSTP can

be seen at St. Martha's Hospital, Bengaluru. The hospital had a regular STP earlier and the management had spent lakhs of rupees per year on its maintenance, which eventually became a burden for them. As it is a charitable hospital, they needed to cut down on costs and decided to go for a low cost and effective STP which could treat 300 KLD (1 kld = 1,000 litres) per day. The hospital decided to go for eco-STP as it required only Rs. 1 lakh annually for wages, labour and maintenance, as compared to a regular STP which would cost Rs. 20 lakh for a 200 KLD plant. Today, the hospital's entire garden is watered by water treated by the eco-STP. The hospital has managed to save Rs. 2.5 lakhs per month on water alone.

3.3 Biological Nutrient Removal Systems

The presence of nitrogen and phosphorus in the treated water poses a problem for the receiving water bodies. These two essential plant nutrients encourage eutrophication. Stringent rules are being placed all across the world to control the concentration ration of nitrogen and phosphorus in treated water. Excess phosphate can be removed by adding alum, ferric oxide or slaked lime, nitrogen (ammonia stripping) and adsorption of organics on activated charcoal and finally chlorination. This is called tertiary treatment. It is expensive. Biological nutrient removal is the process of nitrogen and phosphate removal using microbes.

Step1: Nitrogen removal
Step2: Phosphorus removal

Nitrogen Removal

Using a combination of nitrifying and denitrifying bacteria can be used for removing excess nitrogen, which is a cheaper alternative. During nitrification, ammonium is oxidized to nitrite by ammonium oxidizing bacteria (AOB) and then to nitrate by nitrite oxidizing bacteria (NOB). This process takes place in

oxygen rich conditions. During denitrification, anoxic conditions are created. Nitrite and/or nitrate is denitrified to nitrogen gas as the denitrifying bacteria uses up the oxygen on the nitrate/nitrite molecules, leaving behind base and nitrogen gas. The details are given in the video mentioned below. (Watch Film Nitrogen Removal: Duration 12 min, https://vimeo.com/7376008)

Phosphorus Removal

Phosphorus removal occurs with the use of PAO organisms (phosphorus-accumulating organisms). These are facultative anaerobic bacteria that develop only when their ecological niche exists in the system:

- ✓ Must have a true anaerobic zone - without nitrate/nitrite or dissolved oxygen
- ✓ The anaerobic zone must have volatile fatty acids (VFA) that are used by the PAO.
- ✓ pH must be above 7.0 (GAO organisms start to have an advantage at lower pH - GAO do not uptake phosphorus)
- ✓ Temperature best below 30°C - as other organisms start to outcompete the PAO (again the GAO organisms)
- ✓ Anaerobic conditions must be followed by oxygen rich (aerobic) conditions

PAOs store energy in the form of polyphosphate granules (inside cells). The stored energy powers the uptake of volatile fatty acids (VFA) - usually acetic, propionic, & butyric under anaerobic conditions. The uptake of VFAs ends up releasing phosphate into the surrounding water. Once in an aerobic environment, the PAO organisms use the stored VFAs for energy and uptake the free phosphorus in the water and store it as polyphosphate inside the cells.

Constructed Wetlands

Another option for phosphorus removal, that most mimics natural processes, is constructed wetlands that act as a biofilter to remove trace organics, nutrients, and solids before final discharge. Constructed wetlands should be a first choice option in areas with large amounts of land as they have fewer energy, chemical or labor requirements demanded by either advance biological systems or chemical treatment. In many cases, the wetlands can be a natural area or park that benefits wildlife and local residents. Most of the phosphorus removal in constructed wetlands is accomplished through plant uptake of the nutrients.

3.4 Sludge Management

A major issue with biological treatment of waste water is generation of a lot of sludge. This is the biomass of all the organisms that fed on the waste matter in the waters. How do we deal with the vast quantities of sludge? Recycling the nutrient rich sludge into compost is not a quick-fix, since it contains heavy metal contamination due to mixing of black and grey waters as well as effluents in the municipal waste water. Only, if the sludge is free of toxic material, it can be used for fertilizing crops. Pollution makes it impossible to reuse this sludge. As a result, it is sent to landfill or let into the ocean, neither of which is safe.

Sludge to Energy Technology

The system is based on the combination of a sludge dryer and subsequent incineration in a fluidized bed furnace. Co-generated heat is used for sludge drying operation. Thus, the sludge disposal volume is minimized to 10%. Phosphorus can be later recovered from this ash.

While helping to reduce sludge in the short term, such burning is expensive and requires a great deal of energy. Therefore, using anaerobic treatments we can successfully extract methane from the sludge.

Biogas Harvesting from Sludge Digesters

As discussed in the case study above and seen in several models of biogas plants in Europe, animal and human excreta are relatively low in nutrition. If food waste from restaurants and supermarkets are added, then the anaerobic bacteria can comfortably break it down in sludge digesters. This is called anaerobic co-digestion. The substrate (organic waste)-to-inoculum (anaerobic bacteria) ratios between 2 and 6 are typically used at the laboratory scale, while on industrial scale the ratio between 2 to 4 works best. Methane gas thus created contains roughly 60% CH_4, 29% CO_2 and trace elements of H_2S.It is not suitable for use as fuel gas as the H_2S causes corrosion inside the burners.

Biogas or bio-methane is usually sent to a processing plant for further treatment. It is stripped of H2S (de-sulphurisation) by water scrubbing, caustic scrubbing and Solid Chemical Absorption where an 'iron sponge' consisting of ferric oxide and wood shavings is made to react with gas in a dry scrubber. Molecular sieves are preferred as they help to remove both carbon dioxide and hydrogen sulphide. CO2 is removed by pressure swing adsorption, chemical solvent scrubbing (amine gas treatment), water wash

(pressurized water scrubbing) or membrane separation. Technologies like physical solvent scrubbing (using glycols), membrane separation, cryogenic distillation, supersonic separation, industrial lung technology rotary water scrubbing, can lower the operating cost and compact process designs. According to the International Energy Agency, bioenergy (biogas and biomass) have the potential to meet more than a quarter of world demand for transportation fuels by 2050.

Water Reclamation by De-watering Sludge

Australia uses Geotextile tubes to de-water sludge. Geotextile dewatering containers provide a unique solution to dewatering many types of fine-grained material, sludges and slurries. With the in-line addition of a suitable polymer the pumped solids combine and release water through the pores. Due to the surface tension exhibited by full CRS Envitube® containers, rain cannot permeate the geotextile and the contained solids will become progressively drier whilst remaining fully contained. All it requires for the placement of the units is a level-bund area close to the dredging site ideally allowing the bag filtrate to gravity back to the dam or lagoon.

Case Study on Xiangyang, China - Sludge to Fuel

In Xiangyang, China, the sludge to energy plant is a 3-story stainless steel building that converts several tones of sludge from human waste into fuel for 400 cars. After all the previous attempts failed in composting sludge, TOVEN, a Chinese firm took over a 1,50,000 tonne sludge pile. They struggled for five years to develop the correct technology. The outer surface of the sludge dries easily, while the interiors stay slimy. The foul odour was unbearable. This sludge is low on organic matter (40-50%). They met this deficit with restaurant food waste to bring organic matter to 70%. The resultant slurry is heated to 130^{o}C and sent for co-digestion.

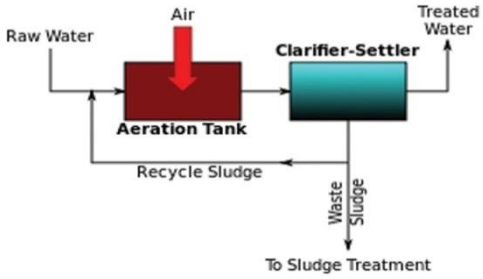
Two 20m high steel tanks inhale 450 tons of this slurry to produce 12,000 cu m of methane. Half the methane is burned to operate the factory, while the rest is compressed to CNG. The remaining solid waste is either sterilized or turned to biochar (more about biochar in Unit 8 Environmental Cost of non-management of waste), an alternative soil used for potted plants. This is a viable process as it uses less energy and effort than composting or incineration, costs less for methane conversion and the company earns 1.7 billion dollars annually.

The environment is benefitting too. Slowly the rotten egg smell of the island is fading. The Han river, an important tributary to the Yangtze no longer receives sludge runoff. This makes it cheaper to purify and supply municipal drinking water. The World Resource Institute says the plant could reduce GHG emissions more than 95% over the course of its lifetime. If China uses even 10% of its sludge this way, it can reduce GHGs equivalent to 380 million tonnes per year! The barriers preventing the replication of this process are preset notions and conventional wisdom of the industry, unsupervised dumping of septage, lack of penalty for not treating sludge, which makes sludge treatment hard to enforce.

Faecal Sludge and Septage Management

In India, Faecal Sludge and Septage Management (FSSM) is the missing link which prevents the country from attaining its larger goals of sanitation and pollution-free environment. There are 7,000 towns in

India with less than 1 million population and 95% of households in these towns are exposed to water contaminated with faecal sludge, which has significant public health and environmental consequences.



Faecal sludge refers to the undigested or partially digested slurry or solids resulting from storage or treatment of black water or excreta. Septage, or residue from a septic tank, needs the same treatment as faecal sludge. It can be raw or partially digested, a slurry or semisolid, and results from the collection and storage/treatment of excreta or black water, with or without grey water. Septage is usually collected only if the septic tank is filled. A truck-mounted or tractor-mounted vacuum tanker is engaged to clear the tank, but the collected sludge is often dumped illegally into urban watercourses, open drains and rivers. Thus, the whole community is potentially exposed to untreated human waste.

Emptying septic tanks: If faecal sludge is liquid enough, it is usually collected by using vacuum pumps or centrifugal style booster pumps. The accumulated sludge, after remaining for years in septic tanks and pit latrines, sometimes becomes hardened, making it very difficult to remove. Although workers enter pits in order to clear them, the practice is unsafe and undesirable. The collected faecal sludge should preferably be processed at dedicated faecal sludge treatment plants. It ought not to be co-treated with sewage in municipal treatment plants. If septage has very high BOD, suspended solids, total dissolved solids, pathogens as well as high nitrogen and phosphorous content, can overload an STP and cause its breakdown.

Processing technologies

Processing technologies include constructed wetlands, anaerobic digestion, and waste stabilization ponds. Another possibility is to use the treated faecal sludge after composting as a soil conditioner or for the production of biogas, charcoal, biodiesel, powdered industrial fuel and electricity. Private-public sector partnerships can help in FSM projects. The business is viable, provided it is managed well and has appropriate technology in place. For containment, emptying and collection of faecal sludge, septic tanks must be built in line with standard specifications and guidelines. The following case study throws light on the management of an FSM system, which has potential to transform the face of sanitation in India within five years.

Case Study: Devanahalli

(Watch Film: India's First Faecal Sludge Treatment Plant, Duration 8 min
https://www.youtube.com/watch?v=WZgT2Vwfvwc)

Devanahalli in Karnataka, with a population of 30,000, piloted the first successful Faecal Sludge Treatment Plant (FSTP). This was done by CDD Society in collaboration with the Devanahalli Town Municipal Corporation. The treatment plant here has an anaerobic digester where the solid sludge is

deposited. Biogas is produced and then it is stabilised in anaerobic reactors before being dried in the drying beds and co-composted with municipal solid waste to prepare soil manure.
The 5-step process that worked in Devanahalli are:

Assessment: A sanitation census that collects data on number of toilets, number of pits and septic tanks, number of septage managing private de-sludgers, and frequency of de-sludging. Operators have to travel far to empty their tanks and there are no designated disposal points. People need to be convinced. All told, the FSTP will have to be aesthetic, odour-free and acceptable to the community.

Land allocation: Planning and zoning authority approvals, ownership, legal access, road access, and approvals from SPCB.

Regulations: Proper regulations need to be in place regarding containment for new houses, licensing and regulation of private operators, outsourcing the operations of the treatment plant to private operators, and for raising property taxes to support the cost of the treatment plant.

Financial model: FSTPs have a low operating cost, affordable by most municipalities. Only one operator is needed to manage the FSTP, since it runs on gravity and does not need electricity for operations.

Community engagement: The manure produced by FSTP is convenient for farm labour to use. It is odour-free, of good quality, and doubles yield. Women's self-help groups can work with every stakeholder in the sanitation value chain.

Others examples of successful FSTPs include those of the mountain town of Leh in Jammu and Kashmir and Ambikapur Nagar Palik Nigam of Jabalpur in Madhya Pradesh. The states of Andhra Pradesh, Rajasthan and Tamil Nadu have evinced interest in adopting this technology.

Innovations in FSSM

- Research is on at the London School of Hygiene and Tropical Medicine to use the larvae of black soldier fly (BSFL)- a non-disease spreading, non-nuisance fly species (Hermetiaillucens) - to feed on pit latrine waste. As the larvae increase in size, they reduce the mass of the waste, thus converting the dangerous pit material into a potentially useful soil conditioner or fertiliser. After the larvae develop into pre-pupae, they can be harvested. Being high in fat and protein, they are suitable replacement for conventional protein sources in animal feeds.

- GenRobotics, a Kerala-based tech start-up, has launched an Iron-Man style semi-automatic robot named 'Bandicoot' that cleans manholes without requiring human beings to enter the pits. Many municipalities in Kerala are now using this robot.

Reedbeds -Alternative Method for Sludge Treatment

The proper utilization and disposal of sludge is one of the most critical issues facing wastewater treatment plants today. Nearly all wastewater treatment plant operators face the problem of storing and disposing bio-solids. Landfill costs are skyrocketing; incineration permits are expensive and difficult to obtain; and land application is limited by availability of permitted land. However, constructed wetland technology such as reed beds provides long-term storage and volume reduction of bio-solids to mitigate these concerns. Widely used throughout Europe, Asia, and Australia, and in more than 50 locations in the United States, reedbed technology features low construction costs and minimal day-to-day operation and maintenance costs. Much interest is also being shown in Canada for their use. The system

reduces water content, minimizes solids, and provides sufficient storage time to stabilize biosolids prior to disposal.

The solution is slowly gaining acceptance in Maine is sludge reed beds. Phragmiteses are only one of nature's age old processes which have been adapted by man in the battle against pollution. They first used years ago, in Europe, in an attempt to deal with iron oxide sludge.

Fig 3.8 Sludge Treatment using Reed bed

Fig 3.9 Preparing the base of the reed bed

Reed beds perform three basic functions: (1) dewater the sludge, (2) transform it into mineral and humus like components, and (3) store sludge for a number of years. Dewatering is accomplished through evaporation (as in a normal sludge drying bed operation); transpiration through the plants root stem, and leaf structure; and filtration through the bed's sand and gravel layers and the plant's root system. Leachate is channeled back to the treatment plant through the underdrain.

3.5 Disinfection

It is very important that the wastewater let out of the treatment plant is pathogen- free. The most commonly used technology since the early 1900s has been chlorination. Just as plastics, DDT, antibiotics and refined oil were considered a boon for mankind until their harmful side-effects began to be noticed, chlorination too has its negative side effects. The following section discusses the methodology, pros and cons, and alternatives to chlorination.

Chlorination

Chlorine is known to be effective in destroying a variety of bacteria, viruses and protozoa, including Salmonella, Shigella and Vibriocholera. Today, wastewater chlorination is widely practiced to reduce microbial contamination and potential disease risks to exposed populations. Chlorination plays a key role in the wastewater treatment process by removing pathogens and other physical and chemical impurities. Chlorine's important benefits to wastewater treatment are listed below:

- Disinfection
- Controlling odor and preventing septicity
- Aiding scum and grease removal
- Controlling activated sludge bulking
- Controlling foaming and filter flies
- Stabilizing waste activated sludge prior to disposal

- Foul air scrubbing
- Destroying cyanides and phenols
- Ammonia removal

Chloramines

Chloramines were also introduced as a viable alternative to chlorine. Chloramines are less reactive and thus more stable than free chlorine, especially at high pH.When chlorine reacts with ammonia, three kinds of chloramines are created: monochloramine (NH2Cl), dichloramine (NHCl2) and trichloramine (NCl_3). They are more appropriately called chloramines. The three species of chloramine constantly and rapidly shift from one form to another. The species that predominates is dependent on pH, turbulence, temperature and the chlorine: ammonia ratio. In time, all monochloramine in a water system slowly degrades to form dichloramine and some trichloramine.

Certain species of microorganisms produce colonies and spores which agglomerate in spherical or large clusters (e.g., Bacillus subtilis) and chlorination of such clusters may destroy the microorganisms on the cluster surface but leave the innermost organisms intact.

Side Effects of Excessive Chlorination

- The allowable chlorine levels in drinking water (up to 4 parts per million) pose "no known or expected health risk [including] an adequate margin of safety."
- Too much chlorine can be dangerous. Exposure to over-chlorination can provoke asthma, lung irritation, and potentially skin and eye irritation. High chlorine levels lower the pH of the water.
- Chlorine can be described as a pesticide whose sole purpose is to cause damage to living organisms.
- According to different studies, drinking and long-term exposure to chlorinated water can potentially increase the risks asthmatic attacks particularly in children who do not have improved airway systems.
- Drinking water contaminated with chlorine destroys cells and tissues inside our body. This explains the carcinogenic behavior of chlorine.
- In other studies, rodents exposed to chloramines and chlorine developed tumors in their intestines and kidneys. If exposed to the skin, chlorine contaminated water can cause irritation and burn the skin as well.
- When watering the garden with chlorinated water the majority of the chlorine evaporates after 8 or so hours, but chloramine takes days to evaporate, meanwhile working to kill off good bacteria found in the soil and necessary for healthy plant growth.
- Chlorine contaminated water is a primary cause of odor and bad taste in drinking water.
- Chloramine, like chlorine, is worse when it is inhaled in gaseous form.
- Chloramines are respiratory irritants with trichloramine being the most toxic. The maximum permissible limit of chloramines in water is 3mg/L in Ontario, Canada.

Chlorination and chloramination have been found to produce undesirable disinfection by-products in the treated water such as trihalomethanes, haloacetic acids and N-nitrosodimethylamine, some of which are suspected carcinogens and some of which can permeate the membranes.

Trihalomethanes (THMs): are disinfection byproducts that are formed when organic matter in the water combines with chlorine. THMs are also formed with chloramine disinfection but at a lower

concentration-- (approximately 1/3 less) than chlorine. THMs are possible but not proven cancer causing byproducts.

Removal of Chlorine/ Chloramine/ Byproducts

Removing chloramine at the point of use is more difficult than removing chlorine. Standard granular activated carbon (GAC) and carbon block products have limited capacity for chloramine reduction. If desired, chloramine and ammonia can be completely removed from the water by boiling; however, it will take 20 minutes of gentle boil to do that. Just a short boil of water to prepare tea or coffee removes about 30% of chloramine. Conversely, chlorine is not as consistently removed by boiling. The safest way to reduce THMs, according to the World Health Organization (WHO), is to remove the organic matter from the water first through pre-filtration before disinfection with chlorine.

Alternatives to Chlorination

Alternative disinfectants, such as ozone and chlorine dioxide, are better, but they too can cause the formation of other byproducts.

Ozone Treatment

Ozone has been used as a disinfectant in water and wastewater treatment due to its powerful oxidation effects. Ozone is effective for deactivating bacteria, viruses, protozoa and endospores. However, due to its instability, ozone must be produced on-site. Ozone can form mutagenic and carcinogenic agents such as bromate in the treated water. Furthermore, ozonation in wastewater treatment leads to a net production of AOC (assimilable organic carbon) which can be easily taken up by bacteria and thus promote microbial growth.

Potassium Ferrate

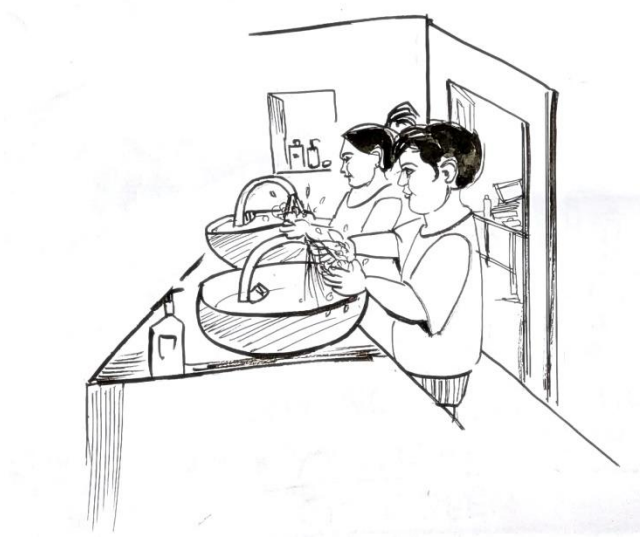
Potassium ferrate is an attractive alternative disinfectant to chlorine in water and wastewater treatment. The advantage of using ferrate is that it does not produce any mutagenic by-products during treatment processes. Science is continually identifying additional chemicals in the drinking water supply, often in minute concentrations. Evidence may be lacking regarding the significant threat to public health.

Removing any added chemicals from drinking water is advantageous. It is better to remove contaminants by adsorption with GAC (Granular activated carbon) instead of adding chemicals that might have unintended consequences. Remember that standard granular activated carbon (GAC) and carbon block products have limited capacity for chloramine reduction. There are several alternatives recommended by the EPA that do not involve adding more chemicals to our drinking water. Rather they remove organic contaminants through enhanced coagulation or sedimentation, filtration, or carbon adsorption. All this demonstrates the need to effectively remove the bad stuff in our drinking water rather than trying to merely treat it with chemicals. Collectively, we can stop the poisoning of our drinking water supplies.

A Better Chlorination Technology

The latest technology in chlorination is EO technology. EO is the product of electrolyzed tap water combined with table salt, NaCl. It is produced by passing a 12V, DC current through a mixture of water and table salt (NaCl). In electrolysis, an electrical current passes through the liquid to break the water and salt into smaller components—a hydrogen ion and hydroxide ion for water and a sodium and chlorine ion for salt. This is Sodium Hypochlorite solution (NaOCl), with 2-4ppm of chlorine present.

This solution contains radical oxygen and chlorine. It is a bleaching agent and an oxidizer, commonly used to bleach wood pulp in the paper industry, but is equally effective as a disinfecting agent. It can be directly applied as a hand wash, and tastes like salt. WHO and WASH are promoting this as the best solution to stay protected. The floods in Karnataka in 2012 had increased the incidences of diarrhea. By introducing the drops, diarrheal cases were brought under control within weeks.



This is possible only if every litre of water is disinfected before drinking. The process is to add 10 drops to clean (non-turbid) water and let it sit for 20 minutes. The disinfected water can be safely used for upto 10 days, if bottle-cap is not opened and 4 days, if under use. In case the water is turbid, the number of drops is doubled to 20 drops per liter. If the water is taken from a surface water source like a pond, the chance of having bacterial spores and Giardia crusts is high. In such a case, allow the water to sit for one hour before use. It is very important to filter the water before adding the drops. For this, many layers of cloth could be used, or any good filter.

Traditional chlorination demands bleaching powder, calcium hypochlorite ($CaOCl_2$). The disadvantages are that producing it is difficult to produce, difficult to use by a layperson and adds a peculiar smell to the water. EO water cuts down on environmental hazards caused by chemical spills during transportation and storage.

Often chlorinated water that is pumped to our homes gets contaminated during transit. Hence excess residual chlorine is added to the water to keep it disinfected till it reaches its destination. If this fails, chance of disease increase. Therefore, CIP- Cleaning in Place is an important step to disinfect water just

before use, preferably in your own overhead tank. Machines can produce EO water at home, directly attached to the water inlet, so that the municipal / well water pumped into the overhead tank gets chlorinated before storage.

For villages and poor sections of society, WASH is teaming up with ASHA workers (social workers) who convince the households and provide the bottles of sodium hypochlorite. Each bottle costs about Rs. 50/- at present. The social worker earns Rs. 25/- for her effort in bringing the solution to the doorstep. For every empty bottle returned, Rs. 5 /- is returned to the customer. The plastic bottles are good food-grade plastic and expensive. Hence a reuse plan is put into the model. There is much opportunity in promoting this disinfection method in India.

The most important thing to remember in this method is to disinfect:

"Every Litre, Everyday!"

Without making disinfection a healthy practice, the chances of recurrence of diarrhea increase.
(Source: WHO, WASH)

Summary

This chapter discussed the alternative ways of biologically treating sewage, such as UASB reactor, trickling filter, rotating biological contactor, advanced oxidation pond and eco-STP. We have also learnt, the ways to remove hard-to-remove persistent chemicals using membrane filters, reverse osmosis and ultra filtration. The scope of membrane filters extends to desalination. Two alternative approaches to desalination were discussed. Removal of nitrogen and phosphorous from treated wastewater is essential to prevent eutrophication health issues (methemoglobinemia- blue baby disease). Biological methods for nitrogen and phosphorus removal require different sets of bacteria that work in unique niche conditions. The sludge recovered from wastewater treatment can be dried and burned to create energy or digested to recover biomethane. Finally, disinfection through the conventional chlorination technique, its evolution, side effects and alternatives were discussed.

New technology is emerging and issues with a few technologies are also coming to the fore. The skill lies in selecting the right treatment methodology for waste water treatment.

Self Assessment Questions

1. How to remove nitrogen and phosphorus from waste water. Why should these be removed?
2. Discuss on UASB Reactor, Trickling Filter, Rotating biological contractor, Advanced Oxidation Process, Membrane Filters, Reverse Osmosis, Ultrafiltration, Eco-STP, Ozone treatment.
3. Given an opportunity to design a wastewater system for a Municipal Ward, which all treatment methods will you employ? Give reasons.

Films

1. Israel: Leading the world in water technology: 9 min https://www.youtube.com/watch?v=RaiCRnIwwbE
2. Nitrogen Removal: 12 min, https://vimeo.com/7376008
3. India's First Faecal Sludge Treatment Plant, 8 min - https://www.youtube.com/watch?v=WZgT2Vwfvwc

4. Chaitanya Karamchedu from Portland, Oregon
https://www.oregonlive.com/portland/index.ssf/2017/02/meet_the_portland_teen_might_a.html
5. https://www.youtube.com/watch?v=u6YS1cUUn8Y

Chapter 4

Clean Water Solutions

Objectives

- To know rainwater harvesting, watershed management, eco-restoration of aquatic bodies.
- To learn about water reclamation/ recycling
- To know how to avoid pesticides, plastic water tanks and fixtures
- To inspire individual and community contribution in water security

Structure

4.1 Introduction
4.2 Ancient Water Technology
4.3 Rainwater Harvesting
4.4 Solution for Flood Management
4.5 Watershed Management
4.6 Urban Watershed Management
4.7 River Restoration
4.8 Water Reclamation
4.9 Individual Responsibility
4.10 Community Responsibility

To Do Activities

- Discuss - How can we save rain water? Supplement with an introduction to ancient Indian technologies and their revival.
- Watch film: Ahar Pyne of Palamu
- Watch film on Hiware Bazar and watershed management
- Visit any riverside to observe presence or absence of riparian habitat. Students may do a small survey of the local stream or river, mapping the areas where riparian buffers exists and can be developed further. Classroom explanation of riparian buffers.
- Explain self-sufficiency in fresh drinking water- rainwater harvesting and SODIS.
- Discuss human engagement in water security and waste management
- Scope out possibilities of career development, research or internship opportunities. Do a self-analysis SWOT test to identify personal qualities and decide the internship project topic.
- Use the physical map of your city/ town to demarcate watersheds. Identify areas where interventions such as gully plugging, trenching can be implemented for watershed management.
- Find creative methods to prepare robust, low-cost rainwater harvesting structures in your college building.

4.1 Introduction

The previous two chapters demonstrated the difficulties in removing pollutants from waste water. This also indicates that we have very little choice in controlling the quality of water we receive through municipal authorities. Climate change, polluted rivers and drying wells are adding to our woes. Is there any way to secure clean water in our own neighbourhood? Let us explore. We have the following choices in water supply:

1. Precipitation
2. Ground water
3. Treated waste water / recycled water

India is a rain-fed nation. The rivers, lakes and groundwater are recharged with the annual monsoons. Certain parts of the country have observed a change in rainfall pattern, primarily drought for the past few years. Yet, several parts of the country face a flood each year. There are three causes for a water shortage despite normal rainfall:

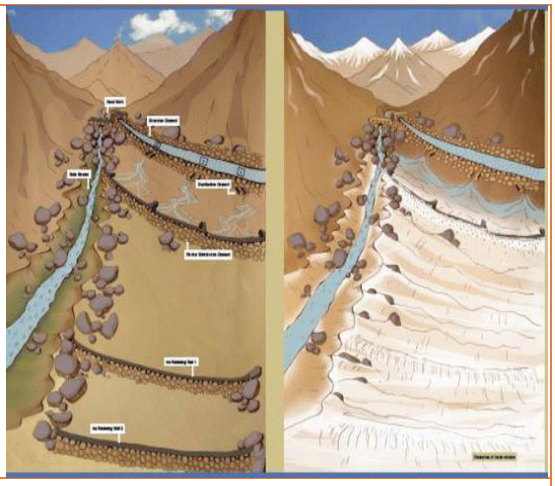
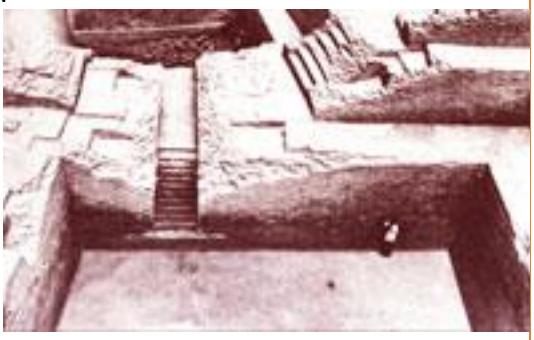
1. Rampant loss of tree cover and humus has reduced ground water recharge,
2. Damming of rivers and diversion of river water has affected hydrology,
3. Overexploitation of water for irrigation and industrial use,
4. Growing urban conglomerates – related concretization and pollution of stormwater.

4.2 Ancient Water Technology

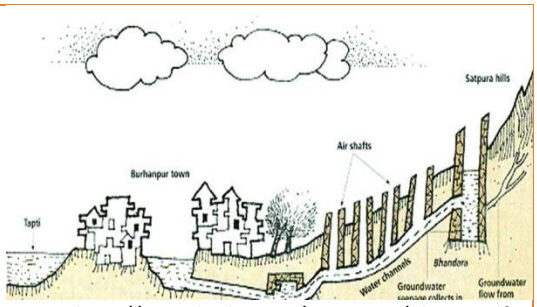
India has faced drought and floods since time immemorial. The first water harvesting structures consisting of intricate channels and check dams were documented in Indus Valley civilization, in the cities of Harpapa and Mohenjodaro. Even today hydrologists accept that the traditional wisdom of water saving holds ground better than modern water supply systems that are unsustainable and inequitable.

The Satvahanas (1st Century B.C.-2nd Century A.D.) introduced the brick and ring wells. Lake and well irrigation was developed on a large scale during the time of Pandya, Chera and Chola dynasties in south India (1st-3rd Century A.D.) and large structures were built across 5 Cauvery and Vaigai rivers. Irrigation tanks were built, many of these by developing large natural depressions. Water resources development on a large scale took place during the Gupta era (300-500 A.D.). In the south, the Pallavas expanded the irrigation system in the 7th Century A.D. The famous Cauvery anicut was built during this period. Large-scale construction of tanks (Tataka) for tapping rain water was also done in Tamil Nadu. The Chola period (985-1205 A.D.) witnessed the introduction of quite advanced irrigation systems, which brought about prosperity in the Deccan region. This included not only anicuts across rivers and streams but also chain-tanks i.e. a number of tanks with connecting channels. The Rajput dynasty (1000-1200 A.D.) promoted irrigation works in northern India. The 647 sq.km Bhopal lake was built under King Bhoja. In eastern India Pal and Sen Kings (760-1100 A.D.) built a number of large tanks and lakes in their kingdoms. There are over 40 such technologies; two from each region are explained here:

Table 4.1 Examples of ancient water technologies from different parts of India (Not an exhaustive list)

State/ Location	Name	Structural design	Image
North India			
J&K, Ladakah (Cold desert/ Tibettan plateau)	**Zing**	Small tanks for collecting water from melting glaciers. Network of guided channels Glacier melt trickles into chanels by evening and is used the next day. A water offician (Churpun) ensures equitable distribution.	
U.P	Sringaverapura tank (1 century B.C.)	Desiltation: Excavations have unearthed a fully brick lined tank that is 800 feet long, 60 feet wide and 12 feet deep. The natural slope of the land brings water from the Ganga to the tank by a nullah. The water passed through two deep earthen tanks, where the silt settled and escaped through the upper end of the settling tank. The inlet to the main tank ended in steps with curve walls to slow down the water. Several wells were also dug in the the bottom of tank to ensure adequate water supply in the dry months.	. 
East India			

Nagaland	Zabo/ Ruza	Rainwater from hillslopes is collected in ponds on terraced hillsides, and meander through the terraced farms. Ponds are used for fish farming and watering cattle.	
Meghalaya	Bamboo drip irrigation A 200-year-old system is used by the tribal farmers of Khasi and Jaintia hills	18-20 l of water entering the bamboo pipe system per minute gets transported over several hundred metres and gets reduced to 20-80 drops per minute at the site of the black pepper cultivation. Bamboo pipes are used to divert perennial springs on the hilltops to the lower reaches by gravity. To divert the water, a short bamboo with a hole at the bottom is placed across the main lines.	 This blocks the main water pipe and diverts the water.
West India			
Rajasthan (Arid region)	Bawadi	Stepwells on hilly outskirts to collect rainwater and divert through canals to city. Water percolates to recharge aquifers. Layered steps narrow and deepen well to prevent evaporation losses.	
Rajasthan (Arid region)	Jhalara e.g. Mahamandir Jhalara, Jaipur 1660 AD	Rectangular stepwells collect the subterranean seepage of an upstream reservoir or a lake.	

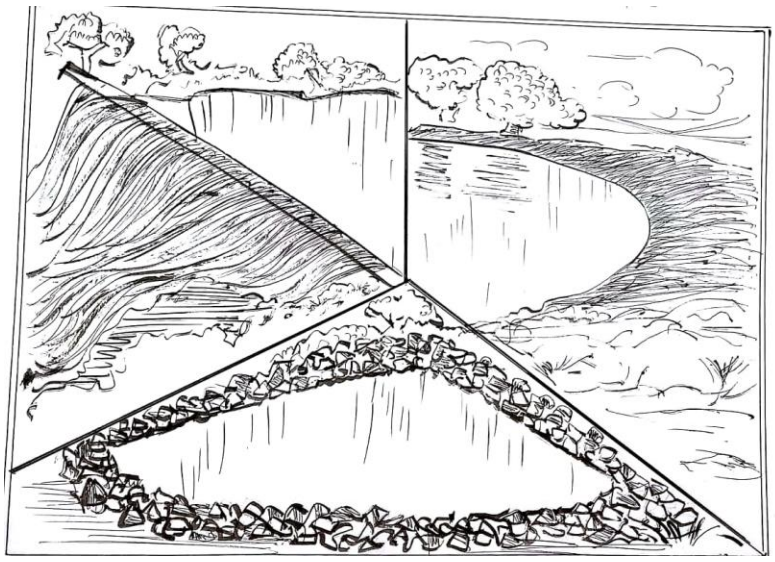
Rajasthan (Thar desert)	Taanka	Cylindrical paved underground pit into which rainwater from rooftops, courtyards or artificially prepared catchments flows. A family can use it yearlong.	
Central India			
Madhya Pradesh	Burhanpur	Well connected water drainage and storage system. The air vents are used by locals as wells. https://www.youtube.com/watch?v=p-OGIeX0hzMideo:	 Source:http://megphed.gov.in/rainwater/Chap2.pdf
South Bihar	AharPynes (support paddy cultivation in low rainfall areas)	Traditional (Mauryan) floodwater harvesting Pynes are artificial rivulets led off from rivers with embankments on three sides	
Nashik, Dhule - Maharashtra	Bhandara-Phad	Stone checkdam (phad) on a river allows kalvas(canals) to channel water for irrigation. Escape routes (sandam), distibutaries (chari) and field channels (sarang) remove excess water.	
South India			
Tamilnadu	Eri	Some Eris divert river water, while other collect only rainwater. Eris are interconnected to make water available to remote areas.	

Kerala	PanamKeni	Kuruma tribe of Wayanad create wooden cylinders(4x4 sqft) out of hollow stems of toddy palm to access sub-surface stream water.	

(Watch film Revival of Ahar Pyne in Palamu District, Jharkhand; Duration 12 min https://vimeo.com/229569089)

Tanks are among the most common traditional irrigation systems in our country- called Keres in Central Karnataka and Cheruvus in Andhra Pradesh and Dongs in Assam.Till recently, tanks irrigated one-third of peninsular India.If the ancient structures are restored and new modern day structures are constructed based on this architecture, localized water issues can be resolved.To ensure a clean source of water for the majority of our population, steps need to be taken at an individual and community level.

4.3 Rainwater harvesting



Rooftop rain water harvesting had been made mandatory for government institutions in Andhra Pradesh, Bihar, Chandigarh, Daman and Diu, Goa, Gujarat, Haryana, Himachal Pradesh, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Nagaland, NCT Delhi, Punjab, Puducherry, Rajasthan, Tamil Nadu, Tripura, Uttar Pradesh, Uttarakhand and West Bengal. Meghalaya, Arunachal Pradesh, Orissa, Jharkhand, Lakshadweep and Andaman & Nicobar are in the process of making such provisions in building by-laws.

Individuals too can easily incorporate rooftop harvesting in their construction plan or make minor changes to add a feature into an existing building. Many households are benefitting from rooftop rainwater harvesting. Its advantages are:

- Easy availability of safe drinking water.
- High quality, soft water.
- Easy to construct, operate and maintain
- Quick recharge of ground water wells.
- Very useful in hilly terrain where rainwater can be easily lost.
- Also good for coastal / saline water areas.

- Best for areas with long dry-spells- i.e. arid areas.
- No fear of contamination or excess chlorination.
- Ability to adjust water use depending on volume of stored water.
- Reduces soil erosion in urban areas.

Precautions to Take With Rooftop Harvesting

- Keep terrace free of debris. Leaf-litter or debris on rooftops and gutters can cause flooding on the roof, and result in building damage. The terrace cannot be used for other purposes capable of polluting the water, such as kitchengardening, garbage disposal (in multi-storey buildings, etc.)
- Make a good quality sand filter with a layer of activated charcoal, to keep silt and dirt out of the tank. Clean the tank annually in the dry season to maintain water quality.
- Keep a 'First flush device' that avoids the first few minutes of rainwater from entering the harvesting system to reduce contamination, if properly maintained.
- Do not apply waterproof paints etc on the rooftop, as it will pollute your rainwater. Do not apply tar based roof material, phenolics, lead based paints.
- If acrylic paints, new concrete or metal is applied, do not collect the first few rains. Animals, birds and insects should be prevented from using the roof. Their droppings can contaminate rainwater.
- Keep tank shut to prevent algal growth. Monitor frequently to check for mosquito breeding.
- Filter/boil the water before consumption.
- Clean the gutters every 3 months. Be cautious while cleaning the rainwater harvesting system, especially the gutters. There could be accidents. Ensure that the ladder always maintains a 3-point contact and refrain from leaning on the ladder. It is preferred to make a system without gutters, for easy maintenance- e.g. a single water spout design.

Precautions for a Recharge Well

Recharge wells are important to maintain the water table. It is recommended for all locations except where the water table is high.

- Recharge well should be far from walls, foundation, column footings, basement wall or underground structure. The distance of the centre of recharge well from the footing should be at least twice the depth of the footing, and thrice the depth of the basement. .
- The soil is not to betoo loose while digging the recharge well.
- The boulder packing should be done by skilled people.
- Provide sufficient concrete / brick lining and make sure that water is not entering into the recharge well from the sides as this may lead to collapse.
- Cover the recharge well properly while construction.
- Provide overflow pipe to avoid water logging around the well in case of overflow.

- Do not create a recharge well if the water table is within 5 feet from the ground level.

Percolation Pits: Rainwater from roofs can be channeled into de-siltation tanks, and percolation pits 60x60x60 cm, filled with pebbles, river sand, or brickjelly and covered with perforated concrete slabs.

Precautions for Storage Tanks

- Construct storage tanks away from septic tanks and other possible contaminants.
- The tank must be lower than the roof to ensure that it fills completely, but the lid should be well above the ground level to prevent floodwater from entering through the lid.
- It can be a ferro-cement tank. The bottom of the tank should be sloping, and easy to clean.
- An overflow pipe which empties into a non-flooding area is needed.
- Excess water could recharge the aquifer through dug well or abandoned handpump or tubewell etc.
- A speed breaker plate must be provided below inlet pipe in the filter to avoid disturbing the filtering material.
- Storage tanks should be accessible for cleaning.
- The inlet into the Storage tank should be screened, and cleaned regularly.

Innovation: Fog Catchers

Fogs are a mass of water vapor condensed into small water droplets at, or just above, the Earth's surface. The small water droplets present in the fog precipitate when they come in contact with objects. The Namib beetle, native to the Namib Desert of southern Africa harvests fog on its solid carapace.

Fog harvesting already exist in at least 17 nations. The frequent fogs that occur in the arid coastal areas of Peru and Chile are traditionally known as camanchacas. These fogs have the potential to provide an alternative source of freshwater in this dry region, if harvested through the use of simple and low-cost collection systems known as fog collectors. Fog harvesting has been investigated for more than thirty years and has been implemented successfully in the mountainous coastal areas of Chile, Ecuador, Mexico, and Peru.

Fog collectors work best in coastal areas where the water can be harvested as the fog moves inland driven by the wind. However, the technology could also potentially supply water for multiple uses in mountainous areas, the water present in stratocumulus clouds, at altitudes of approximately 400 m to 1 200 m, be harvested. Fog-harvesting systems generally consist of a vertical mesh, like an oversized tennis net. Research from MIT and Chile has increased the efficiency of the fog catcher 5-fold in a mild fog condition, making them far more practical and feasible. Three basic parameters for efficient harvesting of the tiny airborne droplets of fog are:

>>the size of the filaments in those nets,
>>the size of the holes between those filaments, and
>> the coating applied to the filaments.

The best performance comes from a mesh made of stainless-steel filaments about three or four times the thickness of a human hair, and with a spacing of about twice that between fibers. In addition, the mesh is dip-coated, using a solution that decreases a characteristic called contact-angle hysteresis. This allows small droplets to more easily slide down into the collecting gutter as soon as they form, before the wind blows them off the surface and back into the fog stream.

Chilean investigators have estimated that if just 4 percent of the water contained in the fog could be captured, that would be sufficient to meet all of the water needs of that nation's four northernmost regions, encompassing the entire Atacama Desert area. And with the MIT-designed system, 10 percent of the fog moisture in the air passing through the new fog collector system can potentially be captured.

Watch Film: Nets Turn Fog Into Drinking Water - Fog Harvesting Cloud Catchers All Over The World. Duration 2 min, https://www.youtube.com/watch?v=AQis6QlWDaQ

4.4 Solution for Flood Management

The arrival of monsoons is an annual event in India and most of the country receives a major portion of rainwater during the monsoon. Lack of preparedness and careful planning prevents us from making use of this precipitation to the maximum. Floods occur when stormwater/ runoff does not get sufficient staying time to percolate into the ground. The intensity and duration of rainfall, reduce tree cover and humus on the ground, steep slopes and poor terrain management together lead to flood-like conditions. Climate change is bound to bring about a change in precipitation patterns, which are beyond our control. However, the rest is well within human capability. The intention of flood control is to slow down the progress of water from higher elevations, allowing maximum percolation and a slow release into the river basin. This will ensure perennial flow of rivers, a mainstay for civilization. Watershed protection aims to protect, restore and enhance wetlands, streams, lakes and rivers.

4.5 Watershed Management

Watershed is defined as a geo-hydrological unit draining to a common point by a system of drains. A watershed consists of a catchment area, or basin and a system of drainage channels. Essentially every valley is a watershed. A watershed has three primary functions:

1 Capture atmospheric precipitation
2 Water infiltration and percolation
3 Release the water into springs that turn into rivers that lead to a lake or sea.

Fig 4.1 Contour bund

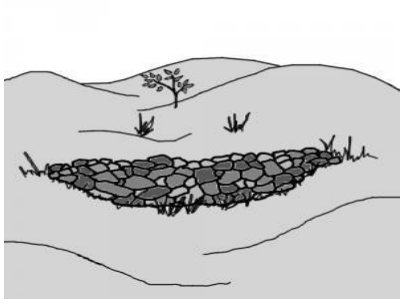


Fig 4.2 Gully Plugging with Boulders

Fig 4.3 Gully plugging with bamboo

(Watch film: What is Watershed Management:2min https://www.youtube.com/watch?v=KQEu9t5ZMVK)

Purpose of Watershed Management

- Water storage, flood control, checking sedimentation.
- Wild life preservation.
- Erosion control and prevention of soil degradation

- Conservation of soil and water.
- To meet agriculture needs.

A watershed should be managed as a single unit. To manage the water that precipitates into the watershed requires a few interventions:

A. Recognition Phase

1. Understand the geography of the valley: Identify uplands, riparian areas(vegetation along river streams), surface water channels and ground water.
2. Contour mapping using a theodolite. Size, slope, shape, drainage density, land use/land cover, geology and soils, and vegetation are important watershed characteristics that affect runoff. Analyze the problems.
3. Plan interventions, with alternatives. The shape of the watershed decides the concentration time. Fan shaped watersheds have faster flows than long, narrow ones.

Fig 4.4 Staggered Trenches

B. Restoration Phase

1. Select the best solution for each part of the watershed.
2. Build contour bunds- a trench and bund system, along each contour line- from ridge to the valley
3. Construct staggered trenches
4. Plug gullies with locally available material- stones or bamboo. Slow down water in gullies and streams.
5. Large check dams can be placed in wider gullies. They can have spillway drains for excess water drain-off to protect the checkdam from damage.
6. Plant a variety of fast growing shrubs and trees near the trenches.
7. Make small check dams to slow down the rivulets.
8. Apply the solution

C. Protection Phase

- Ensure normal function.
- Agricultural practices include ploughing across the slope to help rainwater infiltrate;
- Mulching to cover the soil and prevent evaporation;
- Organic compost- improves soil biota. Most importantly, grow agro-ecologically suitable crops
- Plant more trees on upper slopes and riparians to reduce soil erosion.

Fast growing nitrogen-fixing and multi-purpose tree, shrub and herb species so as to make the entire area a self-sustaining ecological system producing food, fruit, fibre, fertilizer and fuel wood.

D. Improvement phase

Watershed development can be achieved in less than two years. As the ecosystem evolves and gets more complex, it will produce a diversity of food, fodder for livestock and serve as a habitat for birds, reptiles and insects.

4.6 Urban Watershed Management

Certain cities like Bengaluru, Bhopal, Noida had proper urban planning that includes drainage channels and a series of ponds. Certain other cities are not planned well. In some cities the watershed plan is under threat of misuse or disuse. Bengaluru's ponds are being replaced by concrete. Governments

cannot control the inflow of population in cities. Unless solid waste management is tackled, the drainage system will keep getting blocked, causing floods in cities during the monsoon. Take Mumbai as an example, where floods occur mostly due to the rampant use of plastics that block up channels during heavy rains. Now the city is putting up a fight against plastics to control this man-made disaster. With Swachh Bharat (Urban) picking up pace, urban watersheds are expected to improve.

Hyderabad city is making an effort to revive its ponds to improve ground water recharge, beautify the city and clean the city. Infrastructure development without adequate planning is the greatest barrier in urban watershed management. It is commonplace to see high compound walls and raised ground height to prevent flood water from entering private property. This disturbs the natural flow of water. Flyovers cropping up across cities also collect water at their foot. Finally all the roads in the cities are turned into streams, causing much inconvenience to commuters and causing pot holes to develop on roads.It must be remembered that every portion of the watershed is equally important- from the ridge, through the catchment, the upper slopes and riparian regions till the water streams. With proper urban watershed management, every city can find solutions to water scarcity and floods.

1. Specific laws are needed mandating protection of natural areas within cities. Without these laws, protected areas turn into mere transit zones. One good example is the creation of three national parks within the city of Hyderabad- Kasu Brahmananda Reddy N.P., Mahaveer Harini Vanasthili N.P and Mrugavani N.P. Today these are the last bastions of wild spaces in the heart of the city. However, these were not demarcated as per watershed. If large sections of area are demarcated along the watershed within a city, it is easier to manage it.
2. Public parks and green spaces can restore water balance, but rarely they include habitat for native fish.
3. River Basin Compacts: We have laws for water-sharing across states, but we also need River Basin Compacts (like the Delaware River basin Compact in USA) to protect major river systems and their watersheds, and having water quality standards for interstate rivers. With proper watershed management, there will be sufficient, year-long water in the river for the states to share without disputes.
4. The watershed approach emphasizes all aspects of water quality, including chemical water quality (e.g., toxins and conventional pollutants), physical water quality (e.g., temperature, flow, and circulation), habitat quality (e.g., stream channel morphology, substrate composition, and riparian zone characteristics) and biological health and biodiversity (e.g., species abundance, diversity, and range).
5. Full-basin approach: Non-point sources of pollution across the watershed require comprehensive analysis and management. A whole basin approach to protect water quality has proved the most effective because it recognizes connected sub-basins.
6. Urban creeks- all the streams flowing through urban areas receive pollutants such as oily runoff from roads, raw sewage and sullage, garbage and toxic effluents- have a reduced water quality. Creating treatment zones using root-zone technology and bioremediation techniques while maintaining aesthetics, can clean up urban creeks while providing recreational spaces and urban beautification.

4.7 River Restoration

Nearly every city has been built along the banks of a river. Rivers were the lifeblood of civilization, from agriculture to transportation, commerce and state security; rivers supported the city in every way. Today the cities have grown and the rivers have shrunk to a mere shadow of their glorious selves. Encroachment, pollution, diversion of water and major hydro-modifications are the root causes of this.

River restoration, as well as lake restoration, is an integral part of sustainable water management. These are aimed at restoring the natural state and functioning of the river system in support of biodiversity, recreation, flood management and landscape development.

Several expensive efforts at river restoration have been made in the past, only to fail miserably. The reason was that they were infrastructure based. When planning improvements to rivers it is helpful to engage with people and organisations at a catchment level and work to improve the ecological health of the river system. The self-purification capacity of a river needs to be restored. It requires coordination between:

1. Nodal agencies (Government departments) for regulation, protection and conservation;
2. Citizens, groups, CBOs, NGOs, volunteers and environmental clubs;
3. Experts in science, Ecology, Engineering and Technology: Designers, green curators, planners.

River restoration refers to a large variety of ecological, physical, spatial and management measures and practices. The health of our waters will benefit from looking at the river and habitats, from source to sea. This is possible if all citizens and institutions understand and follow the Policies on Water.

1 Water Pollution (Prevention and Control) Act, 1974 and its amendments
2 Water Policy, 2012 and 2002
3 National Environmental policy, 2006
4 National Action Plan for Climate Change, 2008

Green Bridge System

Green bridges are horizontal eco-filtration systems that treat water pollution along the streams. Different physical and biological filters work in combination to remove suspended and dissolved impurities of water and also help in the restoration of ecological food chain. Green bridges are developed using fibrous material with stones. All the floatable and suspended solids are trapped in this biological bridge and the turbidity of flowing water is reduced. Green plants on the bridges increase the DO level in water, which in turn facilitates the growth of aerobic organisms, which degrade organic pollutants. SERI (Shrishti Eco-Research Institute), Pune has developed this technology and has received a patent for it. Green bridges can bring down eco-toxity and restore DO significantly (from 0 to 11 mg/L. Ahar River in Udaipur, MediKunta in Hyderabad, Rasoolabad in Allahabad and Buddha Nala in Ludhiana are examples of this eco-restoration.

(Watch Film: Green Bridges replacing STPs Duration 14 min https://www.youtube.com/watch?v=pJQMDGSe5UI)

Dissolved Oxygen in River Periyar nosedived after water flow was disrupted

Disrupting the flow of Periyar near Pathalam Bund for constructing the regulator led to fish kill in the area, according to officials. The Dissolved Oxygen (DO) content in the water plummeted following putrefaction of organic matter and disruption in water flow during the past three days. The DO level has gone down to 1mg/litre though it would require at least 4mg/litre for fishes to survive. Water has been stagnant in the area as the flow was cut off, according to officials of the Kerala State Pollution Control Board.

The above case occurs from time to time across several rivers. Every Fish kill event is not due to industrial pollution. Sometimes dams are responsible. That is the reason why, governments across the globe are contemplating dam removal.

Dam Removal

In the most extreme form of stress, free-flowing rivers no longer exist. Their restoration requires drastic measures like reduction in water withdrawal and removal of dams. Many countries are realizing that negative impacts of dams outweigh the positive. There has been a growing movement to remove dams where the costs – including environmental, safety, and socio-cultural impacts – outweigh the benefits – including hydropower, flood control, irrigation, or recreation – or where the dam no longer serves any useful purpose. The goal of removal can be multi-faceted, including restoring flows for fish and wildlife, reinstating the natural sediment and nutrient flow, eliminating safety risks, restoring opportunities for recreation, and saving taxpayer money. USA has removed 1,150 dams in the past 100 years. Over 5,000 small dams have been removed across Europe over the past 25 years.

Dam removal is expensive in the short term, but money is saved in the long term. There is danger of releasing the sometimes toxic sediments built up behind the dam wall. Sudden release of water can impact the river system immensely. But rivers are quick to restore themselves after dam removal. Flushing of sediments takes about 6 months, and the fishes return within a month or two. When dams are removed, it improves the river ecosystem, though it cannot be brought back to historic conditions. Dam removal restores natural riverine habitat in the lower stretches, eliminates siltation restores natural seasonal flow variations, eliminates unnatural temperature variations and allows fish to thrive. Flood control in the absence of the dam can be achieved by restoring wetlands, maintaining riparian buffers and other catchment level watershed management actions.

In India, we have 5,254 large dams in operation and another 447 are under construction. It is possible that like Australia, Japan, France, Spain and USA, India too could benefit from decommissioning a few old dams, thereby giving a new lease of life to parts of the rivers. In 2010 the Dam Safety Bill was also introduced by the Government of India at the national level, though it is yet to get the mandate of law. The objective of this Bill is to help develop uniform, countrywide procedures for ensuring the safety of dams. India has 164 dams that are more than 100 years old. We have had 36 dam failures in the past. If in the future, this comes true for India, there will be a need to eco-restore the river stream, adjoining banks, bio-remediate the silted empty reservoir bed (in case toxic pollutants are present).

4.8 Water Reclamation

Water Reclamation or recycling is to put use the treated water to non-potable uses. Over 85% of wastewater in Israel is treated for reuse, most of it in agricultural irrigation, making it the leading nation in water recycling. Australia, a water poor nation, uses technologies like ultra-filtration and reverse osmosis to treat grey water and storm water to potable quality. The costs are high, but the reclaimed water is used for drinking (potable) water, non-drinking uses in households, watering golf courses and recreational parks. Industrial uses such as washing and cooling in power stations and factories, agriculture, horticulture, forestry, pasture, flowers, viticulture and sugar cane growing, fire fighting, groundwater recharge, environmental flows and wetlands. Australia finds community attitude and social acceptance to recycled water a challenge, besides its financial cost. However, the benefits of direct potable reuse may include: Lower energy use, lower greenhouse gas emissions, lower capital and operational costs, and a more robust, climate-resilient water supply.

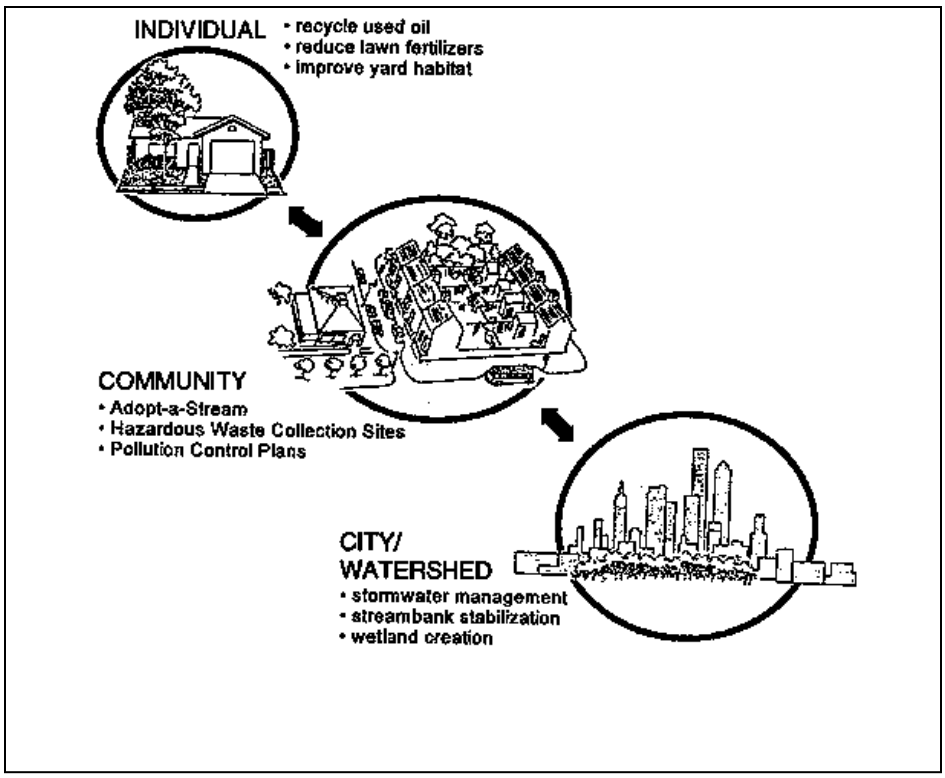


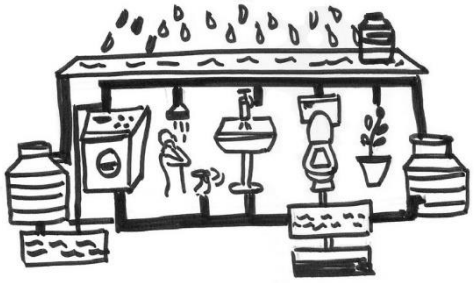
Fig 4.5 Responsibility to Prevent Water Pollution[4]

Watch following Films for more information:

1. (Watch Films Recycling water in Israel: 7 min: https://www.youtube.com/watch?v=u6YS1cUUn8Y
2. Rainwater harvesting:slide show presentation: https://www.slideshare.net/geosaibhaskar/rainwater-harvesting-walamtari-june121)

4.9 Individual Responsibility

- Practice rainwater harvesting
- Keep domestic wastewater separate from sewage. This will allow easier treatment and reuse.
- Switch to natural detergents such as soapnuts (reetha) to make your grey water cleaner.
- Everyone lives in a watershed. Take care of it.
- Plant a rain garden. Excess runoff can cause flooding and stream-bank erosion during rainstorms. Even native grasses, trees and shrubs are good to preserve the soil.



- Limit fertilizers, avoid pesticides.
- Service your septic system every three years.
- Pick up pet waste.
- Buffer streams: Use a buffer zone to protect water.
- Use commercial car washes.
- Avoid paving. Use stone pavers instead of concrete. Paving prevents percolation and destroys topsoil.

[4]Greenfield & LeCouteur, 1994

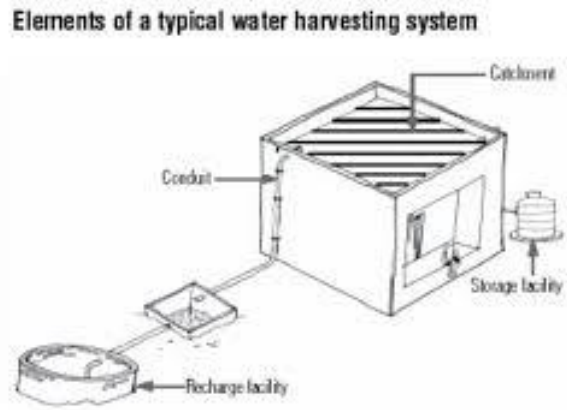
- Ensure that no fixture in your house is leaking. Whenever possible, get water-saving plumbing and toilets.
- 

Fig 4.6 – Elements of a Water Harvesting System

Avoid Detergents

Detergents contain surfactants (10-30%), builders (15% and other chemicals like fragrance. Phosphate, silicate, amide and sulphates of sodium are alarmingly high in sewage due to rampant use of detergents. Tetra Prolyne Derived Alkyl Benzene Sulphonate (TBPS) is a surfactant (produces foaming action) used in dishwash liquids and laundry detergents. It is a persistent pollutant, nearly impossible to degrade

All detergents have pH of 10, while aquatic animals prefer pH between 4 to 6. High pH sloughs off the skin of the fish, making their gills susceptible to infection and causing them to die. Using the indigenous soapnut berries (Ritha or Sapindus spp.) for laundry, and ash or tamarind/lemon rind based dishwashing bars are excellent alternative. Use of traditional coconut husk instead of synthetic scouring pads prevents the release of microplastics.

4.10 Community Responsibility

Clean Water Programme

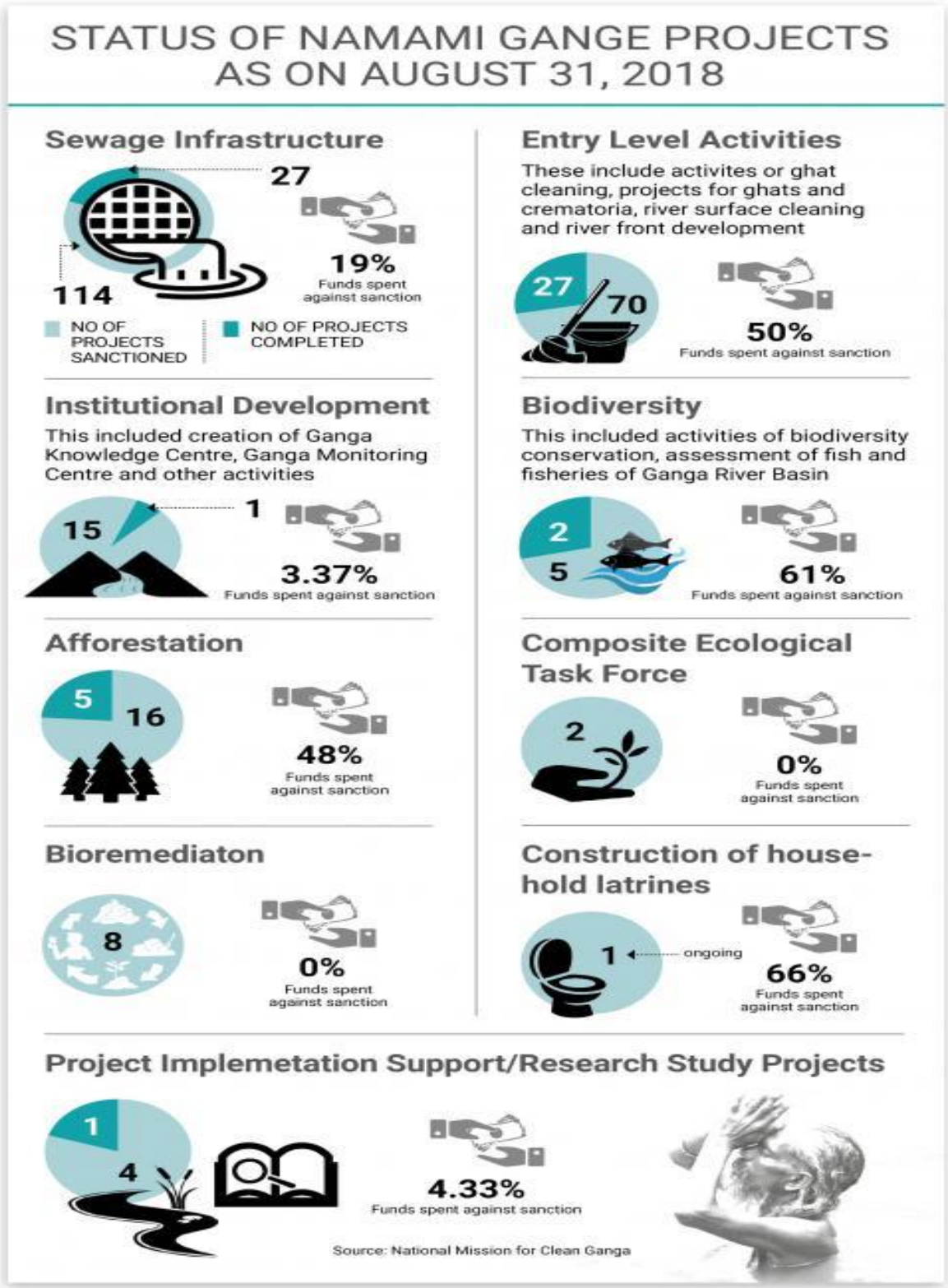
Urban runoff is the leading cause of water pollution. A Clean Water Programme is required to educate the public and businesses on how not to pollute their storm water. Storm water is the abnormal volume of surface water that runs off roads and land as a result of precipitation. Essentially, rainwater mixed with anything rain carries with it as it falls and what the water collects as it flows on the ground is called storm water. A clean water programme should essentially have the following components:

1. Watershed management
2. Municipal maintenance
3. Controls during new construction and development.
4. Monitoring of storm water drains
5. Illicit discharge control and industrial/ commercial inspection
6. Public information and participation
7. Special studies for specific pollutants
8. Judicious use of water

Namami Gange

Namami Gange Programme, an integrated conservation mission, was approved as the flagship programme by the government in June 2014 with a budget outlay of ₹20,000 crore to accomplish the twin objectives of effective abatement of pollution, conservation, and rejuvenation of the Ganga. Under the project, 8 states are covered. Department of Drinking Water Supply and Sanitation proposes to make 1,674 gram panchayats by the Ganga open defecation-free by 2022, at a cost of Rs 1,700 cr (central share).An estimated Rs 2,958 Crores (US$460 million) have been spent till July 2016 in various efforts in cleaning up of the river.The National Mission for Clean Ganga (NMCG) is the implementation wing of National Ganga Council which was set up in October 2016 under the River Ganga (Rejuvenation, Protection and Management) Authorities order 2016. The order dissolved National Ganga River Basin Authority. The aim is to clean the Ganga and its tributaries in a comprehensive manner.

Pollution in River Ganga



Source: nmcg.nic.in

Create Riparian Buffer Zones along Streams and Rivers

Communities should come together to create buffer zones along rivers and streams. Recent studies recommend 100 feet as the minimum buffer width to improve water quality, storm resiliency and wildlife habitat.

Riparian buffers protect the water body from the impacts of human activity. A healthy buffer improves stream health, biodiversity and water quality by:

- slowing runoff,
- filtering pollution,
- preventing soil erosion,
- contributing essential nutrients to the food chain through leaf litter,
- providing woody debris for in-stream habitat,
- shading the stream to keep waters cool,
- absorbing and slowing flood waters by the roots which hold stream banks.

Buffers are important for biodiversity because they provide

- shelter to urban fauna such as birds and small mammals,
- corridors for wildlife movement, helping overcome habitat fragmentation
- carbon from fallen wood branches return as energy source to the food chain.
- Cool waters for fish fingerlings.

A healthy buffer has many different species of native trees, shrubs and grasses and has minimal human disturbance. Stream buffers create space between the water and upland land uses. The wider the buffer, the more effectively it processes nutrients and slows sediments in runoff before they enter the stream.

An unhealthy buffer includes:

- inadequate buffer width.
- lack of vegetation or vegetation with shallow root systems
- presence of invasive plant species
- presence of grazing animals
- hardened shorelines
- impervious surfaces such as pavement

Communities can improve stream buffers by reducing lawn areas and pavement, and removing grazing animals and removing invasive species from streamside areas.

Hurdles in preparing riparian buffers could be:

- Farmers and urban communities reluctant to give away large tracts of land.
- Misuse of buffer areas for waste dumping.
- Pressure for reclamation of riparian buffers for use, such as parking space, river-view construction, gardens, etc.

It is important for the community to realize that a 30-150 ft buffer (depending on slope, soil type and vegetation mix) is effective in reducing surface and sub-surface nitrogen and other persistent pollutants. Even a 15ft riparian buffer removes subsurface nitrates by 80%, but not surface nitrates. This directly implies a safer source of drinking water for the entire community. Hence diverting land for riparian buffers is not acceptable and non-negotiable. However, the vegetation mix can be scientifically adjusted to earn some profits for the community. For instance by planting fruittrees, or harvesting green grass for domestic animals, etc.

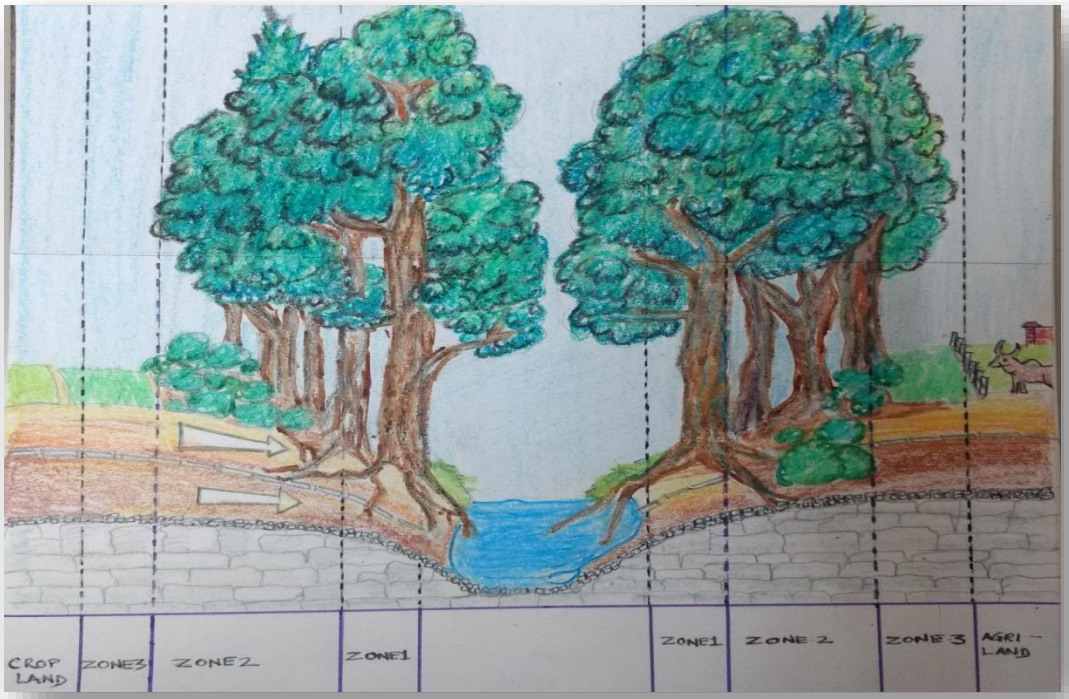


Fig 4.6 Zonation of a Riparian Buffer Source: Stroud Water Research Centre

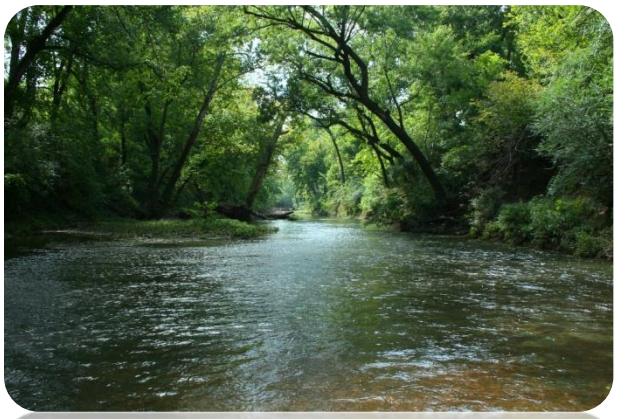


Fig: 4.7(B) Poor riparian buffer

Fig: 4.7(A) Healthy riparian buffer

Poor riparian buffers are created when the vegetation cover is removed, the terrain is ploughed, graded, structures are built and areas are paved. As a consequence, contaminants from roads, housing complexes, fertilizers from agricultural runoff, and animal waste starts polluting the stream and ground water.

Three-Zone Concept in Riparian buffers

Zone 1: Bank Stabiliser- Undisturbed Forest. The area closest to the stream or waterbody should be planted with native species of water-tolerant trees and large shrubs with little or no harvesting. This zone provides bank stabilization and provides leaf litter inputs to the stream. Leaf litter is eaten by macro invertebrates in the stream, which are in turn eaten by fish. When trees grow in Zone 1, they shade the stream, which cools the water and provides better conditions for cold water-dependent fish species. Thisis the narrowest of the three zones, and the least polluted. Ideally, Zone 1 should be at least 15 feet wide.

Zone 2: Managed Forest. The zone upland from Zone 1 should be planted with native faster growing, smaller, shade-tolerant tree or shrub species. This zone allows water runoff to be absorbed and held in the soil. Nutrients and other pollutants are also filtered by the soil. Faster growing plants are able to uptake and store nutrients in their woody biomass. Zone 2 can range from 20 to 60 feet in width.

Zone 3:Runoff Control The zone farthest from the stream and next to land use areas (for example, houses, crops or pastureland), should be planted with native grasses, wildflowers, or other herbaceous plants. These plants slow fast-moving water runoff and filter sediment. Zone 3 can range from 15 to 60 feet in width.

The total recommended width for all three zones is at least 100 feet. Riparian buffers that are at least 100 feet wide provide the minimum protection for water quality and stream protection. Wider buffers provide an even higher level of stream protection and provide better wildlife habitat. Diversity of plants in each zone is essential. Zones with a variety of plant species are more resilient to severe weather (drought or extreme storms), disturbance by deer or rodents, and invasive species or pests. Municipalities can enact local buffer ordinances to protect stream buffers from development. Conservation groups can purchase conservation easements to legally protect streams in perpetuity

(Watch Slide show presentation: https://www.slideshare.net/geosaibhaskar/rainwater-harvesting-walamtari-june121)

Avoid Pesticides

Gardening enthusiasts and farmers need to steer away from chemical fertilizers and pesticides. In agriculture sector, synthetic fertilizers and pesticides are a primary cause of polluted agricultural runoff. By choosing organic manure as fertilizers we provide soils with not only the 3 macro nutrients NPK, but also provide humus, microbes and encourage soil fauna, which improves the soil structure and humidity. As a result, runoff is less in volume and free of chemicals. Synthetic fertilizers improve crop yield but minimize protein content, thereby promoting mass malnutrition.

India uses 16 kg of fertilizers per hectare (figures of 1997). Phosphates cause algal blooms. Permissible nitrate levels in water are 45mg/l. In Rajasthan the nitrate level is 800mg/l. Excess nitrogen increases nitrates in water which causes methaeglobinanaemia (lack of oxygen, blue baby diseases) in the bloodstream due to nitrites that bond with haemoglobin. Nitrate poisoning has been reported in cattle feeding on nitrate rich soils.

The Environmental Working Group says that 70% of conventionally grown fruits and vegetables contain up to 230 different pesticides or their breakdown products. Strawberries and spinach contained the highest pesticide residues, followed by apples, grapes, peaches, cherries, pears, tomatoes, celery, potatoes and sweet bell peppers. 98% of peaches, cherries and apples contained at least one pesticide. (2018 report). Pesticides have a variety of effects on the human body. As given in the following table:

Pesticide	Effect
Aldrin	Toxic by inhalation, skin absorption (1-3 g)and ingestion , carcinogen
Acrylonitrile	Shallow respiration and convulsion
Bidrin	Highly toxic on inhalation or through skin
Binapacryl	Highly toxic fungicide. Causes acute vomiting, hypernoea
Carbaryl	Highly toxic insecticide
Chloradane	Stomach and contact poison that causes neurological disorders
Cryolite	2-3 ppm exposure causes mottling of teeth in mammals
Cyanide	Causes death by asphyxia and tissue oxidation.
Marcaptan	Offensive odour causes acute nausea
Malathion	Highly toxic rodenticide and insecticide. Acute skin irritation
Parathion	Absorption of over 12 mg is fatal.

--- Buy organic and locally grown fruits and vegetables.
--- Grow your own products.
--- Wash with Vinegar or soda: Wash fruits and vegetables before eating. Use 4:1 water: vinegar, or soak for 15 minutes in a tub of water with a dash of baking soda to remove pesticides on the surface of fruits and vegetables. The pesticides are broken down by upto 96%, but not totally removed.
--- Eat fruits and vegetables with low levels of pesticide residue: pineapples, mango, papaya, asparagus, brinjal, cantaloupe (musk melon), cauliflower, broccoli, cabbage, onions and sweet corn.
--- Use non-toxic methods for controlling insects in the home and garden, e.g. natural pest control. Pesticides are hard to remove from water without tertiary treatment, which is expensive and not always practiced. Use of neem oil, tobacco leaf tea, fresh (human or bovine) urine, and used coffee grounds (leftovers of filter coffee) are good alternatives for pest management. Nicotine sprays are a traditional remedy for a range of pests, including whiteflies, gnats, root and leaf aphids, thrips and leafminers. While commercial nicotine sprays are so potent that they can kill as many beneficial insects as plant predators, homemade "tobacco juice" is short-lived and much milder.

Build Self-reliance for Clean Drinking Water

As a community, we need to ensure a good source of clean drinking water. Solar disinfection (SODIS) is one such method for fighting water-borne diseases. The World Health Organisation (WHO), UNICEF, and the Red Cross recommend the SODIS method as a way to treat drinking water in developing countries. Solar disinfection (SODIS) was developed in the 1980s to inexpensively disinfect water used for oral rehydration solutions.

SODIS Method

Fill transparent bottles with low-turbidity water, shake them to oxygenate, close the lid and place the bottles on a roof or rack for 6 hours (if sunny) or 2 days (if cloudy). The combined effects of ultra-violet light (UV)-induced DNA damage, thermal inactivation, and photo-oxidative destruction inactivate disease-causing organisms. In the laboratory, SODIS has been proved to inactivate the viruses, bacteria, and protozoa that cause diarrheal diseases. Field data have also shown reductions of viruses, bacteria, and protozoa in water from developing countries treated with SODIS. In four randomized, controlled trials, SODIS has resulted in reductions in diarrheal disease incidences ranging from 9-86%.

Advantages

- Proven reduction of viruses, bacteria, and protozoa in water
- Proven reduction of diarrheal disease incidence
- Simplicity of use and acceptability
- No cost, if using recycled plastic bottles
- Minimal change in taste of the water
- Recontamination is low because water is served and stored in the small narrow necked bottles.

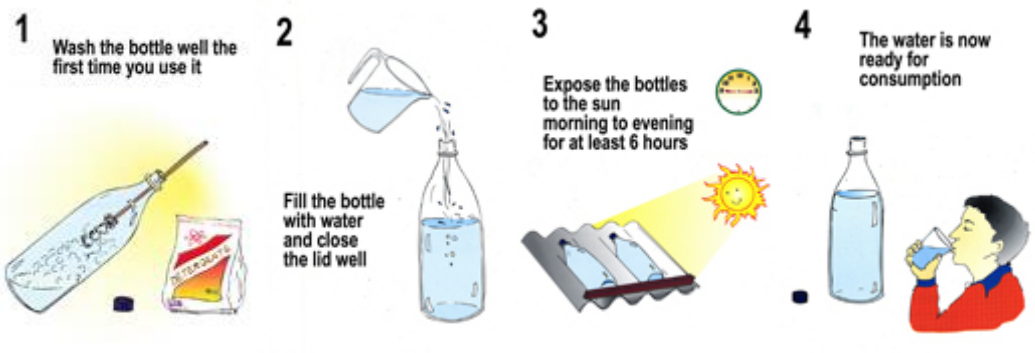


Fig 4.8 Steps in Solar Disinfection

Disadvantages

- Need to pre-treat water of higher turbidity with flocculation and/or filtration
- Limited volume of water that can be treated all at once
- Length of time required to treat water-6-48hrs
- Large supply of intact, clean, suitable plastic bottles required.

SODIS works well with PET bottles, certain types of glass, 19-L polycarbonate plastic water cooler containers and plastic pots which are popular in India. After treatment, the water is hot and has air bubbles on the inner surface of the bottle, indicating the water is ready for consumption.

PET Bottles **Water Cooler Containers** **Plastic Pots**

Fig 4.9 Different Containers for SODIS

Experiments on slightly- to heavily- scratched bottles show that bottle scratches do not influence the quality of SODIS disinfection, however the SODIS disinfection is greatly influenced by ambient temperature and bottle diameter.

PVC plastic can work for SODIS, but is to be avoided due to scope for leaching. To identify PVC bottles, observe a bluish gleam. This bluish hue is especially marked at the edges of a piece of bottle material that has been cut out. If PVC is burnt, the smell of the smoke is pungent, whereas the smell of PET is sweet. PET burns more easily than PVC.

Precautions for Glass: UV-A transmission is largely determined by the content of iron oxide in the glass. Ordinary window glass has thicknesses of 2 mm or more is practically opaque to UV-radiation. Certain specific glasses (Pyrex, Corex, Vycor, Quartz Glasses) transmit significantly more ultraviolet radiation than the ordinary window glass. However, for an appropriate technology like SODIS large scale utilization of these special glasses may not be very attractive due to their high costs and rare availability in the developing areas of the world. The advantage of glass is that no photoproducts are created, and it is heat resistant, but heavy, expensive and can be easily smashed.

Precautions with PET: PET is lightweight, relatively unbreakable, transparent, taste-neutral and chemically stable. However, they deform above 65 °C. There are ageing effects. Hence they should be replaced periodically. 19-L Polycarbonate water dispenser bottles: Advantage: large volumes of water can be disinfected at once. The lid is well sealed. Disadvantage: BPA is found in polycarbonate water bottles. It may leach into the drinking water, as it heats under the sun. Exposure to BPA has health effects on the brain, behavior and prostate gland of fetuses, infants and children. However, the Food and Drug Administration (FDA) has said that BPA is safe at the very low levels that occur in some foods. This assessment is based on review of hundreds of studies. This is still under research. Plastic Pots: In India, without the technical knowledge of SODIS, many village folk leave their water pots in the sunshine all day to achieve disinfection. The pots are convenient to carry and stack. They are made usually of recycled plastics, so leaching issues cannot be discounted.

Over 2 million people in 28 developing countries use SODIS for daily drinking water treatment. Community motivation and training for users should be given on how to correctly and consistently use SODIS for treating household drinking water. Experience has shown that SODIS is best promoted and

disseminated by local institutions with experience in community health education. Important partners are community-based organizations (CBOs) such as women's clubs, youth associations or self-help groups, well-established NGOs working on community development projects, institutional organizations such as health posts, hospitals, and teacher training centers, and government programs. Individuals, such as community and religious leaders as well as politicians and decision-makers, play a key role and should be involved from the beginning of a project. SODIS promotion in a new area usually begins with a pilot project of one year that reaches 2000-4000 families. A long-term training approach and repeated contact with the community is needed to create awareness on the importance of treating drinking water and to establish corresponding changes in behavior.

Case Study on Dangers of Using Plastic Water Tanks

Our entire effort towards providing clean water is jeopardized by storing the water in a plastic water tank or running water through PVC pipes.They are ubiquitous, cheap and convenient to use but they may be harming you in ways you did not anticipate. The plastic tanks and bottles available in the market today are mostly manufactured from Polyethylene (PE), Polypropylene (PP), Bisphenol (BPA), High Density Polyethylene (HDPE), Polyethylene Terephthalate (PET) and cross-linked Polyethylene (PEX), or Thermoplastic Polymer, which have very well-known health risks for end users.

PVC pipes

Experiments on freshly placed PVC pipes carrying fresh drinking water in housing give a smell of plastic in water for the first entire month of use! According to a study published in the Journal of Water and Health: "In three new PEX pipes, MTBE was detected in concentrations above the recommended US Environment Protection Agency taste and odour value for drinking water, but decreased below this value after five months in service." They further quote, "odour from some of these pipes could negatively affect drinking water for up to one year".

Plastic Tanks

Leaching occurs when plastic is exposed to UV rays, high temperature as well as from natural breakdown. When these plastic tanks are exposed to strong heat, especially in the long summer months when the mercury rises above 40^{o}C, the chemicals start to melt down and mix with water. These plastics are also known to alter the physical properties of water despite the manufacturer's claims that these alterations dissipate with time.

Research carried out by the Department of Public health, Government of Western Australia discovered that plastic tanks were causing copper poisoning due to the corroding of water pipes attached to these plastic tanks. Rainwater mixes with the drinking water in the tanks left open, and the naturally acidic rainwater then reacts with the copper pipes and that contaminated water moves into the drinking water taps in the households. This issue does not occur with cement tanks, as they leach out lime into the water which ultimately reduces the acidity and corrosion of pipes. Dissolved copper initiates gastric problems, and headaches and liver damage. Plastic tanks also affect the biological properties of water where different micro-organisms grow and multiply at a faster rate compared with clay or cement tanks.

PET Bottles

A recent report by the National Institute of Environmental Health Sciences, USA, states: "Polyethylene Terephthalate (PET) is widely used to make clear plastic bottles for bottled water and other beverages, condiments and cosmetics. There is concern that estrogenic chemicals such as phthalates may leach into the contents from bottles made from PET, although PET is not a phthalate derivative. The contents of the PET bottle, and the temperature at which it is stored, both appear to influence the rate and

magnitude of leaching. Endocrine disruptors other than phthalates, specifically antimony, may also contribute to the endocrine-disrupting effect of water from PET containers."

A study published in the journal, Food and Chemical Toxicology, reported that PET bottles used for beverages release potentially toxic compounds like Acetaldehyde, Dimethyl Terephthalate, Terephthalic acid. Empirical work on this theme by a group of chemists working at Salahaddin University, Kurdistan, Iraq noticed the release of carcinogenic compounds into mineral water (natural and carbonated) from Polyethylene Terephthalate (PET) bottles, which indicates a possible introduction of toxic compounds into drinking water. Moreover, sunlight and storage temperature were reported to affect the physicochemical properties of drinking water. Time of exposure and temperature are important factors for the leaching of PET into drinking water.

The dissolved chemicals, when ingested by people through drinking water, have many known effects on the human body. For instance, Bisphenol A severely affects the endocrine system and is also known to cause cancer, asthma, cardiac problems and reproductive system irregularities in women. These problems are more prevalent in infants and children than adults. Due to these problems developed countries have banned the use of plastic tanks for drinking water storage. Governments, health departments and environmental agencies need to initiate a proactive approach to raise awareness about the dangers of using plastic water tanks to ensure the provision of contamination-free drinking water to society.

Human engagement in Water Security and Solid Waste Management

Previously we have discussed Individual and community actions to be taken for solid waste management and water security.

For water security, we discussed that individuals need to:

- Harvest rain water
- Choose to dispose their wastewater separate from sewage.
- Choose to treat their sewage and wastewater as much as possible before disposal.
- Be responsible towards keeping their storm water drains free of debris and the surroundings unpolluted to ensure that rainwater does not get polluted on contact with the ground.
- Maintain humus and vegetative cover in their yards to encourage groundwater recharge
- Assist in maintaining the water conservation structures in the community
- Buy and use products after reading labels. Choose environmentally benign chemicals/ products only.
- Think long-term and buy durable products to reduce waste, reduce pollution and save money (vis-a –vis use-and throw goods that seems cheap at first but have a long-term environmental impact and are costlier to clean/dispose).
- Make waste reduction, waste segregation a habit.
- Be committed and involved in all community/ society level interventions in this regard. Maintaining self-reliance for water and waste management is a continuous process thatrequires deep human involvement.

Though logically and ethically correct, these are very difficult to implement on-ground. In general, in India, the citizens' dependence on Government intervention has incapacitated them to solve their localized problems, such as water deficiency, lack of public hygiene, etc.

Success stories in decentralized, self-governance do appear in media, but the struggle to achieve it may take years, if not decades. As professionals and PG Diploma holders in Environmental Hygiene, waste water and waste management, there are a few things you need to know about guiding individuals as well as communities to commit to the protection of the environment, particularly regarding waste management and water pollution.

1. Be a good salesman
2. Keep a futuristic approach
3. Repeat contact with community
4. Provide hand-holding support
5. Stage-gating/ mid—course correction
6. Conflict mitigation/ arbitration

There is also a variety of services you can choose to provide, for which you need to convince the individual/ community to invest in your idea of a clean environment or sustainable solutions.

- Education,
- Service portal,
- Connecting varied stakeholders
- Developing framework
- Job opportunities in water and waste water management technologies
- Financing institutions, Public- Private Partnerships and organizations.

Summary

Rainwater harvesting, watershed management and buffering river streams are all practices to ensure a continued supply of fresh water to communities and habitats. Avoiding pesticides, detergents and plastics can substantially reduce the burden of cleaning water. Water deficit nations- Australia and Israel- are pioneering in water reclamation. USA, Europe, and Japan are destroying old dams to allow free flow of rivers. Urban watersheds have been mostly destroyed. They can be developed with technological and ecological interventions and citizen support. When individuals and communities work for water restoration, a lot can be achieved.

Self Assessment Questions

1. Name a few traditional water conservation strategies. Mention the region they belong to.
2. How can a rainwater harvesting system be put for your own residence?
3. What could be the effects of destroying a medium sized dam? Analyse from Environmental Hygiene, Solid Waste and Water resources perspective.
4. Group Assignment: Study the physical map of your city/ town. Identify the different watersheds. What kind of interventions can you suggest for improving the urban watershed?

Text Book

B.K. Sharma, Water Pollution, 2005 Goel Publishing House, Meerut.
https://www.biologicalwasteexpert.com/blog

Films

1. Revival of AharPyne in Palamu District, Jharkhand Duration 12 min https://vimeo.com/229569089
2. What is Watershed Management: Duration 2min. https://www.youtube.com/watch?v=KQEu9t5ZMVk
3. Hiware Bazar: Duration 13 min, Hindi, https://www.youtube.com/watch?v=CwCX0JKgl7U&t=683s
4. Michael Pritchard: How to make filthy water drinkable, Duration 7 min,https://www.youtube.com/watch?v=rXepkIWPhFQ
5. Green Bridges replacing STPs Duration 14 min https://www.youtube.com/watch?v=pJQMDGSe5UI
6. Recycling water in Israel: 7 min: https://www.youtube.com/watch?v=u6YS1cUUn8Y
7. Rainwater harvesting: slide show presentation: https://www.slideshare.net/geosaibhaskar/rainwater-harvesting-walamtari-june121)

Chapter 5

Testing of Water, Waste Water, Soil and Solid Waste

Objectives

- To know the importance of monitoring water quality
- To know sampling techniques
- To learn laboratory techniques of water quality analysis

Structure

5.1 Importance of Water Monitoring
5.2 Water sampling techniques
5.3 Water analysis parameters and methodology
5.4 Microbiological Analysis
5.5 Soil Testing
5.6 Toxicity Characteristic Leaching Procedure (TCLP)

To Do Activities

- Focus on sampling techniques, with field work.
- Learn about issues of safety, preventing sample contamination, proper documentation and storing samples - essential knowledge for students, even if they do not conduct lab experiments themselves.
- Conduct the practicals. Students must observe the techniques and jointly conduct the experiments, so that they gain confidence around lab equipment.
- Show all videos of the experiments before practicals.
- If students are of science background, they must collect water samples and soil samples in the specified manner and conduct all laboratory experiments systematically. They should compare their results with the acceptable norms and present their conclusions.
- Emphasize on the value of scientific documentation to validate observations and quantify the effects of any intervention.
- Collect samples from fresh water bodies, from a lake and from a river, using the sampling methods explained.
- Conduct all experiments to check the physical and chemical qualities of water. Is the water of good quality or polluted?

"A ruined planet cannot sustain human lives in good health. A healthy planet and healthy people are two sides of the same coin."

– Dr. Margaret Chan, ex ED of the World Health Organization

5.1 Importance of Water Monitoring

Experts believe that environment pollution is 5 times more hazardous than climate change. If ignored, it can result in extinction of humans in 100-150 years. There are1.44 lakh hazardous chemicals listed by the European Chemicals Agency. Around 2000 new chemicals are added to this list every year.

It is not possible to test the presence of these many chemicals in water to certify it clean or dirty. There are a few standard tests that assess the pollution level in water. Water is a universal solvent, and the basis of life on Earth. Interaction with a variety of substances change the quality of water, including its temperature, pH, dissolved oxygen, total dissolved solids, and total suspended solids. Clay, silt, humus contribute to suspended solids in water, which is responsible for turbidity.

Importance of monitoring BOD, COD, DO

Three important terms one comes across when discussing waste water treatment and water pollution are DO, COD and BOD. DO is the dissolved oxygen present in water, also known as total oxygen content TOC. DO is higher at cooler temperatures and it escapes when the water is heated. COD is the chemical oxygen demand of water. It refers to the amount of dissolved oxygen required to oxidize all the chemicals in the water. BOD stands for biological oxygen demand, which is the amount of dissolved oxygen required by microbes to consume/ break down the organic matter present in the water. DO or TOC in water should always be higher than COD to **ensure the survival of aquatic animals**. On most occasions the student will take assistance from an analytical laboratory to study the water samples. It is important to sample properly in order to get unbiased results. The following text will guide you through the process.

5.2 Water Sampling techniques

(Watch Film on Sampling Wastewater at a Wastewater Treatment Facility 1993 EPA Training Film**,** Duration 23 min https://www.youtube.com/watch?v=MaiWU1kL2wU)

Tips to Avoid Sample Contamination

1. Plan the order in which sample will be collected by doing a reconnaissance survey.
2. Sample the cleanest site first- pristine environment, low turbidity, upstream from known/ suspected source of contamination.
3. Use clean hands/ dirty hands technique.
4. Collect field blank and equipment blanks to trace back contaminants, if any.
5. Record potential sources of pollution at each site.
6. Wear powder-free, disposable gloves, change them before each step of sample collection.
7. Use equipment and collection bottles cleaned as per proper procedure.
8. Collect sufficient number of samples, in the prescribed order.

Clean Sampling Procedure

This is especially important for detecting substances in low concentrations 100 µ g/L
Use equipment made of non-contaminating material, cleaned rigorously before fieldwork, and between sampling.

1. Clean Hand/ Dirty Hand (CH/DH): Field teams are trained and practiced so that only one person (CH) makes direct contact with samples. The other partner (DH) does the job that can potentially contaminate the sample during sampling. This is essential especially for trace element detection 1µg/L and for iron, aluminium, and manganese 200 µg/L.
2. Rinse your clean sampling bottles first with the sampling water from source. Then fill them up with water.
3. If testing ground water, minimize disturbance to the bottom sediments. If using pump sampler, run water continuously to achieve volume equivalent to 3 samples.
4. If the water is contaminated with toxic levels of chemicals, then the purge water should be disposed as per regulations, so as not to contaminate clean areas.

Avoid exchange of atmospheric gases: Samples for DO, and other gas related samples must not be exposed to air for long. Ground water DO is much lesser than surface water. Exposure to oxygen can cause precipitation of iron, which will then show up much less in the experiments.

STEP 1 Prepare for Sampling: Use glass/ fluorocarbon plastic for organic compounds. For inorganic compounds avoid rubber and metal. For microbial analysis and BOD, prepare bottles as suggested (later in text). Keep safety equipment (parking cones, gloves, helmets, eye protection etc) ready. Set up a clean work station. Keep equipment ready.

STEP 2 Select Sampling Location: Measure discharge at the cross section, locate centroids.

1. Maintain safety of personnel.
2. Minimize bias in sampling.
3. Study nature of stream flow.

4. Study objective, including data quality requirements.
5. Review requirement of equipment blanks, field blanks, concurrent samples.
6. A representative sample should include all elements from a cross section of flowing water.
7. Isokinetic, depth-integrated, discharge-weighted sample is standard procedure.- EDI/ EWI
8. Site characteristics, sampling-equipment limitations, or study objectives may constrain how a sample is collected.
9. Equal-width increment method: Divide the cross-section into a number of equal – width increments. Collect samples by lowering and raising a sampler through the water column. Do not pause on touching the steam bed.
10. Equal- discharge increment method: Each EDI is 20% of the stream width. EDI graphs require periodic verification.

STEP 3 Collect Samples

a. Dip Sampling: Dip a narrow-mouthed bottle into the water. Avoid collecting particulates. Stand downstream, keep your hand downstream. Use a weighted bottle if the water is too deep for wading.
b. Discrete sampling: Point sampling for still water. Lower the sample to a particular depth with a weighted bottle. Then, open and close the bottle. This can be done at selected depths along a cross section.
c. Isokinetic point sampling: EDI/EWI.
d. Pump sampling: suction lift or submersible pump or a portable pump bring up the water.

If sample compositing or splitting is required, ensure all particulates in the sampler are transferred, with gently swirling and quick pouring. Note the date, time, weather condition, etc at the time of sampling. Note any abnormality- unnatural colour of discharge, fish kill, etc. Blind samples can also be selected. A blind sample is designed to find out the bias and variability introduced in a laboratory or among laboratories during procedures.

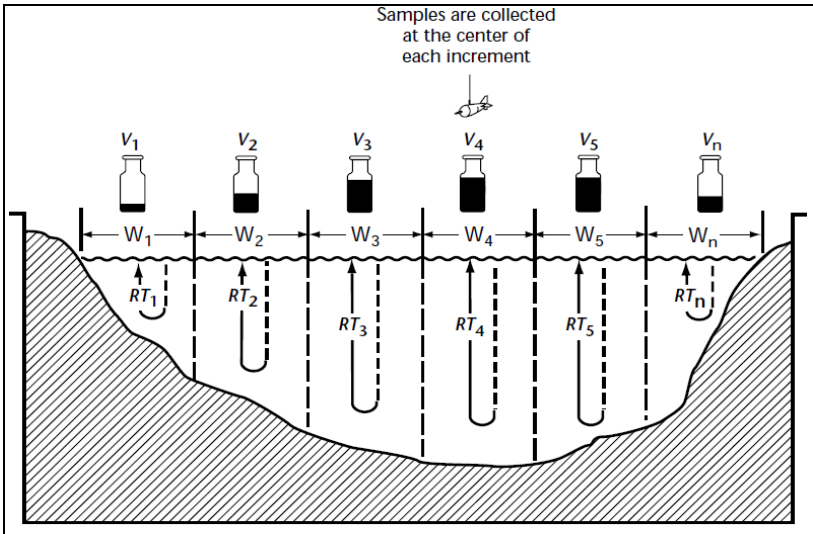
Sampling flowing water: EWI/ EDI

Isokinetic sampling: A sample collected in such a way that the water-sediment mixture moves with no change in velocity as it leaves the ambient flow and enters the sampler intake. Equal-width-increment (EWI) and equal-discharge increment (EDI) sample-collection methods are specifically designed to result in the collection of discharge-weighted, depth-integrated, isokinetic samples. When either method is used properly, the resulting samples contain the same property concentrations.

If the cross-sectional width is ≥ 5 ft, use a minimum of 10 equal width increments. If cross-sectional width is < 5 ft, use as many increments as practical, but keep minimum 3 inches apart. The descending and ascending transit rate should be constant in each direction. Don't exceed max allowable transit rate.

Sampling Still-Water

For pond, reservoir, storage pools, etc the water quality characteristics are different in various areas, as there are no currents and the water does not mix. A number of sampling sites around the water body, and a few in the middle of it need to be selected. Samples must be collected at a known depth. Maintain sample integrity as it is brought up. A bottle attached to a weighted rope marked with knots to measure a constant depth and a thief-type sampler whose cap can be opened and shut remotely is required.



Equal-width-increment (EWI)

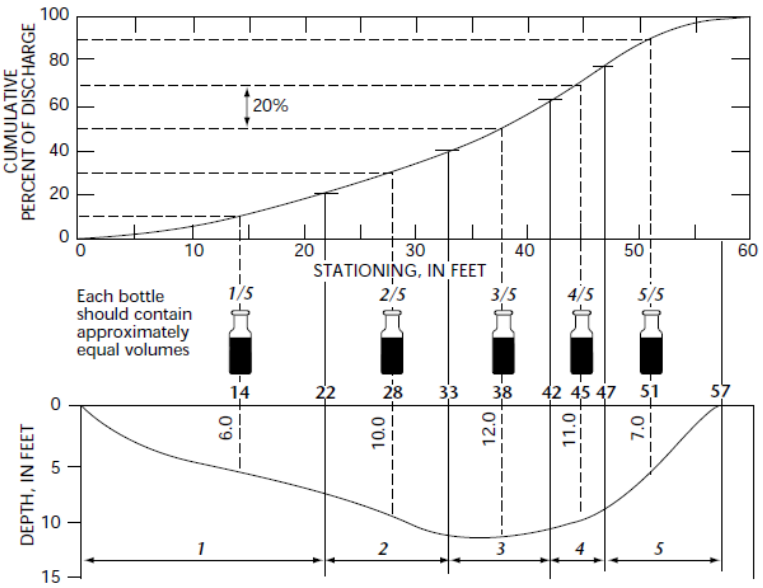
Where:

RT: Equal transit rate at each sampling vertical.

W : Equal width for each increment

V: Volume collected is proportional to discharge at each increment.

Sampling vertical: the vertical transit rate relative to sample volume that is proportional to the stream discharge of each increment.



Equal-discharge-increment (EWI)

Variable dept, variable transit rate.

Sampling verticals: 20% of flow per section.

Fig 5.1How to sample with Equal-width-increment (EWI) and Equal-discharge-increment (EWI)[5]

[5]EWI: Edwards and Glysson, 1998; EDI: Bruce Ringer, US Geological Survey, 1978

Non-Isokenic Methods

When the streams are too fast, too slow, automatic pumping samplers are needed, extreme cold temperatures where nozzle freezes the non-isokenic method is used. Non-isokenic method is used for still waters too.

A. **Dip Sampling**: Dipping a narrow mouthed bottle into a water body. Stand downstream, keep hand downstream when holding bottle. If the water body is too deep, lower a weighted bottle sampler.
B. **Discrete Sampling**: Choose a range of sampling sites, and collect a number of discrete samples, so that an unbiased estimate of mean concentration can be arrived at.

Remember, sampling near a bridge or pier could artificially increase sediments, due to eddy currents. If the eddy comes in the cross section to be sampled, treat it as a solid obstruction; subtract the eddy width from the cross section and determine width of increments accordingly.

Sampling Groundwater

Well type and well construction must be noted. Be aware of the factors that can affect water quality. Prevent contamination.

Well Types

- Supply well: For domestic, public, industry, commercial, irrigation use. Pumps deliver a large volume of water. This water is sub-sampled. Avoid sampling from a holding tank or chemical treatment system.
- Monitoring wells: These are for data collection and monitoring. The pumps are small- portable, low capacity.

Well Construction

After taking water sample, check the integrity of the well. Check depth of water to well bottom. If there are too many particulates, a bias could occur in the readings. The well should be re-developed or purged until the turbidity returns to near- background levels. Write down the static water level in the well before sampling. The initial water column height should be 4 ft more than the length of the sampling device.

Check for hazardous conditions, e.g. toxic fumes, before sampling. Do not stir up the water while sampling. Bailing or other dipping devices are not recommended for heavy metals or VOCs (volatile organic compounds). Use CH/DH method for well water sampling too. If using a pump to fill samples, the rate of flow should be 500mL/min for 250+ mL bottles, 150 mL/min for 40 mL vials.
Do not churn the water when making composite samples. Do it in an enclosed or protected space to prevent gassing or degassing of the sample.

STEP 4 Processing of Samples

Readymade water testing kits are available, and can also be assembled for field survey.

STEP5 Clean Equipments

Rinse sampling equipment with deionozed water before it dries. Clean equipment between samplings. Collect field blanks after cleaning and before re-use. Equipment blank is needed at least annually. Collect blanks for quality control (QC) on the same day as sampling.

5.3 Water Analysis Parameters

Testing of water to find its physical, chemical and biological characteristics is part of processing of sample. This also includes adding certain chemicals to 'fix' oxygen, storing the sample in a safe manner to prevent degradation. The following aspects are studied as part of water analysis:

Physical Characteristics: Colour, turbidity, total solids, dissolved solids, suspended solids, odour and taste are recorded as the physical characteristics of water.

Colour

It indicates the presence of minerals such as iron, copper and manganese or substances of vegetable origin such as algae and weeds. Colour tests indicate the efficacy of the water treatment system. Colour in water can be measured by eye, by comparing a sample to a series of slides or tubes of various hues. It is cumbersome and not suitable for certain types of contamination. Sophisticated colour measurement equipment e.g. MD 100 Photometer are equipped with high-quality interference filters. They are compact, portable and safe. They use LEDs as a light source to test water in a transparent sample chamber. They can also store comprehensive date of past results for ease of recall.

Turbidity or Total Suspended Solids

Turbidity in water is because of suspended solids and colloidal matter. It may be due to eroded soil caused by dredging or due to the growth of micro-organisms. High turbidity makes filtration expensive. If sewage solids are present, pathogens may be encased in the particles and escape the action of chlorine during disinfection. Water clarity methods involve a secchi disc or tube. They are often quick and inexpensive, but are only as accurate as the person using them. Turbidity meters use nephelometry (90 degree scattering).

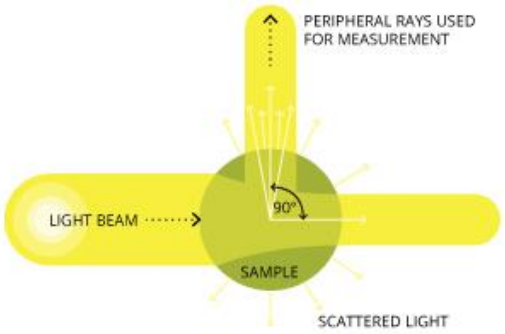


Fig 5.2 Working of a Turbidity Meter

Turbidity sensors can be placed directly in the water source. Total suspended solids (TSS) are the main cause of turbidity. The most common, and accurate, method of measuring suspended solids is by weight. To measure TSS, a water sample is filtered, dried, and weighed.

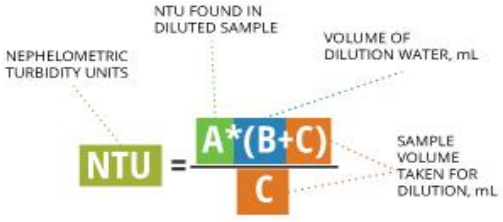


Fig 5.2Formula for Nephelometric Turbidity Unit

This method is the most accurate technique for measuring total suspended solids, however it is also more difficult and time-consuming. Clear water is not always healthy, and likewise turbid water does not necessarily indicate an issue. Turbidity data must always be taken in context.

Water Temperature

Measuring temperature is very important because it allows scientists to better understand other measurements. Investigation such as dissolved oxygen, pH and conductivity Warmer water tends to have lower levels of dissolved oxygen. Warm water can be fatal for sensitive species, such as trout or salmon, which require cold, oxygen-rich conditions.

Water temperature is checked immediately after transparency. An alcohol-filled thermometer or a temperature probe is used for the purpose. Dip the thermometer to the depth of 10 cm for 3 minutes. Calculate the average of three samples for accuracy.

Odour and Taste

Odour and taste are associated with the presence of living microscopic organisms; or decaying organic matter including weeds, algae; or industrial wastes containing ammonia, phenols, halogens, hydrocarbons. This taste is imparted to fish, rendering them unpalatable. While chlorination dilutes odour and taste caused by some contaminants, it generates a foul odour itself when added to waters polluted with detergents, algae and some other wastes.

Odour and Taste are tested by organileptic tests, by a person actually smelling or tasting the water.

Salinity/ Total Dissolved Solids

TDS are minerals, salts, metals, cations or anions dissolved in water. Total dissolved solids (TDS) comprise inorganic salts (principally calcium, magnesium, potassium, sodium, bicarbonates, chlorides, and sulfates) and some small amounts of organic matter that are dissolved in water. TDS gives water its particular taste.

Specific Conductance/ Electric Conductivity of water measures total dissolved salts. In other words, it measures salinity**.**TDS is checked by an Electric Conductivity Meter. Water sample is poured in a clean, sterilized, dust-free beaker. A probe of an electric conductivity meter is dipped in the beaker and an electric current is passed. Resistance is measured. Wait till the reading stabilizes. The purity of water is measured in micro-Siemens (µS). Pure distilled water has 0 µS.

TDS= KE x EC. Where TDS is in mg/L, KE is the correlation factor and EC is the conductivity in µS.KE varies between 0.55 and 0.8.

High quality deionized water has a conductivity of about µS/m at 25 °C, typical drinking water in the range of 5–50 mS/m, while sea water about 5 S/m (or 50,000 µS/cm) (i.e. sea water's conductivity is one million times higher than that of deionized water).Digital TDS meters are available for ease of testing. As per Bureau of Indian Standards (BIS), the limit for TDS in potable water is 500 mg/L and hardness for calcium and magnesium is 200 mg/L. An RO Purifier company suggests:

Table 5.1 Expressing Quality of Drinking Water in Terms of TDS

Water Quality Rating	Level of TDS parts per million (ppm)
Excellent (For everyone)	Between 50 – 150
Good (for athletes)	150 – 250
Fair (Might be bad for kidneys)	250 – 300
Poor (Might be very bad for kidneys)	300 – 500
Unacceptable	Above 1,200

For an average person, a TDS of 250 to 500 ppm is good in drinking water; with an ideal TDS of 350ppm.Water upto 1000 TDS is also safe for use. However, RO purified mineral waters are de-mineralized with a TDS of less than 100ppm. Such water is aggressive and tends to encourage leaching from plastic bottles. Low TDS water is also considered less healthy by some as it cannot provide the body with trace elements that are essential for proper health. Low TDS water may be a necessity in many industrial processes.

Table 5.2Expressing Quality of Water in the Environment in Terms of TDS

CATEGORY	Level of TDS parts per million (ppm)
Fresh water	500
Brackish water	500 - 30,000
Saline water	30,000 - 50,000
Hypersaline	40,000

Chemical Characteristics

pH, hardness, presence of a selected group of chemical parameters, biocides, highly toxic chemicals, and BOD are estimated.

pH

pH is a measure of hydrogen ion concentration. pH is equal to −log10 c, where c is the hydrogen ion concentration in moles per litre. It is an indicator of relative acidity or alkalinity of water. Values of 9.5 and above indicate high alkalinity while values of 3 and below indicate acidity. Low pH values help in effective chlorination but cause problems with corrosion. Values below 4 generally do not support living organisms in the marine environment. Drinking water should have a pH between 6.5 and 8.5. pH testing meter and pH paper strips are most commonly used. pH test paper tells the exact pH, while litmus paper just tells us of the sample is acidic or alkaline. It is best to check pH on site at the time of sampling.

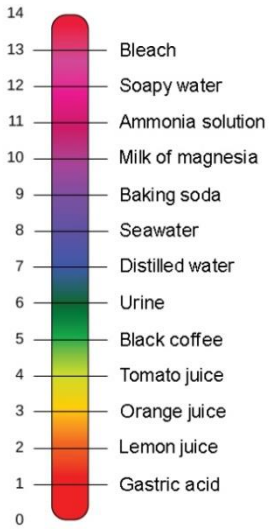


Fig 5.3 Expressing different fluids on the pH scale

Hardness

"Hard water", refers to specific minerals that consume soap and cause scaling in water heaters and boilers. More the minerals, harder is the water. Soft water refers to the absence of these minerals. The minerals that precipitate with soap are polyvalent cations such as calcium, magnesium, iron, manganese, and zinc. The concentration of calcium and magnesium in natural waters generally far exceeds that of any other polyvalent cation. Therefore, hardness is generally considered to be the concentration of calcium and magnesium in water. Water hardness is most commonly measured by titration with an EDTA

(ethylene diamine tetra acetic acid) solution. A titration involves adding small amounts of a solution to a water sample until the sample changes color. Hard water test kits are available. Calcium hardness can also be measured separately from magnesium hardness by adjusting the pH and using different indicators.

Dissolved Oxygen

DO or Total Oxygen Content (TOC) in the water, is critical for the water's ability to support life. Therefore it is an indicator of the health of the ecosystem. Modern techniques for measuring dissolved oxygen concentrations involve either an electrochemical or optical sensor. The dissolved oxygen sensor is attached to a meter for spot sampling and laboratory applications or to a data logger, process monitor or transmitter.

Winkler (or iodometric) Method of Titration: The traditional method of titration is the Winkler Method. The Winkler method now exists in seven modified versions which are still used today. Dissolved oxygen can escape or get used up in the time between sample collection and the tests in laboratory. Addition of more oxygen later may also skew results. Hence, it needs to be immediately 'fixed' at the time of sampling.(Watch Film 2 The Winkler Method. Duration 6 min. https://youtu.be/FKdzbgHaQQM)

While this method was considered the most accurate and precise for many years, it is also subject to human error and is more difficult to execute than the other methods, particularly in the field.

Optical Dissolved Oxygen Sensors: Optical dissolved oxygen sensors measure the interaction between oxygen and certain luminescent dyes. When exposed to blue light, these dyes become excited (electrons gaining energy) and emit light as the electrons return to their normal energy state.When dissolved oxygen is present, the returned wavelengths are limited or altered due to oxygen molecules interacting with the dye. The measured effect is inversely proportional to the partial pressure of oxygen.Optical DO sensors are ideal for long-term monitoring programs due to their minimal maintenance requirements. They can hold a calibration for several months and exhibit little (if any) calibration drift. These dissolved oxygen sensors also do not require any warm-up time or stirring when taking a measurement.

Electrochemical DO sensors: Galvanic and polarographic sensors use two polarized electrodes, an anode and a cathode, in an electrolyte solution. The electrodes and electrolyte solution are isolated from the sample by a thin, semi-permeable membrane. The DO diffuses across the membrane at proportional rate to its pressure in water. It is then consumed by the cathode. The electric current thus produced gives us a reading.

Biological Oxygen Demand (BOD)

BOD denotes the amount of oxygen needed by micro-organisms for stabilization of decomposable organic matter under aerobic conditions. High BOD means that, there is less of oxygen to support life and indicates organic pollution.

Water Sampling for DO/ BOD: Biochemical Oxygen Demand (BOD) is the amount of dissolved oxygen needed by aerobic biological organisms to break down organic material present in a given water sample at certain temperature over a specific time period. Biological oxygen demand is a 5-day biochemical assay procedure that measures the oxygen consumed by bacterial from a decomposition of organic matter. It is essential to have an accurate measurement of dissolved oxygen to accurately determine BOD.BOD results represent approximate freshwater oxygen demands, because

ambient stream conditions like temperature, sunlight, water movement and populations cannot be replicated in the laboratory.

Sample Collection for BOD: In flowing water, bacteria are suspended spacially and temporally, meaning, at different times they may be present in different zones in the water. It is important to get a good representative sample.

Sample storage for BOD: Samples should be promptly analysed (within 2 hours of collection). If not, they should be stored at 1-4^{o}C (chilled but not frozen) to prevent sample degradation, for no more than 24 hours. They must be analysed within 24 hours. Remove from fridge, allow reaching 20^{o}C, then analyse. The decomposition test has two phases:
Stage 1: Carbonaceous phase- Where dissolved oxygen is converted to CO_2 and
Stage 2: Nitrogenous phase: Organic nitrogen, ammonia, and nitrite are converted to nitrate.

Nitrogenous oxygen naturally occurs after 6 days. For some sewage where nitrites, ammonia, and nitrifying bacteria are present, nitrification can occur much before day 6. If the intent is only to measure carbonaceous BOD only, a chemical that prevents nitrification should be added. The result will then be $CBOD_5$ (carbonaceous BOD).

Equipment
Equipment for BOD sampling should be washed with 0.2% non-phosphate detergent, rinsed with tap water and rinsed 3-5 times with deionized water.

1. Constant- temperature chamber- thermostatically controlled to maintain 20+- 1^{o}C, kept in total darkness (to prevent photosynthetic DO from being formed).
2. Aquarium pump, plastic air tubing, air diffusion stones, washed as above.
3. BOD bottles – 300 ml, ground glass stoppered, Labelled for sample identification. Washed as above.
4. Glass beads: borosilicate beads, solid, spherical, 5mm. Washed as above.
5. Graduated Cylinder: Borosilicate, 50 to 250 ml.
6. Overcap: Aluminium foil/ paper/ plastic cup to prevent evaporation from the BOD bottle stoppers.
7. Pipet: 1-50 ml, bacteriological, large bore.
8. Thermometer: 5-40oC, with 0.5oC graduations.
9. Sample containers: 1 L, (Polyethylene/ polypropylene/borosilicate glass) wide mouthed, screw top lids.
10. Waste Disposal container: capped, and of appropriate material to carry sample and chemical waste.

Reagents

1. Calcium Chloride (CaCl2)Solution: 27.5 g CaCl2 in de-ionized water, diluted to 1 L.
2. Dilution water: high quality deionized water, free from toxic chlorine or toxic metals.
3. Ferric Chloride ($FeCl_3$) solution: 0.25 g $FeCe_3.6H_2O$ in de-ionized water, diluted to 1 L.
4. Magnesium sulphate ($MgSO_4$) solution: 22.5 g $MgSO_4.7H_2O$ in de-ionized water, diluted to 1 L.
5. Phosphate buffer solution: 8.5 g of KH_2PO_4, 33.4 g of $Na_2HPO_4.7H_2O$ and 1.7 g of NH_4Cl in de-ionized water, diluted to 1 L.

Reagents for Pre-treatment

1. Sodium Hydroxide (NaOH): 40g NaOH in 900 ml de-ionized water, diluted to 1 L. Store in plastic container. For pre-treatment of acidity.
2. Sodium Sulphite(Na_2SO_3) : Dissolve 1.575g of Na_2SO_3 in 1L de-ionized water.
3. Sulphuric Acid ($H_2 SO_4$): Slowly mix 28 mL conc. $H_2 SO_4$ (stir while adding) to 900 ml de-ionized water, diluted to 1 L. For pre-treatment of alkalinity.

Method

Fill a 60 ml DO bottle with the water sample slowly submerge the DO bottle in water, tilting it to a 45° angle. Water should slowly flow in. Fill it to the brim, release any trapped air towards the top and cap the bottle. Oxygen fixing requires Manganese Sulphate and alkaline Potassium Iodide Azide. Add 8 drops each of Manganese Sulphate and alkaline Potassium Iodide Azide. The water is likely to overflow, as the bottle was filled to the top. Cap the bottle and shake it thoroughly. Manganese hydroxide, a white precipitant is formed.

The standard oxidation (or incubation) period is 5 days at 20°C. BOD_5 indicates the effect of sewage and other organic wastes on DO in surface waters. But it has limited value. Analyses of COD, fecal bacteria and nutrients are needed to aid the interpretation of BOD_5. Place a magnet inside the dark BOD bottle. This magnet will be agitated when kept on a magnetized plate and keep the mixture stirred. Make an estimation of the expected range of the sample. Measure volume as per chart provided.

Table 5.3 Selection of Sample Volume Based on the Estimated BOD range

Estimated range mg /L	Factor	Sample Volume (mL)
0-4000	100	22.7
0-2000	50	43.5
0-800	20	97
0-400	10	164
0-200	5	250
0-80	2	365
0-40	1	432

Use a funnel to pour. Get three different volumes for each sample. Add nitrification inhibitor. Add NaOH to the plastic enclosure in the manometric cap. Firmly close the bottle to maintain an airtight environment. Reset the manometric tab. Keep the bottle in a magnetized tray into an incubator at 20 0C in dark conditions. The manometer measures the decline of pressure in the bottle, caused by oxygen consumption. On day 5, take reading. By day 5, oxidation is 60-70% complete. The Dissolved oxygen on day 1 and day 5 are noted. BOD is (D1- D5)/ P, where P is the volumetric fraction of water. For example, if 5 ml sample is added to a 300 ml BOD flask, P=5/300=0.0167. BOD is measured in mg of O_2/L. For natural waters, BOD should be 1 mg/ L. For raw domestic sewage, it is around 300 mg/L. Below 100mg/L is weak sewage, over 300 mg/L is strong sewage. Typically, waste water BOD is 110- 440 mg/L and should be brought down to 20 mg/L for discharge.

If BOD were always used, treated wastewater would need to be held, and a problem with the treatment process wouldn't be detected until five days later! This would mean that wastewater would need to be held until results could be verified.A more appropriate method is COD.

Chemical Oxygen Demand -COD

Chemical oxygen demand (COD) is an indirect measurement of the amount of organic matter in a sample. With this test, you can measure virtually all organic compounds that can be digested by a digestion reagent. COD method determines the quantity of oxygen required to oxidize the organic matter in a waste sample, under specific conditions of oxidizing agent, temperature, and time. COD contrasts with biochemical oxygen demand (BOD), which relies on the use of microorganisms to break down the organic material in the sample by aerobic respiration over the course of a set incubation period (typically five days).

BOD and COD correlate with one another in virtually all samples, but BOD is always lower than COD as the biochemical breakdown of organics is often not as complete as the chemical method. Since a BOD test takes five days to complete, COD is used to monitor the treatment process in day-to-day operations. The COD test takes only a few hours to complete. Since COD test utilises a specific chemical oxidation the result has no definite relationship to the Biochemical Oxygen Demand (BOD) of the waste or to the Total Organic Carbon (TOC) level. COD converts all organic matter- biodegradable and non-biodegradable- into carbon dioxide and water. COD takes only two hours to digest.COD is an independent measurement of organic matter in the sample, rather than as a substitute for the BOD or TOC test.

Mid-Level Chemical Oxygen Demand Method: The method can be applied to domestic and industrial waste samples having an organic carbon concentration greater than 50 mg/L.

Collection: Collect the samples in glass bottles, if possible. Use of plastic containers is permissible, if it is known that no organic contaminants are present in the containers. Traces of organic material either from the glassware or atmosphere may cause a gross, positive error.

Storage: Samples should be preserved with sulphuric acid to a pH < 2 and maintained at 4°C until analysis. Cool the flask while adding sulphuric acid solution to prevent loss of VOCs.

Testing: Biologically active samples should be tested as soon as possible. Samples containing settleable material should be well mixed, preferably homogenized, to permit removal of representative aliquots.

Reflux apparatus: Glassware should consist of a 500 mL Erlenmeyer flask or a 300 mL round bottom flask made of heat-resistant glass connected to a 12 inch Allihn condenser by means of a ground glass joint. Any equivalent reflex apparatus may be substituted provided that a ground-glass connection is used between the flask and the condenser. Condition the glassware by running blank procedures to eliminate traces of organic material.

Organic and oxidisable inorganic substances in the sample are oxidized by potassium dichromate in 50% sulphuric acid solution at reflux temperature. Silver sulphate is used as a catalyst and mercuric sulphate is added to remove chloride interference. The excess dichromate is titrated with standard ferrous ammonium sulphate, using orthophenanthroline ferrous complex as an indicator. For lower concentrations of carbon such as in surface water samples, the Low Level Modification should be used.

Precautions

Extreme care should be exercised to avoid inclusion of organic materials in the distilled water used for reagent preparation or sample dilution.

When the chloride concentration of the sample exceeds 2000 mg/L, the modification for saline wateris required. Chlorides are quantitatively oxidized by dichromate and represent a positive interference. Mercuric sulphate is added to the digestion flask to complex the chlorides, thereby effectively eliminating the interference on all but brine and estuarine samples.

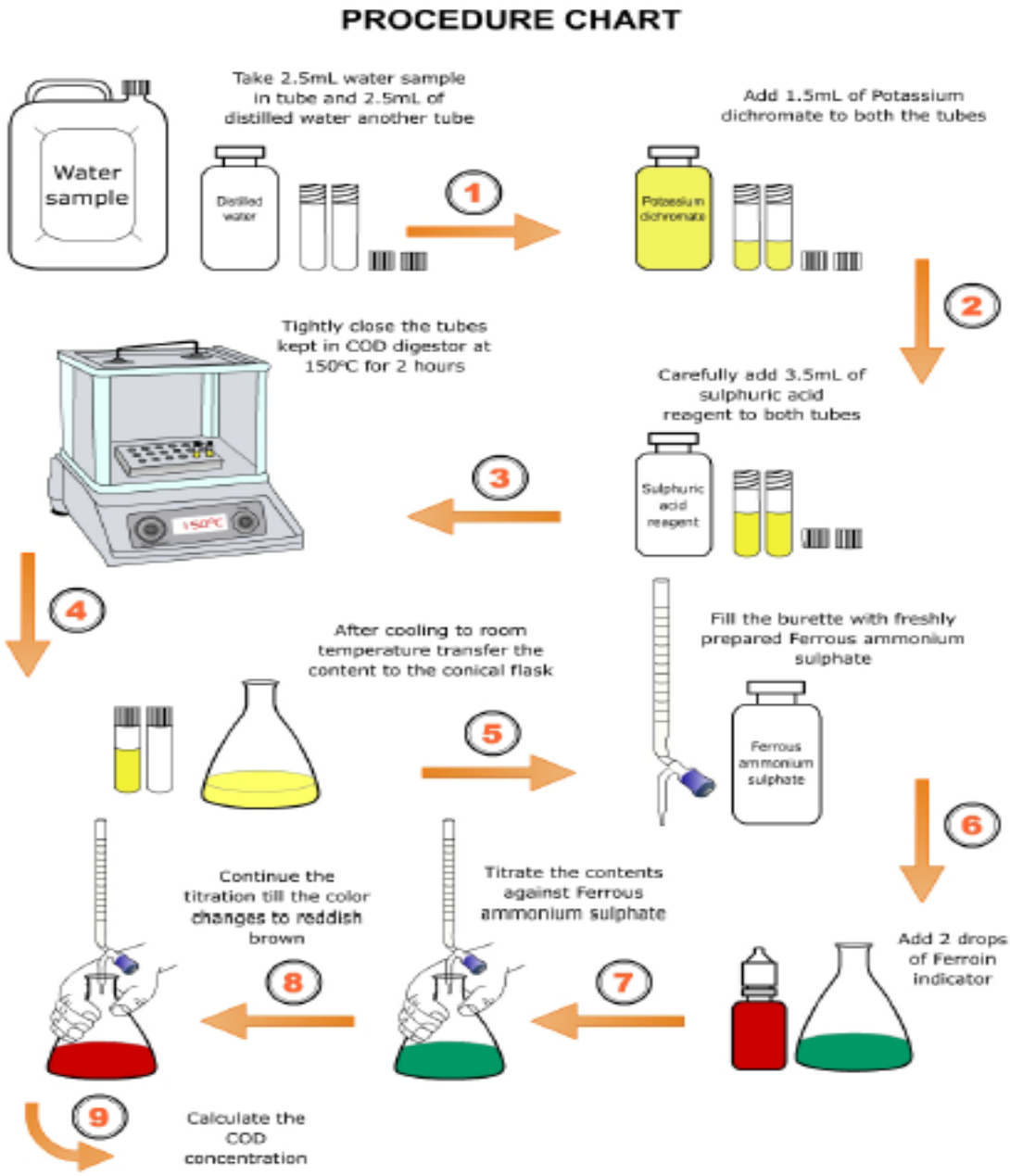


Fig 5.4 Procedure to Follow While Assessing COD

Reagents

1 Distilled water: Special precautions should be taken to ensure that distilled water used in this test be low in organic matter.
2 Potassium dichromate solution (0.250 N): Dissolve 12.259 g $K_2Cr_2O_7$, primary standard grade, previously dried at 103°C for two hours, in distilled water and dilute to 1000 mL.
3 Sulphuric acid reagent: Conc. H_2SO_4 containing 23.5 g silver sulphate, Ag_2SO_4, per 4.09 kg bottle. With continuous stirring, the silver sulphate may be dissolved in about 30 minutes.
4 Standard ferrous ammonium sulphate (0.25 N): Dissolve 98.0 g of $Fe(NH_4)_2$ $(SO_4)_2.6H_2O$ in distilled water. Add 20 mL of conc. H_2SO_4 (6.8), cool and dilute to 1 liter. This solution must be standardized daily against standard $K_2Cr_2O_7$solution.
5 Mercuric sulphate: Powdered $HgSO_4$.
6 Phenanthroline ferrous sulphate (ferroin) indicator solution: Dissolve 1.48 g of 1-10 (ortho) phenanthrolinemonohydrate, together with 0.70 g of $FeSO_4.7H_2O$ in 100 mL of water. This indicator may be purchased which is already prepared.
7 Silver sulphate: Powdered Ag_2SO_4.
8 Sulphuric acid (sp.gr. 1.84): Concentrated H_2SO_4

Standardisation: To approximately 200 mL of distilled water add 25.0 mL of 0.25 N $K_2Cr_2O_7$solution. Add 20 mL of $H_2SO_4$and cool. Titrate with ferrous ammonium sulphate using 3 drops of ferroin indicator. The color change is sharp, going from blue-green to reddish-brown.

Procedure

Add a known excess amount of oxidant to the water sample under acidic conditions at high temperatures. After digestion, a titrimetric or spectrophotometric test can determine the remaining oxidant.

Water Sample + $K_2Cr_2O_7$(a strong Oxidant) + H_2SO_4 (acidic condition) + Ag_2SO_4 (catalyst)

Digest for 2 hours at 150^oC.The result will be CO_2 + H_2O + Cr^{3+}. The amount of Chromium ions is assessed after the oxidation is complete.

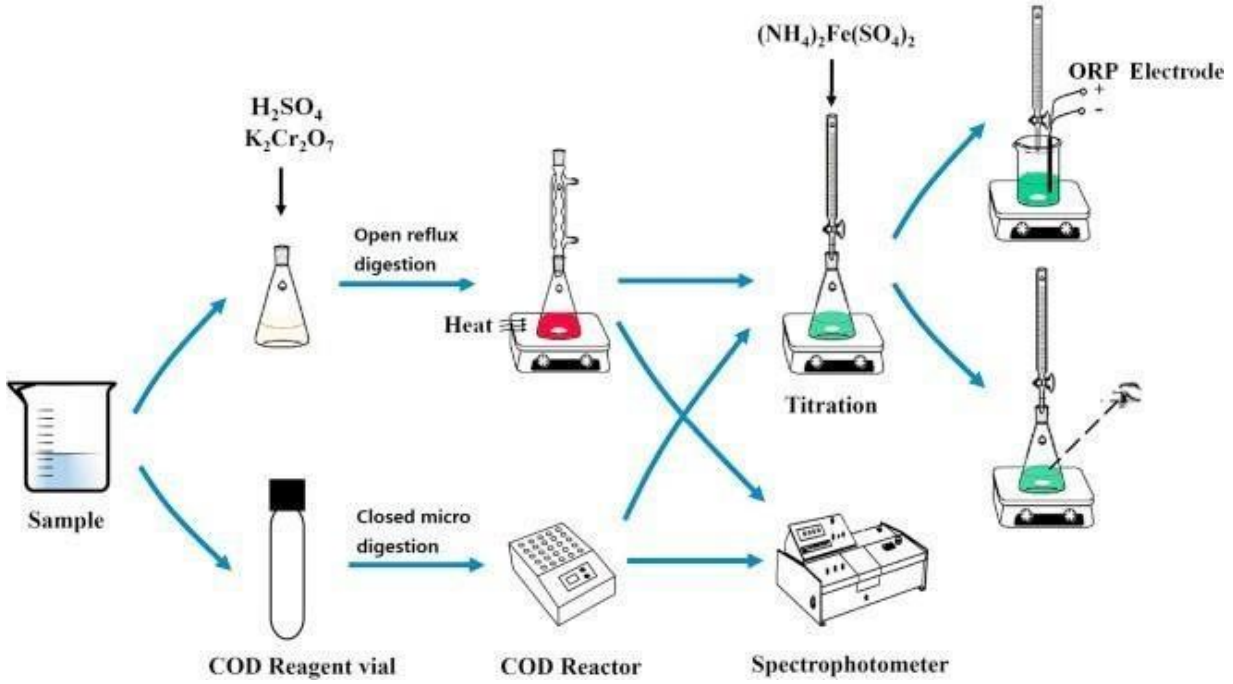


Fig 5.5 Two Methods to Assess Chromium ions – Colourimetric and Titration.

Colourimetric Method

COD	Absorbance
0	0.000
50	0.0280
100	0.0380
200	0.0750
300	0.1110
500	0.1880

Table 5.4 Chart to derive COD by Absorbance

Both Chromium species are coloured and absorb light, but at different wavelengths. Dichromate ion is visible at 420nm, chromium ion at 600-620 nm. At the end of the experiment, the dichromate has a near-zero absorbance. So, COD is determined by absorbance in a spectrophotometer at 600 nm as it measures the absorption of light by the sample. As per the Beer- Lambert Law the light absorption is proportional to the concentration of the species. A calibration curve is prepared. Standard solutions with known COD concentrations are prepared. A solution of potassium hydrogen phthalate (KHP). 5- 7 dilutions are made of the stock solution. The absorbance of all standards is read in the spectrophotometer. A graph is made, with absorbance on the x axis and concentration on the y axis. Where y = ax+b.

Switch on a dry block heater at 150^{o}C temperature. Create reference blanks of the ionized water samples to ensure that the ionized dilution water does not cause interference. Make 3 samples of 2.5. mL each. Prepare water samples. Shake thoroughly. Pour 2.5 mL samples. Add reagents. It is an exothermic reaction. It should be done under a fume hood. Add 1.5 mL of Potassium dichromate solution. Then add 3.5 mL of sulphuric acid. Cap the vials tightly and give a brisk shake. Keep reference blanks and samples in the dry block digester for 2 hours. Let them cool. Observe the colours. The darker the yellow colour, higher the COD and therefore higher the amount of organic matter in the sample. Sample must remain yellow or orange after digestion. A green sample shows COD values out of range. The sample should be diluted and the test should be repeated.

Mix the reaction vials. Turn on the spectrophotometer at 600 nm wavelength. First measure the absorbance of the reference blanks. Set at zero. Measure and note the absorbance value of samples. If any absorbance values are too far from the remaining, discard that sample. After getting all absorbance values, use the calibration curve to plot your values and find out the corresponding COD.

B Titration Method
The above process is carried out till the sample turns green. That means, all the-dichromate has been turned to chromium ions. Now it is titrated against standard Ferrous Ammonium Sulphate(FAS) solution. It is then back titrated till the colour changes back to orange.

Calculation of COD in the sample in mg/L:

$$(B\text{-}A) \times N \times S$$

where: A = milliliters of $Fe(NH_4)_2(SO_4)_2$ solution required for titration of the blank,
B = milliliters of $Fe(NH_4)_2(SO_4)_2$ solution required for of the sample,
N = normality of the $Fe(NH_4)_2(SO_4)_2$ solution, and
S = milliliters of sample used for the test.

5.4 Microbiological Analysis

Microorganisms that affect human health greatly include pathogenic bacteria, pathogenic viruses, pathogenic protozoa, and cyanobacteria.

Table 5.5 List of Microorganisms Possibly Present in Water and the Diseases Associated with them[6].

Microorganisms		Disease
Bacteria	Salmonella typhi	Typhoid
	Salmonella choleraesuis	Typhoid, gastroenteritis
	Salmonella enteritidis	Typhoid, gastroenteritis
	Shigella sp.	Dysentery
	Vibrio cholera	Cholera
	Camplobacterjejuni	Enteritis
	intestinal pathogenic coliform	gastroenteritis
	Mycobacterium tuberculosis	Tuberculosis
Virus	rotavirus	Gastroenteritis
	poliovirus	Infantile paralysis
Protozoa	Cryptosporidium	Typhoid
	Giardia	Typhoid
	Entamoeba	Dysentery

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Algae	Microcystis	Liver disorder
	Aphanizomenon	Nervous disorder
	Anabaena	Nervous disorder
	Cylindrospermopsis	Liver disorder

The discharge of wastes from municipal sewage is an important water quality issue around the world, particularly for sources of drinking-water. Municipal sewage contains human faeces and water contaminated with these effluents may contain pathogenic (disease-causing) organisms and, consequently, may be hazardous to human health if used as drinking-water or in food preparation. Faecal contamination of water is routinely detected by microbiological analysis. It is impractical to attempt the routine isolation of pathogens because they are present in relatively small numbers compared with other types of micro-organism. Moreover, there are many types of pathogen and each requires a unique microbiological isolation technique. The approach that has been adopted is to analyse for indicator organisms that inhabit the gut in large numbers and are excreted in human faeces. The presence of these indicator organisms in water is an evidence of faecal contamination and, therefore, of a risk that pathogens are present. If indicator organisms are present in large numbers, the contamination is considered to be recent and/or severe. Bacteria in water are, in general, not present individually, but as clumps or in association with particulate matter. When enumerating bacteria in water is not the number of individual bacteria present which are counted, but the number of clumps of bacteria or the particles and their associated bacteria. Each clump or particle may have many bacteria associated with it.

Characteristics of Indicator Organisms

Total Coliforms

Coliforms are a large group of Gram-negative, rod-shaped bacteria that share several characteristics. The group includes thermo tolerant coliforms and bacteria of faecal origin, as well as some bacteria that may be isolated from environmental sources. Thus the presence of total coliforms may or may not indicate faecal contamination. In extreme cases, a high count for the total coliform group may be associated with a low, or even zero, count for thermo tolerant coliforms. Such a result might be caused by entry of soil or organic matter into the water or by conditions suitable for the growth of other types of coliform. In the laboratory total coliforms are grown in or on a medium containing lactose, at a temperature of 35 or 37 °C. They are provisionally identified by the production of acid and gas from the fermentation of lactose.

Thermo tolerant (faecal) Coliforms

Coliform organisms which grow at 44 or 44.5 C and ferment lactose to produce acid and gas are known as thermo tolerant (faecal) coliforms. In practice, some organisms with these characteristics may not be of faecal origin and the term “thermo tolerant coliform” is, therefore, more correct and is becoming more commonly used. More than 95 per cent of thermo tolerant coliforms isolated from water are the gut organism Escherichia coli, the presence of which is definitive proof of faecal contamination.

In the laboratory thermo tolerant, coliforms are grown on media containing lactose, at a temperature of 44 or 44.5 °C. They are provisionally identified by the production of acid and gas from the fermentation of lactose. Nutrient-rich environments may encourage the growth or persistence of some species of thermo tolerant coliform other than E. coli. This possibility should be considered when, for example, an

unusually high result is obtained from water that was thought to be relatively clean. In such a case, the advice of a microbiology laboratory should be sought for the determination of the more specific indicator, E. coli.

The presence of faecal streptococci is evidence of faecal contamination. Faecal streptococci tend to persist longer in the environment than thermo tolerant or total coliforms and are highly resistant to drying. It is, therefore, possible to isolate faecal streptococci from water that contains few or no thermo tolerant coliforms as, for example, when the source of contamination is distant in either time or space from the sampling point. Faecal streptococci grow in or on a medium containing sodium azide, at a temperature of 37-44 °C. They are usually detected by the reduction of a dye (generally a tetrazolium-containing compound) or the hydrolysis of aesculin. Routine methods may give “false positives” and additional confirmatory tests may be required.

Table 5.7Comparison of Methods for Analysis of Coliform Bacteria

Multiple Fermentation Tube Technique Most Probable Number (MPN) Technique	Membrane Filter Technique
Slower: requires 48 hours for a positive	More rapid: quantitative results in or presumptive positive about 18 hours
Labour-intensive	Less labour-intensive
More culture medium needed	Less culture medium needed
Requires more glassware	Requires less glassware
More sensitive	Less sensitive
Result obtained indirectly by statistical approximation (low precision)	Results obtained directly by colony count (high precision)
Not readily adaptable for use in the field	Readily adapted for use in the field
Applicable to all types of water	Not applicable to turbid waters
Consumables readily available in most countries	Cost of consumables is high in many countries
May give better recovery of stressed or damaged organisms in some circumstances	

Heterotrophic Plate Count: The heterotrophic plate count includes all of the micro-organisms that are capable of growing in or on a nutrient-rich solid agar medium. Two incubation temperatures and times are used: 37 °C for 24 hours to encourage the growth of bacteria of mammalian origin, and 22 °C for 72 hours to enumerate bacteria that are derived principally from environmental sources. The main value of colony counts lies in comparing the results of repeated samples from the same source. If levels increase substantially from normal values, there may be cause for concern.

Multiple Fermentation Tube Technique

This method is used for the analysis of drinking-water. In fact, this is the only procedure that can be used if water samples are very turbid. This is the most fundamental method of conducting bacteriological analyses.

Separate analyses are usually conducted on five portions of each of three serial dilutions of a water sample. Individual portions are used to inoculate tubes of culture medium five aliquots of water from each of three consecutive 10-fold dilutions; for example, five aliquots of the sample itself, five of a 1/10 dilution of the sample and five of a 1/100 dilution. Aliquots may be 1-ml volumes, each added to 10 ml of single strength culture medium, or 10-ml volumes, each added to 10 ml of double-strength medium. These are incubated at a standard temperature for a standard period of time.

The presence of coliforms is indicated by turbidity in the culture medium, by a pH change and/or by the presence of gas.MPN index is determined by comparing the pattern of positive results (the number of tubes showing growth at each dilution) with statistical tables. The tabulated value is reported as MPN per 100 ml of sample. To help to reduce the cost a smaller number of tubes is incubated at each dilution, for example three instead of five. Or, one tube with 50 ml of sample and five tubes with 10 ml of sample are inoculated and incubated.

Culture Media and Buffered Dilution Water

Each part of the test requires a different type of medium. Dehydrated powder, packaged in pre-weighed amounts suitable for making one batch of medium, to be dissolved in an appropriate volume of distilled water, dispensed to culture tubes and sterilised before use. Ampoules of ready-to-use media are the most convenient form but are the most expensive and have the shortest shelf-life. Media should be stored in a cool, dark, dry place. Large bottles containing dehydrated media must be tightly resealed after use to prevent spoilage.

Stock solution of buffered dilution water is prepared by dissolving 34.0 g of potassium dihydrogen phosphate, KH2PO4, in 500 ml of distilled water. The pH is checked and, if necessary, adjusted to 7.2 by the addition of small quantities of 1 mol l-1 NaOH solution. Distilled water is added to bring the final volume to 1 litre. The buffered water is stored in a tightly stoppered bottle in the refrigerator.

1.25 ml of stock solution is added to 1 litre of distilled water, mixed well and dispensed into dilution bottles in quantities that will provide, after sterilisation, 9 or 90 ml. The bottles are loosely capped, placed in the autoclave, and sterilised for 20 minutes at 121 °C. After the bottles have been removed from the autoclave, the caps should be tightened and the bottles stored in a clean place until needed. When enumerating coliforms, lauryl tryptose (lactose) broth is used in the first (isolation or presumptive) part. In the second (confirmation) part, brilliant green lactose bile (BGLB) broth is used to confirm total coliforms.

Table 5.7 Culture Media for MPA Analysis

Medium	Uses	Incubation temperature	Remarks
Isolation media			

Lactose broth	Total or thermotolerant coliforms	48 hours at 35 ± 0.5 °C or 37 ± 0.5 °C for total coliforms and 24 hours at 44 ± 0.25 °C or 44.5 ± 0.25 °C for thermotolerant coliforms	Prepare single strength medium by diluting double strength medium with distilled water. Each tube or bottle should contain an inverted fermentation (Durham) tube.
MacConkey broth	Total or thermotolerant coliforms	48 hours at 35 ± 0.5 °C or 37 ± 0.5 °C for total coliforms and 24 hours at 44 ± 0.25 °C or 44.5 ± 0.25 °C for thermotolerant coliforms	
Improved formate lactose glutamate medium	Total or thermotolerant coliforms	48 hours at 35 ± 0.5 °C or 37 ± 0.5 °C for total coliforms and 24 hours at 44 ± 0.25 °C or 44.5 ± 0.25 °C for thermotolerant coliforms	Available commercially in dehydrated form as Minerals Modified Glutamate Medium
Lauryl tryptose (lactose) broth	Total or thermotolerant coliforms	48 hours at 35 ± 0.5 °C or 37 ± 0.5 °C for total coliforms and 24 hours at 44 ± 0.25 °C or 44.5 ± 0.25 °C for thermotolerant coliforms	
Confirmatory media			
Brilliant green lactose bile broth	Total or thermotolerantcoliforms (gas production)	44.5 ± 0.25 °C for thermotolerant coliforms	
EC medium	Thermotolerant coliforms (indole production)	44.5 ± 0.25 °C for thermotolerant coliforms	Addition of 1 % (m/m) L- or DLtryptophan may improve performance of the medium
Tryptone water	Thermotolerant coliforms (gas + indole production)	44.5 ± 0.25 °C for thermotolerant coliforms	
Lauryl tryptose mannitol broth with tryptophan	Thermotolerant coliforms (gas + indole production)	44.5 ± 0.25 °C for thermotolerant coliforms	

Requirements

Apparatus

1. Incubator(s) or water-baths: capable of maintaining temperature of choice.
2. Autoclave: to sterilise glassware and culture media.
3. Distillation apparatus, with storage capacity > 20 L distilled water.
4. Laboratory balance: accuracy ± 0.05 g, with weighing scoop
5. Racks: for tubes, bottles. Must fit autoclave.
6. Pipettes, reusable, glass, 10-ml capacity graduated in 0.1-ml divisions, and 1-ml capacity graduated in 0.01-ml divisions.
7. Test-tubes, 20 × 150 mm for 10 ml of sample + 10 ml of culture medium, with metal slip-on caps.

8. Bottles, with loose-fitting caps, calibrated at 50 and 100 ml, for 50 ml of sample + 50 ml of culture medium.
9. Measuring cylinders, unbreakable plastic or glass, capacity 100, 250, 500 and 1,000 ml.
10. Thermometer
11. Refrigerator: for storing culture media.
12. Hot-air sterilizer
13. Bunsen burner or alcohol lamp
14. Durham tubes, 6 × 30 mm
15. Pipette cans for sterilising pipettes.
16. Flasks for preparation of culture media.
17. Wash-bottle.
18. Pipette bulbs.
19. Wire loops for inoculating media, and spare wire.
20. Spatula.
21. Container for used pipettes.
22. Brushes for cleaning glassware (several sizes).
23. Fire extinguisher and first-aid kit.
24. Miscellaneous tools.
25. Waste bin.

Consumables

1. Culture media: for example lauryl tryptose broth, brilliant green lactose bile (BGLB) broth, and E. coli medium.
2. Disinfectant for cleaning laboratory surfaces and the pipette discard container. √ Detergent for cleaning glassware and equipment.
3. Phosphate-buffered dilution water.
4. Autoclave tape.

Method

1. Prepare culture medium.
2. Prepare a range of sample dilutions

Table 5.7Sample volumes and number of tubes for MPN

Sample type	Sample volume (ml)				
	50	10	1	0.1	0.01
Treated drinking-water	1	5			
Partially treated drinking-water		5	5	5	
Recreational water		5	5	5	
Protected-source water		5	5	5	
Surface water			5	5	5

3. Pipette the samples and dilute into tubes. Gently shake. Label them.

4. Place the rack in an incubator or water-bath for 48 hours at 35 ± 0.5 ºC or 37 ± 0.5 ºC.
5. After 18 or 24 hours, note which tubes show growth. Record turbidity, gas, or colour change, if ph indicator is added. Record it. Return tubes to incubator. Observe at 48 hours.
6. Prepare tubes with confirmation culture medium. Using a sterile wire loop, transfer inocula from positive tubes into confirmation culture medium. Sterilize loop between transfers by passing over a flame till the loop is red-hot. Cool before reuse. Label tubes carefully (with same codes as before). Incubate for time mentioned in the 'culture media for MPN chart'.
7. Note the tubes with growth, production of gas. Record it.
8. Compare with chart given by APHA, 1992, or WHO, 1985.

Membrane Filter Technique

This technique is used for larger number of samples. Portable testing kits are also available for field testing. It gives a direct count of total coliforms and faecal coliforms present in a given sample of water.

1. A measured volume of water is filtered, under vacuum, through a cellulose acetate membrane of uniform pore diameter, usually 0.45 µm.
2. Bacteria are retained on the surface of the membrane which is placed on a suitable selective medium in a sterile container and incubated at an appropriate temperature.
3. If coliforms and/or faecal coliforms are present in the water sample, characteristic colonies form that can be counted directly.

Membrane filtration and colony count techniques assume that each bacterium, clump of bacteria, or particle with bacteria attached, will give rise to a single visible colony. Each of these clumps or particles is, therefore, a colony forming unit (cfu) and the results are expressed as colony forming units per unit volume. In the case of thermo tolerant coliform bacteria the result should be reported as thermo tolerant coliforms cfu per 100 ml.

This technique is not suitable for turbid waters, surface waters and high sewage, because such waters clogup the filter. Always test two or more samples from the same source for confirmation. Culture Medium: There are several culture media. One of the commonly used media is Lactose agar with Tergitol 7 for total or thermo tolerant coliforms. Incubation is for 18-24 hours at 35 ± 0.5 °C or 37 ± 0.5 °C for total coliforms and 18-24 hours at 44 ± 0.25 °C or 44.5 ± 0.25 °C for thermo tolerant coliforms. Prepared plates have maximum shelf-life of 10 days. Store prepared plates at 4 °C.

Apparatus

1. Incubator/ water bath
2. Membrane filter apparatus: with aspirator and suction flask.
3. Autoclave or pressure cooker and heat source
4. Boiling pan to disinfect filtration apparatus between uses.
5. Laboratory balance
6. Racks for bottles of prepared culture media and dilution water. Must fit autoclave.
7. Distilling apparatus with 5L storage capacity
8. Refrigerator
9. Hot-air sterilizer.
10. Thermometer
11. Pipette cans, boxes for pertri dishes, reusable bottles for culture media.
12. Measuring cylinders – 100 ml and 250 ml.
13. Bottles of 9 ml buffered dilution water

14. Flask to prepare culture media.
15. Wash bottle, blunt edged forceps, pipette bulbs, spatula, container for used pipettes
16. Brushes for cleaning glassware, and other miscellaneous tools.
17. Fire extinguisher and first aid kit.

Consumables

1. Methanol (not ethanol or methylated spirits)
2. Disinfectant for discarded pipettes.
3. Culture medium
4. Phosphate buffered dilution water
5. Petri dishes
6. Polythene bags to wrap pertridish if dry incubator is used.
7. Magnifying lens, to help count colonies
8. Wax pencils to label petri dishes.
9. Autoclave tape.
10. Detergent for cleaning equipment.

Method

1. Disinfect the filtration apparatus, between analysis of consecutive samples by autoclaving/ immersing in boiling water for 1 min/ rinsing with methanol and distilled water/ flaming with methanol, exposure to formaldehyde gas by burning methanol in the absence of oxygen (field technique).
2. Add absorbant pad to the petridish.
3. Soak pad with nutrient medium
4. Disinfect blunt-ended forceps and cool
5. Remove membrane from sterile packet and place in filtration apparatus.
6. Pour sample over membrane. Apply vacuum to suction flask to draw out the sample.
7. Remove filter with sterile forceps and place in petridish.
8. Label and incubate petridish.
9. Count colonies after full incubation. Express the result as number of colonies per 100 ml. If filtered volume was small, calculate (# of colonies/ volume filtered) x 100

Table 5.8CPCP Guidelines Water Quality Standards for Surface water for Designated Best Use

Designated best use	Quality Class	Primary Water Quality Criteria			
		Total coliform organisms (MPN*/100 ml)	pH	DO	BOD
Drinking water source without conventional treatment but with chlorination	A	<50	6.5 - 8.5	>6 mg/l	<2 mg/l
Outdoor bathing (organized)	B	<500	6.5 - 8.5	>5 mg/l	<3 mg/l

Drinking water source with conventional treatment	C				
Propagation of wildlife and fisheries	D	Free ammonia (as N) > 1.2 mg/l	6.5 - 8.5	>4 mg/l	
Irrigation, industrial cooling, and controlled disposal	E	Sodium Aborption Ratio <26	6.5 - 8.5	Electrical conductivity <2250 µmhos/cm	Boron <2 mg/l.

5.5 Soil Testing

Soil needs to be tested for fertility, to determine available concentrations of plant nutrients. Also, it is test for pollution, geotechnical, geo chemical and ecological investigations.
For testing soil, 10- 20 sample points are chosen for every 40 acres. Sampling spots can be chosen in a network, z-scheme, diagonally or along tilling lines.

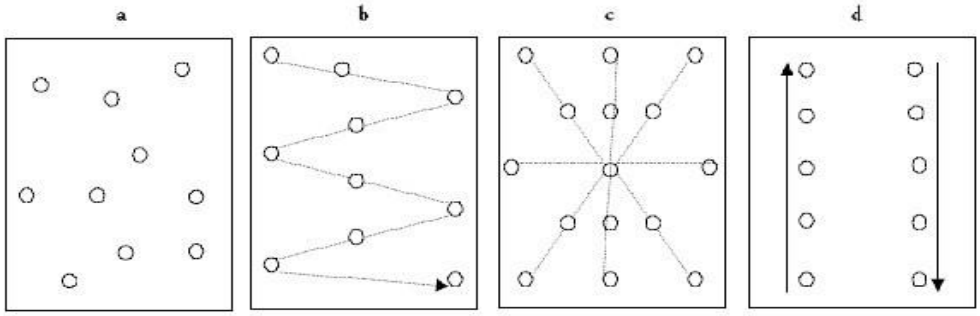


Fig 5.6 Methods to Select Sampling Spots in the Field for Soil Sampling.

Sampling is done by digging a pit. The soil is vertically cut along the pit wall to a depth where roots are present.0-30 cm for field crops, 30-60 cm for permanent crops. Determine the soil unit (or plot). Make a traverse over the soil unit (or plot). Clean the site (with spade) from where soil sample is to be collected. Insert the spade into soil. Standing on the opposite side, again insert the spade into soil.A lump of soil is removed. A pit of 'V' shape is formed. Its depth should be 0-6" or 0-9" or 0-12" (i.e., Depth of tillage).

Take out the soil-slice (like a bread slice) of ½ inch thick from both the exposed surface of the pit from top to bottom. This slice is also termed furrow-slice. Usually a composite sample is collected by combining soil from several locations. Up to 1 kg of soil is sent for testing.
(Watch Film 3 Soil Sampling: How to collect a soil sample for analysis duration 3 min. https://www.youtube.com/watch?v=3YuA20kZ1EA)

The composition of soil is affect by depth of the soil sample and timing. Soil chemistry changes over time as biological and chemical processes breakdown or combine compounds. Laboratories test soil for major

nutrients- N, P, K, secondary nutrients- S, Ca, Mg, micro-nutrients- Fe, Mn, Cu, Zn, Bo, Mb, Cl. Soil pH is an important quality to test. Common soil contaminants include Petroleum products, industrial solvents, pesticides, salts and plant fertilizers. Also, heavy metals like Arsenic, Barium, Cadmium, Copper, Mercury, Lead and Zinc. Lead is particularly dangerous. Geo technical tests include shear strength, compressive strength, consolidation, permeability, foundation load, soil index, standard penetration test (SPT), Dynamic Cone Penetration (DCP)and moisture/density.

Soil Testing Parameters Include
Physical: texture, structure, permeability, porosity, water holding capacity, etc.
Chemical: pH, Salinity (EC)- we measure with pH, Cation exchange capacity, etc.
Microbial: soil resporation, enzyme activities, etc.

Soil sampling for industrial pollutants is done in accordance with ISO norms. Samples are collects from 0-20 cm surface and 20-40 cm sub-surface. The samples are crushed, mixed, dried, grinded, sieved. For pH, Total nitrogen and total organic carbon, a fraction of less than 2 mm was used. An aqueous solution of 1:2.5 is made. After mixing and settling of particulate matter (after 30 min), the pH and EC are checked. Total Nitrogen content is studied by Kjeldahl method. (Watch Film Determination of Available Nitrogen Content in the Soil by Kjeldahl Method, duration: 7 min. https://www.youtube.com/watch?v=3uQOezl_Uos)

TOC is measured as follows:

- Take 1 g of soil in a 500 mL conical flask.
- Add 10 mL of 1N $K_2Cr_2O_7$ solution and shake to mix it.
- Then add 20 mL Con. H_2SO_4 and swirl the flask 2 or 3 times.
- Allow the flask to stand for 30 minutes on an asbestos sheet for the reaction to complete.
- Pour 200 mL of water to the flask to dilute the suspension. Filter if it is expected that the end point of the titration is not to be clear.
- Add 10 mL of 85% H_3PO_4 and 1 mL of Diphenylamine indicator and back titrate the solution with 0.5 N Ferrous Ammonium Sulphate, till the colour flashes from violet through blue to bright green. H_3PO_4 gives sharper endpoint, by making the colour change, distinct through a flocculating effect.
- Note the volume of Ferrous Ammonium Sulphate.
- Carryout blank titration (without soil) in a similar manner.

Calculation

% of Organic Carbon in Soil (R) is,

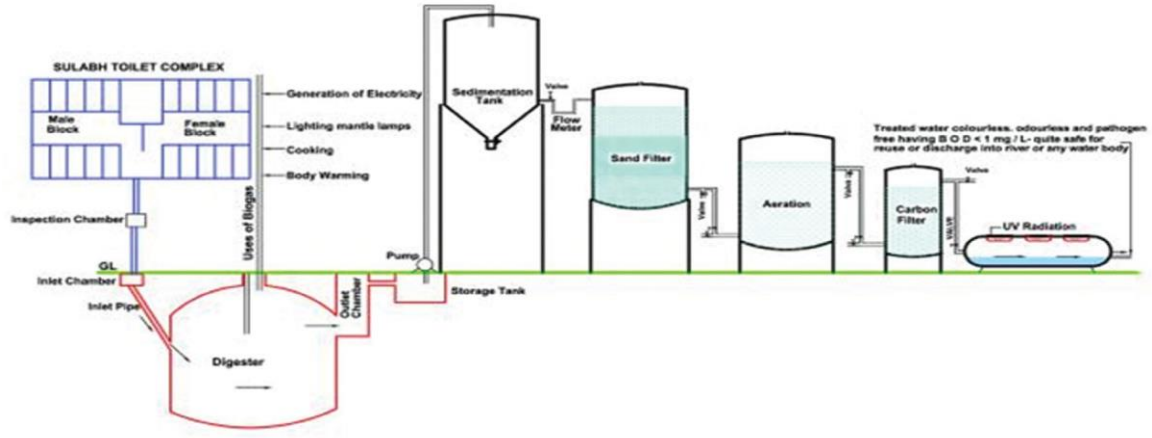
$$R = \frac{(V_1 - V_2) \times N \times 0.003 \times 100 \times C}{W}$$

Where,

W - Weight of Sample
V_1 - Blank Titre value
V_2 - Titre value of the Sample
N - Normality of $K_2Cr_2O_7$ (Here it is 1N)
C - Correction Factor (1.334, 1.724)

Soil samples are mineralized with aqua regia (a very strong acid formed by the combination of concentrated nitric acid and concentrated hydrochloric acid)in a microwave oven at 180°C for 15 min. They are diluted with appropriate diluting agents and a spectrophotometer is used for analysis.

How Biodigesters Work



5.6

5.6 Toxicity Characteristic Leaching Procedure (TCLP)

A highly toxic component of solid waste is leachate, a liquid produced when rain percolates through garbage dumps. It has great potential to contaminate soil.

The TCLP is designed to determine the mobility of both organic and inorganic analytes present in liquid, solid and multi-phase wastes.

>> TCLP simulates leaching through a municipal landfill.

>> It helps determine hazardous and nonhazardous wastes for disposal in the appropriate landfill.

>> It studies how percolating liquids may react with solid waste in simulated landfill conditions.

>> TCLP finds out the amount of EPA-listed contaminants are present and likely to be absorbed into soil and groundwater.

>> Further, it indicates the possible public health or environmental health hazards exist in the sludge being tested.

Here, a soil sample extraction method is employed for chemical analysis. A collection of four leaching tests are conducted, that follow the tiered approach of leach testing. Each test is designed to vary a critical release-controlling parameter (pH, liquid-to-solid ratio, leaching time) to provide leaching data over a broad range of test conditions. Leaching characterization under LEAF (Leaching Environmental Assessment Framework) consists of testing using one or more of the following four methods:

- Method 1313: pH Dependence:- Liquid-Solid Partitioning (LSP) as a Function of Eluate pH Using a Parallel Batch Extraction Procedure.
- Method 1314: Percolation Column:- Liquid-Solid Partitioning (LSP) as a Function of Liquid-to-Solid Ratio Using an Up-Flow Percolation Column Procedure

- Method 1315: Mass Transfer Rates:- Mass Transfer Rates in Monolithic and Compacted Granular Materials Using a Semi-dynamic Tank Leaching Procedure
- Method 1316: Batch L/S:- Liquid-Solid Partitioning (LSP) as a Function of Liquid-to-Solid Ratio Using a Parallel Batch Extraction Procedure

SPLP analysis by EPA 1312 is designed to mimic the leaching of contaminants exposed to normal weathering in situ by acid rain.TCLP extraction is performed by subjecting the material tested to a simulated landfill leachate. Acetic acid is chosen as the extraction fluid as it is the major component of typical municipal landfill leachate. The pH is maintained at 4.93. This sample/ acetic acid mixture is subjected to 18+ - 2 hours of rotary extraction. The resulting liquid is analysed for 39 contaminants from the EPA's TCLP final Rule, including 8 metals, 11 organic VOCs, 12 semi-volatile organic compounds, 6 pesticides and 2 herbicides. The TCLP test must only be done for those wastes which are destined for a landfill. Otherwise, wrong interpretation is likely. For materials not destined for landfills, leaching is possible due to acid rain. Hence, such materials are subjected to SPLP. Here, instead of acetic acid, the test is done with nitric acid and sulphuric acid to simulate acid rain.The TCLP test method has essentially 6 steps.

STEP 1: Separate the liquid and solid portions of the waste (as needed): Liquids (containing less than 0.5% dry solid material) are filtered through glass fiber to create a TCLP extract. Wastes (containing 0.5% or greater dry matter) are separated and stored for later analysis.
STEP 2: Crush the solid portion of the waste: Using a standard 9.5 mm sieve, we filter solid material and prepare it for extraction by cutting, crushing or grinding to a particle size of 1 cm or less.
STEP 3: Extract the solid material: Place the crushed solid portion in a system that simulates the conditions of a landfill by filtering a large quantity of water through it. The solid material is then extracted for at least 18 hours with a slightly acidic fluid equal to 20 times its weight. The materials are placed in a tumbler to simulate the leaching action of water seeping through waste in the landfill.
STEP 4: Final Separation: Collect the leachate from the system. The liquid waste is then separated from the solid waste through a fiber glass filter. The solid material is discarded and the liquid components are then assessed.
STEP 5: Recombine the separated liquid portion of the waste (if any) with the collected leachate. The initial liquid components may be added or may be analyzed separately, depending on compatibility.
STEP 6: Analyze the leachate for constituents of concern. Atomic spectrometry technologies such as atomic absorption spectrometry (AA), inductively coupled plasma optical emission spectrometry (ICP-OES), and inductively coupled plasma mass spectrometry (ICP-MS), are often used because they provide the sensitivity various global regulations require.

The TCLP test is an expensive and time-consuming procedure. It's important to know that there are three scenarios where TCLP is not required.

1. If a total analysis of the waste demonstrates that the individual contaminants are not present in the waste, or present in levels that could not possibly exceed the regulatory threshold, then the TCLPis not required. For wastes that are 100% physically solid, the maximum theoretical leachate concentration is 1/20 of the total concentration in the waste.
2. If this value is below the regulatory threshold, the TCLP need not be run.
3. If the waste is 99.5% or more liquid, then the waste itself is the extract, and can analyze it directly without performing the TCLP.

Here are three examples of when it is necessary to run a TCLP. For example, the regulatory level for the toxicity characteristic for lead (D008) is 5 ppm

1. If a wastewater solution contains 5 ppm or more dissolved lead, then it would be a D008 waste. A lower concentration would not be D008.
2. If a semisolid sludge contains 5 ppm or more total lead, then it would be a D008 waste. A lower concentration would not be D008.
3. If a solid brick or dry ash contains less than 100 ppm dissolved lead, then the extract could not possibly have more than 5 ppm lead, and the solid could not be a D008.
4. If a solid brick or dry ash contains 100 ppm (20 times 5 ppm) or more elemental lead, then it is possible that the extract produced by the TCLP could have 5 ppm or more elemental lead, therefore the TCLP or an equivalent procedure must be performed.

Table 5.9List of Contaminants to be Tested in TCLP

RCRA8's Heavy Metal	Hazardous Waste Code	EPA Allowable Limits		ORGANOCHLORINE PESTICIDES	TCLP Regulatory Level, mg/L
Arsenic	D004	5.0 ppm (mg/L)		Chlordane	0.03
Barium	D005	100.0 ppm (mg/L)		Endrin	0.02
Cadmium	D006	1.0 ppm (mg/L)		Lindane	0.4
Chromium	D007	5.0 ppm (mg/L)		Methoxychlor	10.0
Lead	D008	5.0 ppm (mg/L)		Toxaphene	0.5
Mercury	D009	0.2 ppm (mg/L)		Heptachlor (and its Epoxide)	0.008
Selenium	D010	1.0 ppm (mg/L)			
Silver	D011	5.0 ppm (mg/L)			
VOLATILE ORGANICS		**TCLP Regulatory Level, mg/L**		**SEMIVOLATILE ORGANICS**	**TCLP Reg Level, mg/L**
Benzene		0.5		o-Cresol	1 200
Carbon Tetrachloride		0.5		m-Cresol	1 200
Chlorobenzene		100.0		p-Cresol	1 200
chloroform		6.0		Cresol	1 200
1,4-Dichlorobenzene		7.5		2,4-Dinitrotoluene	0.13
1,2-Dichloroethane		0.5		Hexachlorobenzene	0.13
1,1-Dichloroethylene		0.7		Hexachlorobutadiene	0.5
Methyl Ethyl Ketone		200.0		Hexachloroethane	3.0
Tetrachloroethylene		0.7		Nitrobenzene	2.0
Trichloroethylene		0.5		Pentachlorophenol	100.0
Vinyl Chloride		0.2		Pyridine	2 5.0

CHLOROPHENOXY ACID HERBICIDES	**TCLP Reg Level, mg/L**		2,4,5-Trichlorophenol	400.0
2,4-D	10.0		2,4,6-Trichlorophenol	2.0
2,4,5-TP (Silvex)	1.0			

Summary

Water, waste water, soil and leachate are important parameters for environmental health with direct impact on human health. Water is tested for various physical properties, chemical properties and microbiological properties. Sampling is the most important step in the sampling process. It needs to be meticulously planned and executed. Many modern electronic devices are available for testing the samples. Presence of organic carbon and dissolved oxygen are the two main characteristics which determine the condition of water. BOD, COD, DO, TDS, TSS, pH, etc are important tests to be undertaken. Conventional methods, though time consuming give accurate results. One needs to select the testing methods most appropriate to the situation. Dumping of solid waste on land has the dangers of leaching and polluting surface and ground water. The presence of dangerous contaminants in solid waste as well as hazardous waste is tested by TCLP and SPLP respectively.

Self Assessment Questions

1. Explain how BOD and COD are tested in waste water.
2. How is water sampling done?
3. Under what conditions should the TCLP test be done?

Further Reading

Guidelines for water quality monitoring, CPCB,
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Films

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2. The Winkler Method. Duration 6 min. https://youtu.be/FKdzbgHaQQM
3. Soil Sampling: How to collect a soil sample for analysis duration 3 min. https://www.youtube.com/watch?v=3YuA20kZ1EA
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Course 5 Community Mobilization and Change Management

PG Diploma in
Waste Management &Environmental Hygiene

Mahatma Gandhi National Council of Rural Education
Hyderabad - 500004

Foreword

"It's not what you do, but the way that you do it". Change management and strategy development need to be seen within an overall technical development context augmented with a number of techniques and tools for assuring impact and sustainability.Change Management means that when there is need for an organizational change, a smart business strategy has to be put in place for achieving the change. Other requirements includecreating the conditions for successful change, and creating the right culture. Development of waste management strategies also requires similar 'change drivers' to be put in place to assure sustainability. Providing the framework for structuring the desired change to the existing waste management system and the enaction of these 'supporting' change activities will make it implementable and appropriate to given conditions.The involvement of communities needs to be encouraged through policies that employ SMMEs (small, micro andmedium enterprises). Waste management policies for job creation and entrepreneurialcommunity-based collection systems also need to be implemented. Community waste management systemshave a place in the integrated waste systems.

Most cities in the developing world face a high level of environmental pollution mainly due to inadequate provision of basic services like waste collection and water supply. Economic development, rapid urbanization and changes in consumption patterns have contributed to an increase in the quantity and complexity of the waste generated. The resulting effect is unlimited waste generation, leading to greater demand for waste management services. However, municipalities with limited human, technical and financial capabilities have little capacity to address this issue. In this context, the participatory management approach, where roles and responsibilities regarding waste management is suggested. Under this approach, people can play an active role and can contribute significantly to service delivery. The people's behavior is regarded as a major barrier to the successful implementation of waste management and hence studies have focused on raising awareness or imparting environmental education to garner people's participation. People tend to keep their homes clean but when it comes to their immediate environment, they leave the onus on the municipality. A socially responsible behavior needs to be inculcated. Moreover, people's lack of self-confidence in their abilities to exercise control over their own actions or community initiatives seems to be a further limitation.

Community Mobilization and Change Management are the parameters that define how we govern ourselves as a community. Collective efforts lead to reformation and help to achieve the desired results. For an objective or a goal to be achieved, the community needs to be mobilized and managed in an organized manner.

This course on Community Mobilization and Change Management is suitable for students of all streams - Commerce, Humanities, Science, Management, Journalism, Mass Media, Healthcare services (B Pharm, Social Work), Education, and Engineering. The extent of environmental damage and the innovations in combating the issues require scientific understanding of the subject.

The subject has vast possibilities and several interlinking themes. There is extensive scope to explore and experience different aspects of sanitation, pollution, environmental hygiene and waste management during classroom learning, practical experiments in field and laboratory, internship and dissertation. There is a sea of opportunity in this field of waste management and environmental hygiene, and an urgent need of skilled as well as dedicated workers to make our country clean and green.

Nature has interlinked realms. Similarly, subjects dealt in this course cannot be compartmentalized. They necessarily have to merge with one another. It is therefore important that students try to make these linkages in their minds rather than treating subjects in isolation. Students can make the most of this learning opportunity as they prepare to launch their careers in a field that holds great premise.

Dr. W G Prasanna Kumar

Chairman, MGNCRE

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The sincerity with which the course curriculum was completed and published can be assessed from the fact that a prior National Consultation Workshop was held with several subject matter experts and academicians across the country, to review the contents of the course material.

The workshop was held to familiarize Central, State and Private Universities, local and social bodies with the contents of the curriculum and to discuss and share feedback on ways to improve the course curriculum. The workshop also focused on building industry–academia partnerships in Waste Management and Environmental Hygiene through an intellectual interaction. The findings and inputs of the consultation were subsequently incorporated in the course material.

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Objectives

- To promote interdisciplinary pursuit of knowledge for community mobilization with behavior change communication
- To provide tools that drive community effort for sustainable waste management
- To persuade individuals and communities to change habits, sensitize public and provide mentorship for lifestyle changes

Rationale

Waste management and environmental hygiene is the need of the hour and needs to be addressed across all sectors and communities. The course on Waste Management and Environmental Hygiene gives the student an overview of waste management including collection, transfer, transport, and disposal along with methods of processing, basic disposal facilities, disposal options, recycling, project management and GIS applications, reclamation and remediation, entrepreneurship and job opportunities in waste sector. In addition, this course provides the student with relevant information about waste markets, recycling trends, cost and affordability of waste management practices, and incentive based concepts. This course is therefore essential for the students who wish to pursue a career in waste sector as moving ahead, waste management will become an infrastructural necessity.

Competency

The course will be taught and implemented with the objective to develop required skills sets in the students so that they are able to acquire following competencies: plan segregation, collection, transportation, recycling and disposal of wastes, know recycling trends and available waste markets, acquire skill development and know the scope and entrepreneurship opportunities in the waste management sector.

Methodology

The theory will be taught and practicality of the course will be addressed through questionnaires, self-assessment and dissertation. The course will be through class room lectures, guest lectures, field visits, audio – video learning mode, brainstorming sessions, seminars and Q&A. A lecture series will strengthen students' understanding of waste management which will help in acquiring different learning outcomes in rational and theory to practice approach. Competency that will be gained as part of course outcome includes - understanding, learning, applying and implementing skills, knowing career prospects in waste management sector, and internship and placement opportunities.

Topics Covered

- Urban Neighborhoods and Rural CommunitiesDignity of Labour/ Collectivisation
- Public Health/ Bio HazardsHealth care/Gender Issues
- Social security schemesCase studies of successful models across the country
- Changing legal requirements/arbitration/negotiation/persuasion techniques
- Effective communication/ Personality development
- Strategies for effecting change, helping people to adapt to change

Community Mobilization and Change Management – An Introduction

The world is a global village. Everywhere, the common problems with environment, health and hygiene abound. A community is often referred to a set of people who lead a civilised life in an organised manner. For generations, we have evolved as communities, across geographical entities, but have least focused on nature's warnings. The need of the hour is community mobilization and change management.The objective of this course is to make an individual and the society and environment to integrate and converge as a single entity. This course will help you understand how theoretical subjects of law, sociology health and current affairs merge together, tools that provide life tools for community effort, to persuade individuals and societies to change habits, and to sensitize public and mentor changes in lifestyle for long-term effectiveness.

Typically a waste management system in a developing country displays several problems including low service coverage, open dumping and unregulated burning of waste. Unlike in urban areas, rural communities usually have no official structures to handle the waste which in turn affects the environmental health. Behavioral and attitudinal changes are necessary though they are the hardest things to change. Learning from mistakes and innovating on development projects must be initiated to produce long-term results.

Chapter 1 provides an overview of community mobilization and change management. The importance of community mobilizationis discussed in detail. Introduction to change management and its key characteristics are explored. System perspective of change management is explained with the help of case studies. Chapter 2 provides overview of change management process. Key attributes to initiate, plan and deploy change are discussed in detail. Importance of change leaders and their characteristics are discussed. Identifying stakeholders of change and understanding their perspectives are mapped in this chapter. Methods of change communication and essential guidelines are listed for effective change management implementation. Chapter 3 discusses Community Mobilization with multiple tangible and intangible outcomes. The tangible outcomes include improved household income, employment and social development. The intangible outcomes refer to skill development, personality development and better lifestyle to individuals. This chapter explains the key benefits of community mobilization apart from community development. The key challenges of community mobilization are also discussed.

Chapter 1

Dynamics of Community and Change Management

Objectives

- To understand change management and need for community change
- To know the importance of community mobilization
- To explore system level understanding from the perspective of change management and community mobilization
- To evaluate the need for change at community level

Structure

1.1 Overview of Change Management
1.2 Community Mobilization
1.3 Importance of Community Mobilization
1.4 Importance of Change Management
1.5 Understanding System Perspective of Community Change Management

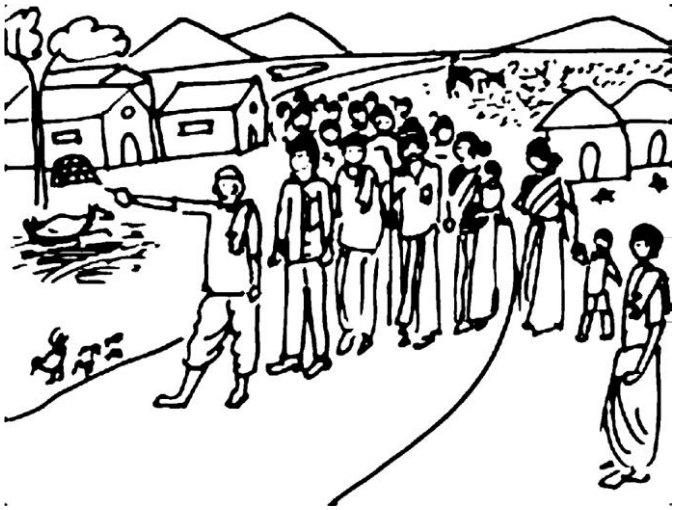
To Do Activities

- Seek questions about recent change that students underwent and what are all the challenges they faced during the transformation
- Provide an example of community change that happened in your district
- Discuss the changes required to improve the environment
- Watch the videos and discuss about the impact of individual change to social change

1.1 Overview of Change Management

Change management involves set of processes that help to reach a new status of transformation. It facilitates the people to understand the need for the change. We live in a social system in which all natural and man-made products co-exist. Natural system includes all human beings, animals, plants and non-living things. Nature is designed in such a way that, it can decompose all the waste and produce good soil out of it. However, improper waste management spoils the environment badly. Environmental hygiene is dependent on the proper waste management system and sanitation.

Change management involves set of processes that help to reach a new status of transformation. It facilitates people to understand the need for the change.



Government of India has initiated many programs to spread the importance of waste management and proper sanitation. All the programs are implemented across the country in three levels namely- individual level, institutional level and social level. To eradicate dengue spread, every individual is advised to store water in closed containers; the stagnated water at every office/school was removed (or) treated. For any change in practice to happen, the stakeholders involved in the change should be informed about the necessity of the change.

> Government of India recently launched a project on 'Swachh Bharat' to spread the importance of clean and safe environment.

'Swachh Bharat' is one of the government-initiated programs to provide clean environment. However, this program calls for individual and group participation. Campaign and program information is provided through media. District and village level participation is made possible by GramaPanchayat and Grama Sabhas. The program reaches the urban areas through social media. The importance of clean environment is communicated to individuals, institutions and social levels.

The following figure helps to understand the levels of change management from the view to provide environmental hygiene. It is important to understand that for a social change, the change should start from an individual.

Fig1.1 Change Levels for Environmental Hygiene

Prof. Lawrence Hrebiniak of the Wharton School at the University of Pennsylvania offers a framework for change management. He distinguishes the change into two broad categories.

a) Size of the change problem or content of change and
b) Time available for change

It is further divided into complex and simple changes with respect to size. Social and enterprise-level changes are considered as complex (large) and process changes are considered as small changes within a system. Similarly, the time can be divided into long and short based on the time to change and adaptability. The key attributes of size of the problem and time provides with four significant change management types.

		Time Available	
		Long	**Short**
Size of Problem	**Large**	Sequential Change	**Complex Change**
	Small	**Evolutionary Change**	**Managerial Intervention and Change**

Table 1.1 Four Types of Change

Managerial interventions and changes are relatively easy to execute compared to sequential and complex changes. Evolutionary change, as the term implies, occurs by itself. The real challenge in change management is when the size of problem is large. A large change agenda coupled with short time-frame is the most difficult type of organizational change that managers can face. *Complex change*, as the term implies, is most difficult challenge in change management. The social issues in community mobilization are either evolutionary in nature or lead to a complex system change.

1.2 Community Mobilization

A community is defined as a group of people who have common objective(s) to act together. The community mobilization is a process by which the desired status is achieved. A community's ability to act together may have existed for centuries or it may be triggered in a very short time by some urgent problem. The following figure explains the community mobilization and initiation of changemanagement:

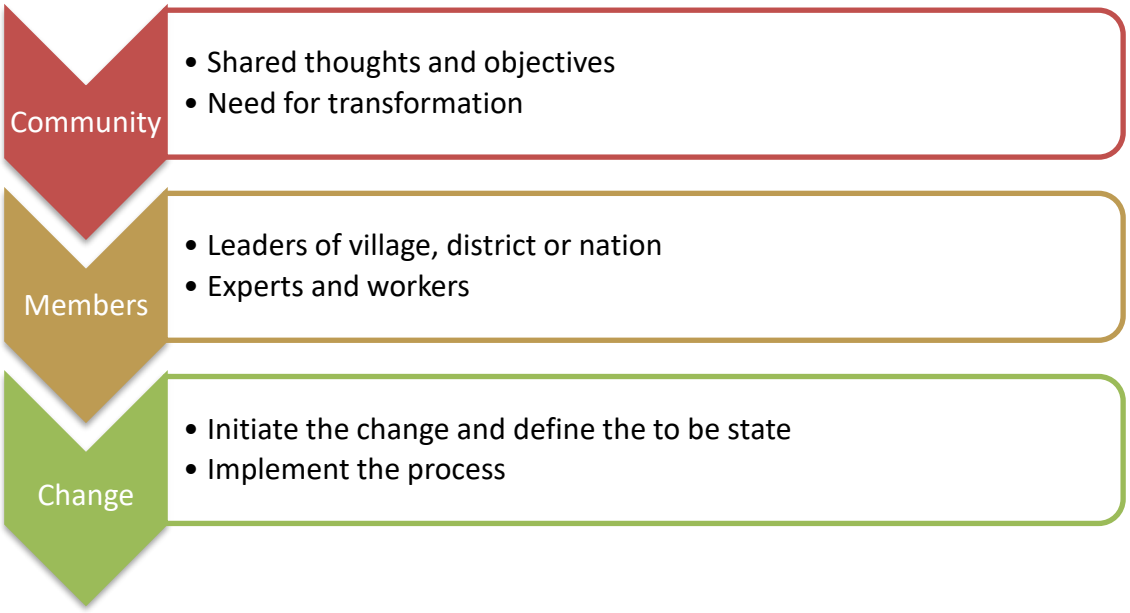


Fig 1.2 Community Mobilization and Social Change

Different communities include the place they live and the people they work with. In the past, community mobilization has usually meant initiatives in a neighborhood, village or local district level. Today, however modern communications technology has challenged traditional ideas of community. National and even global communities have emerged with shared concerns to prevent the spread of virus, to care for those affected by HIV and AIDS and to advocate health and human rights. People belonging to community mobilization share common understanding of the system under change. There is sense of mutual belonging of shared concern and common wish. They decide to work together in order to create action plan, implementation, change and create benefits for the society. The results may benefit the small social set up, group or country based on the size of mobilization and time.

Community mobilization follows a pattern. The change initiation and planning are complete much before the implementation of change through community mobilization. The resource planning within the community can be developed as a movement. Thus, community mobilization is the process of engaging communities to identify community priorities, resources, needs and solutions in such a way as to promote representative participation, good governance, accountability and peaceful change.

1.3 Importance of Community Mobilization

Community engagement is a way of ensuring that community members have access to valued social settings and activities, feel that they are able to contribute meaningfully to those activities, and develop functional capabilities that enable them to participate fully. It is important to cope up with social, economicaland technological changes.

Fig 1.3 Community Mobilization – Core Need

Resource mobilization refers to all activities involved in securing new and additional resources for organization (or) society. It also involves making better use of, and maximizing, existing resources. Resource mobilization is often referred to as 'Social Improvement' in community mobilization and 'New Business Development' in organizational context. It generally follows key attributes and process steps for successful execution. The following key process steps are executed for community mobilization -

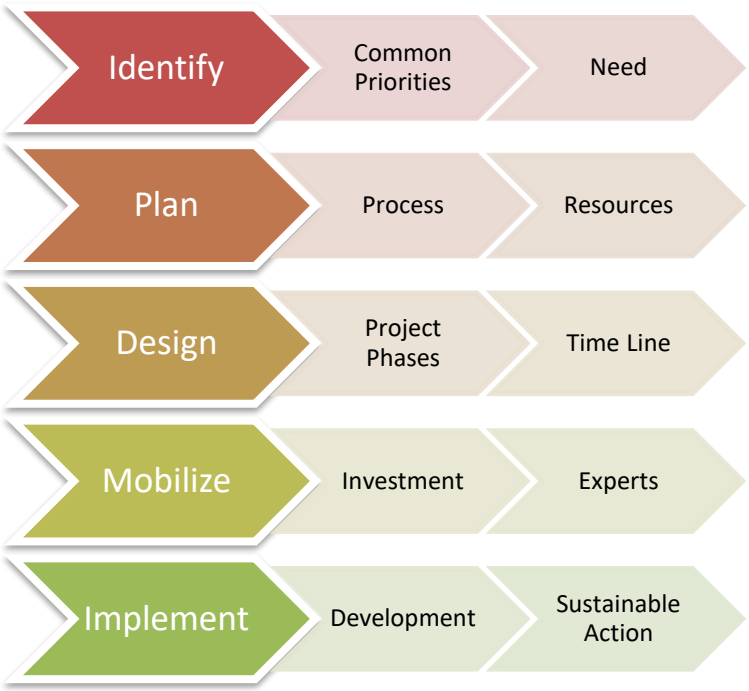


Fig 1.4 Key Attributes and Process Steps to Change Management

Often questions arise such as, “How do you start,” “How do you begin to engage communities,” or “How do you get them to participate and begin to organize.” Any community mobilization (or) change management process is initiated by proper identification of the need to change. The size of problem is to explore based on its complexity and timeline. The appropriate plan is to establish to leverage resources such as manpower and cost. The change process is communicated and implemented with the help of stakeholders and change agents.

1.4 Importance of Change Management

Rapid growth in innovation and technology in all industries is expected to provide improved quality of life and increased population. Increased population necessitates changes in multiple avenues in terms of communication, transportation and healthcare system.

Change management helps to cope up with the environmental changes in society level and technology changes in organizational level

Ebola outbreak witnesses a rapid change in the process especially in funerals. Healthcare workers (change agents) transform the processes and people.

For example, in year 2014 – 2016, Ebola Virus Disease outbreaks occurred in remote villages in Central Africa, near tropical rainforests. The virus is transmitted from wild animals and transmitted to humans. The spread among humans was so fast that it could reach the rest of the world in a week. Personal hygiene and community engagement were initiated to control the spread of Ebola since hygiene plays a vital role to control the spread. The required processes were initiated to bring change among people and at society level. The system is well interlinked in Ebola case that ‘number of unsafe funerals’ directly influences the ‘getting infected’. In many countries, funerals are believed to provide last respects. Many people gatherto show their respects. However, in Ebola death case, the individuals understand the importance of change in the funeral process that large gathering is prohibited to control the spread. Thus, change management helps to cope up with the environmental changes at society level and technology changes at organizational level. The following figure helps to understand the importance of change at social and organizational levels:

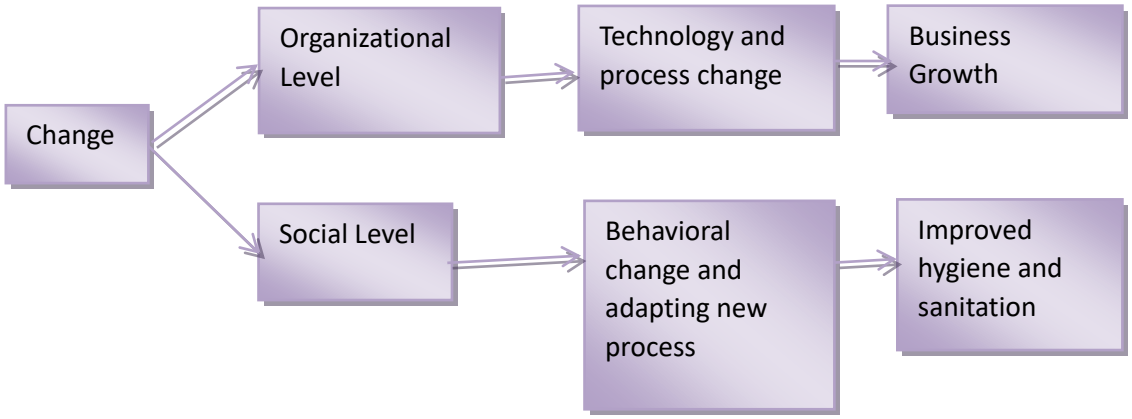


Fig 1.5 Importance of Change at Organizational and Social Levels

Every change that has been initiated should result in improved life style to human beings and must protect the environment. It is important to acknowledge the need for the change prior to plan or

implement the change. For any organization, change can happen in terms of technology, strategy and process. This provides business sustainability and competitive advantage.

The journey of change involves sailing in the stormy seas of uncertainty and complexity. There is ambiguity surrounding the definition of the final destination and the terrain to be traversed to be successful in reaching that visualized future state. In such a context, differences are inevitable. The following aspects of mobilization are considered while planning for the change:

- What are the most important aspects to analyze and act upon to achieve the goal of value added products and new products?
- How would things develop over time – for example, how long would it take to sort out technology issues to manufacture new products of consistent quality, how would competitors respond to the PSU's moves, or when PSU's products would gain customer acceptance and support?
- What barriers are likely to be confronted on the way and what are the ways in which they should be managed?
- What aspects of the problem are more important and so need greater attention?
- How detailed should the analysis be at different stages?
- Which coordination mechanisms would be the most effective in helping to achieve the goal?

1.5 Understanding System Perspective of Community Change Management

To understand the effective problem solving (i.e., environmental hygiene), the system and its components should be explored along with its level of influence. It helps to classify the problems and solutions since all the sub-systems and components are interlinked.

System thinking is a holistic approach to analyze and understand a systemthat helps to explore the constituents, components and their relation. It helps to understand how a system works over time within a specific context. Two examples for system level mapping is provided in this unit namely, environmental hygiene and waste management system.

> System thinking process structurally explores the system and its operation over a time.

Government policy and regulation plays a vital role to protect a system. The rules and law enforcement help people to adhere to the prescribed actions. To map environmental hygiene system representation, it can be divided into multiple systems, components and constitutions. The following figure explores the environmental hygiene system:

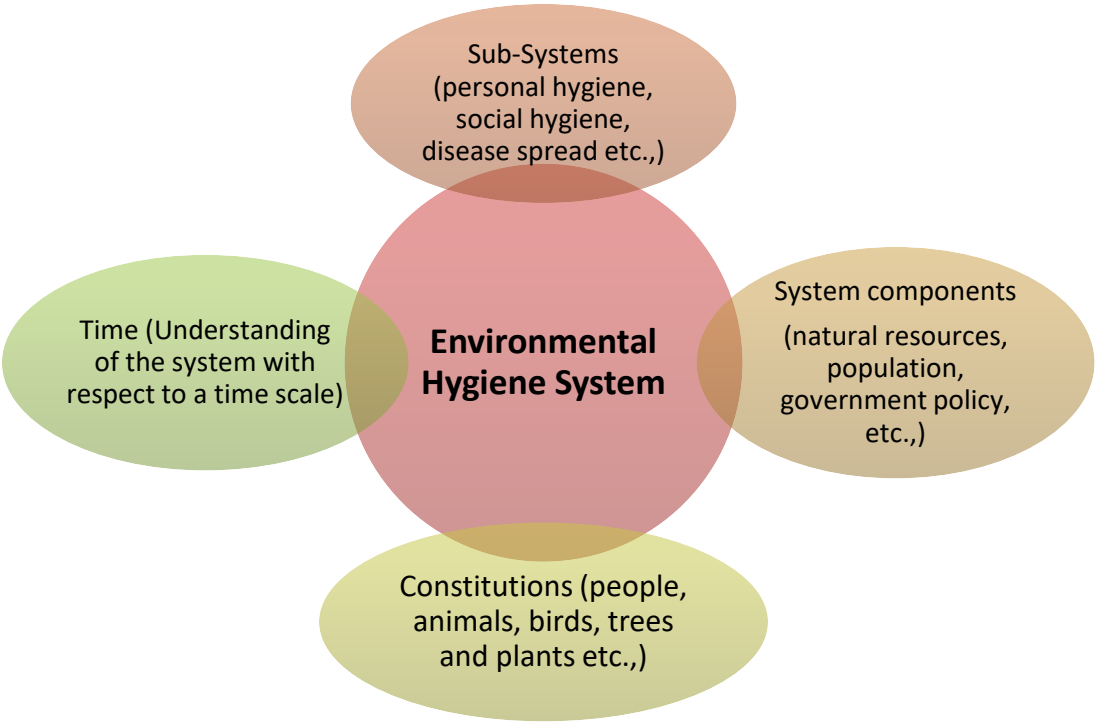


Fig 1.6 Environmental Hygiene System Representations – Holistic Level

Summary

This chapter provides an overview of community mobilization and change management. Importance of community mobilization and need for change management is explained in detail. Four types of changes along with key attributes of change management are explained. Finally, the need to explore system perspective prior to change initiation is explained with case studies. This will help to understand the size of change problem and appropriate planning for smoother transition.

Self Assessment Questions

1. What is change management and why is it important?
2. What is community mobilization?
3. Write two examples of community mobilization you are involved in.
4. How do you represent the system level perspective of a change?

Further Reading

1. James F Kirle, 'The community leadership Handbook: Framing Ideas, Building relationships and Mobilizing Resources', Fieldstone Alliance (5 May 2013)

Video Link

- Importance of change management https://www.youtube.com/watch?v=__IlYNMdV9E)

Chapter 2
Governance of Change

Objectives

1. To understand key change management processes
2. To explore the importance of team for change management
3. To identify and map the appropriate processes and stake holders
4. To map the key characteristics of change leaders
5. To understand the importance of change communication

Structure

3.1: Change Management - Key Process Flow
3.2: Team for Change Management
3.3: Understanding the Stakeholders
3.4: Characteristics of Change Leaders
3.5: Change Communication

To Do Activities

- Consider any social change in your nearby area and establish detailed FMEA table. Analyze the importance of identifying risks and mitigating risks.
- Plan for a change in your classroom. Identify a change leader and team members. Plan and execute the change.
- Watch videos on change management and plan for a group discussion about the need for any change

2.1 Change Management – Key Process Flow

For a successful change management, a systematic thinking approach is required. Identification of primary, secondary and tertiary processes help to implement the change. The primary processes are discussed here and the detailed processes (secondary & tertiary) are explored. For any change management, the following key processes are required.

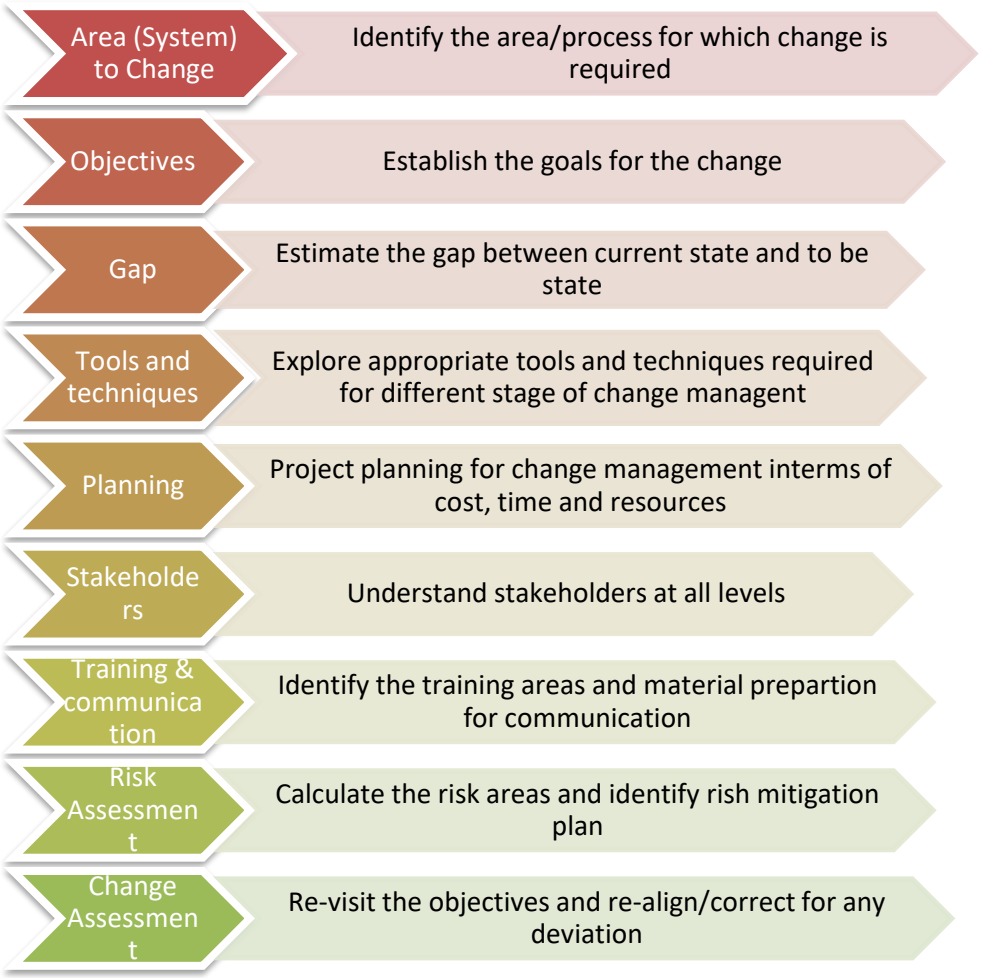


Fig 2.1 Key Process Steps for Change Management

For any change to happen, identification of appropriate area (system) is mandatory. The area(s) is (are) identified based on observation of problems/ complaints. The need for the change is identified based on social cause, technology, economy etc. The current stage of the problem and expected change benefits need to be identified. For a successful change management, it is important to establish process map, identify risks and resources. Transformation can only happen if the benefits are communicated to the stakeholders.

The objectives are identified for the change transformation along with possible benefits to the stakeholders. Identification of stakeholder and process mapping is discussed in detail in the following unit. The perceived 'ease of use' and 'benefits' will facilitate to deploy change management. The gap between current state and to-be state can be identified with the help of many tools such as gap analysis, Pugh matrix, benefit analysis etc. The different attributes such as cost, time and resources are analyzed with greater detail to avoid risks. Failure Mode Effective Analysis (FMEA) can identify the possible risks while deploying change. Risk mitigation plan helps to prepare to overcome risk. The step by step process of FMEA facilitates to identify and mitigate risk in the areas of service, manufacturing, process and policy implementation.

2.2 Team for Change Management

When individuals donot engage with ambiguity for whatever reason and remain highly selective in trying out different approaches, they do not gain too many new experiences. Only a new experience can serve as a basis for new learning. When the experience and exposure are restricted, the supply line of basic inputs for learning and capability building gets choked. In such a situation, individual and organizational capabilities tend to stagnate or even decline.

Characteristics of Purposeful Change Agent
▪ Highly energetic and highly focussed ▪ High levels of self-awareness ▪ High levels of clarity about their own intentions, values and beliefs ▪ Are very careful in picking their goals and battles ▪ Feel personally responsible for company's fate ▪ Welcome opportunities to pursue new goals ▪ Are good at generating and using their energy ▪ Are skilled in finding ways to reduce stress and refuel themselves ▪ Are proactive (They first decide what they must achieve and then manage the external environment)

Any change capability is enhanced when individuals in that system enhance their own capabilities. The three related aspects to capability building by individuals are listed below:

First, they must have confidence in their abilities to learn to enhance their own capabilities. Their positive expectations that their efforts will lead to increased capabilities that are transparent and actions are ethical in nature. These characteristics are called as self efficacy.

Second, they understand the capability. They establish goals with timeline and develop an action plan to expand their capabilities. This is called focus.

Third, they must exert the necessary effort and energy to achieve their goals. This energy is required to drive capability building. Thus the process of building capability requires paying attention to individual attributes such as self-efficacy, focus and energy.

Capability building occurs by achieving challenging goals through process of learning and change. It requires paying attention to learning processes and behavioural contexts that promote learning. As the implementation of change happens, as a leader, it is essential to re-visit the objectives. Re-align the 'change path' and results to the objectives. Change management is an iterative process. There is no strict path or solution since it involves people management predominantly. Frequent review with team members and establish a cross-functional team helps to align the objectives and results.

Cross-functional team represents people from different functions of relevance to the change area. Cross-functional team helps to identify the risks in their respective functional areas. However, there will be a change agent who will lead the entire change management project for any specified task. The change agent is responsible for the smoother transformation of the proposed change initiated. The following figure represents the team to deploy change management. It was found that successful teams in this study were engaged in real-time learning, i.e. analyzing and drawing lessons from the surgical process as it was unfolding. Teams that were successful in learning were also high-performing. The design and management of teams significantly contributed to their effectiveness in learning.

This study also suggests that team leaders in cross functional teams need to:

i. Be accessible,
ii. Explicitly ask for input by inviting suggestions, and
iii. Be willing to admit their mistakes.

These three behaviours create psychological safety for team members and encourage them to experiment with new ideas and behaviours. The research has also found that team leaders who reframe the task of the group as responding to an organizational challenge are likely to be more effective than those that view the task of the group as a technical one. Reframing technical problems as organizational issues creates a higher sense of purpose that can make team members more focused and energised.

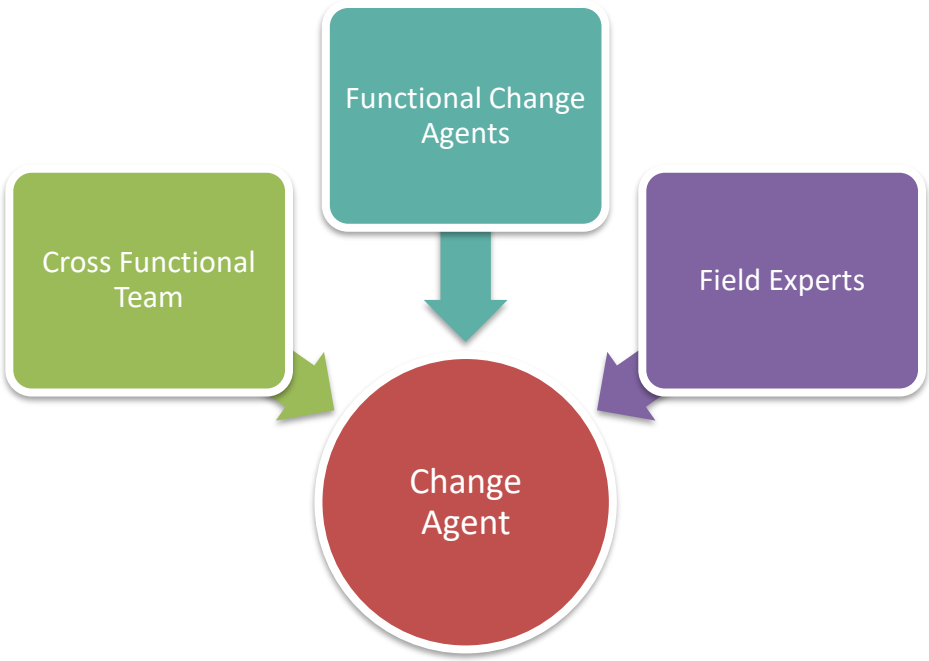


Fig 2.2 Team for Change Management

The cross-functional team shares the knowledge of the functional area, looks for potential risks and deploys the change in the respective areas. Change agents of other functional areas train the people for fieldwork and plan for resources. Field experts provide appropriate technology and tools to the change agent for the smoother execution of the objectives.

The process can be classified into internal and external. Internal processes refer to the system where in the change takes place. The external processes are the one that are outside the study area. For example, river Cooum - not throwing the garbage into the river is internal to the change area, however waste treatment processes are external to the area of concern.

The following figure represents the process of classification from the perspective of change management.

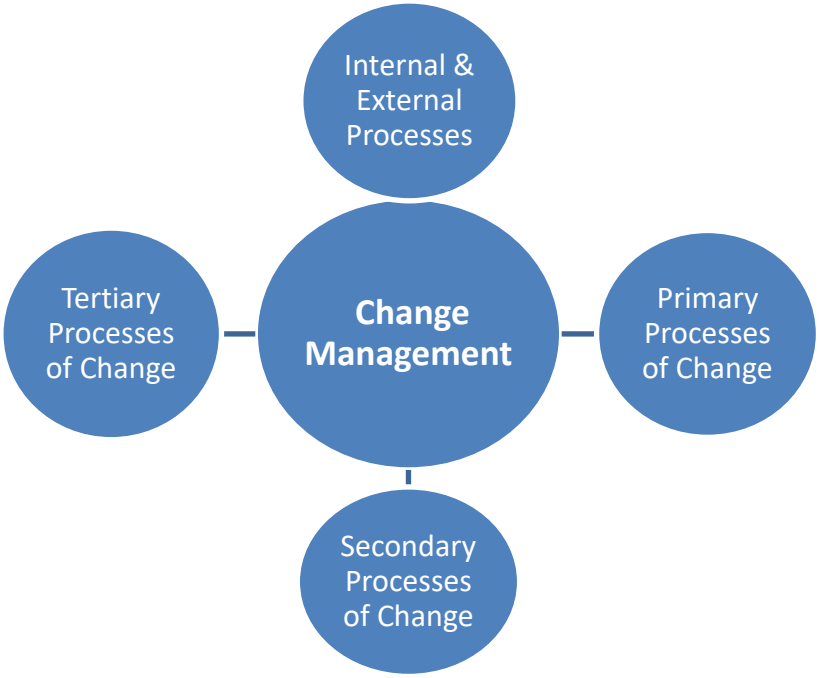


Fig 2.3 Types of Change Management Processes

The process of change management involves frequent visit/re-visit to the objective. For every milestone of the projects the results of the milestone need to align/re-align against the objectives. This will help the team to understand the deviation and keep a course correction plan if required.

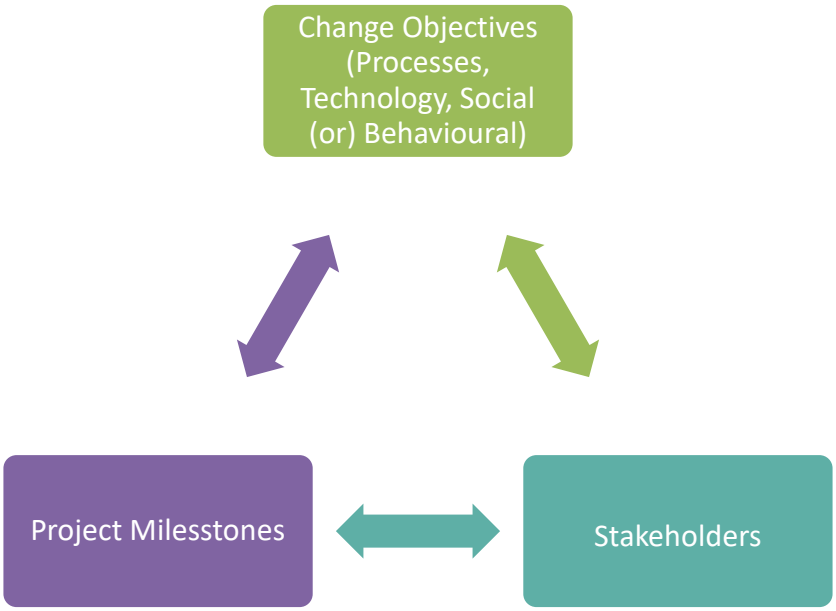


Fig 2.4 Review of Change Management Process

2.3 Understanding the Stakeholders

For a change management to happen, it is important to understand the different people involved. This will help to understand the system, people and their level of association with the system. Stakeholders are people, part of a system under study. Without them, the system cannot exists or operates. For a health care system to operate, the stakeholders are government, physicians and patients. However, pharmacy companies, medical equipment manufacturers and hospital staff etc. are also stake holders. The following figurerepresents the stakeholders of healthcare system.

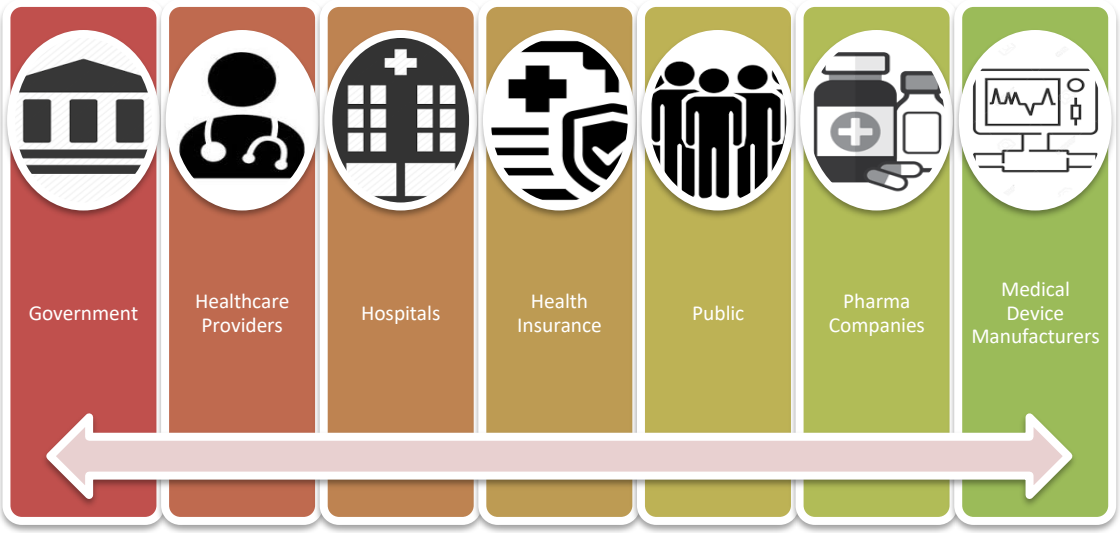


Fig 2.5 Health Care Stake holders

Understanding stakeholders' perspective is considered as one of the key attributes of change management. The problem can be better understood (or) solved if the stakeholders' perspective is studied fully.

The stakeholders can be mapped by understanding the system operation and value chain. The system can be explored by dividing into sub-systems, components, processes and sub-processes. System is executed by set of people / machines / processes put together. System can be divided into simple and complex system. Every process can be divided into multiple sub-processes and associated people (stake holders) will be identified. For a successful change management, it is important to establish process map, identify risks and resources. Transformation can only happen if the benefits are communicated to the stakeholders.

To treat dengue fever, the process can be mapped as follows -

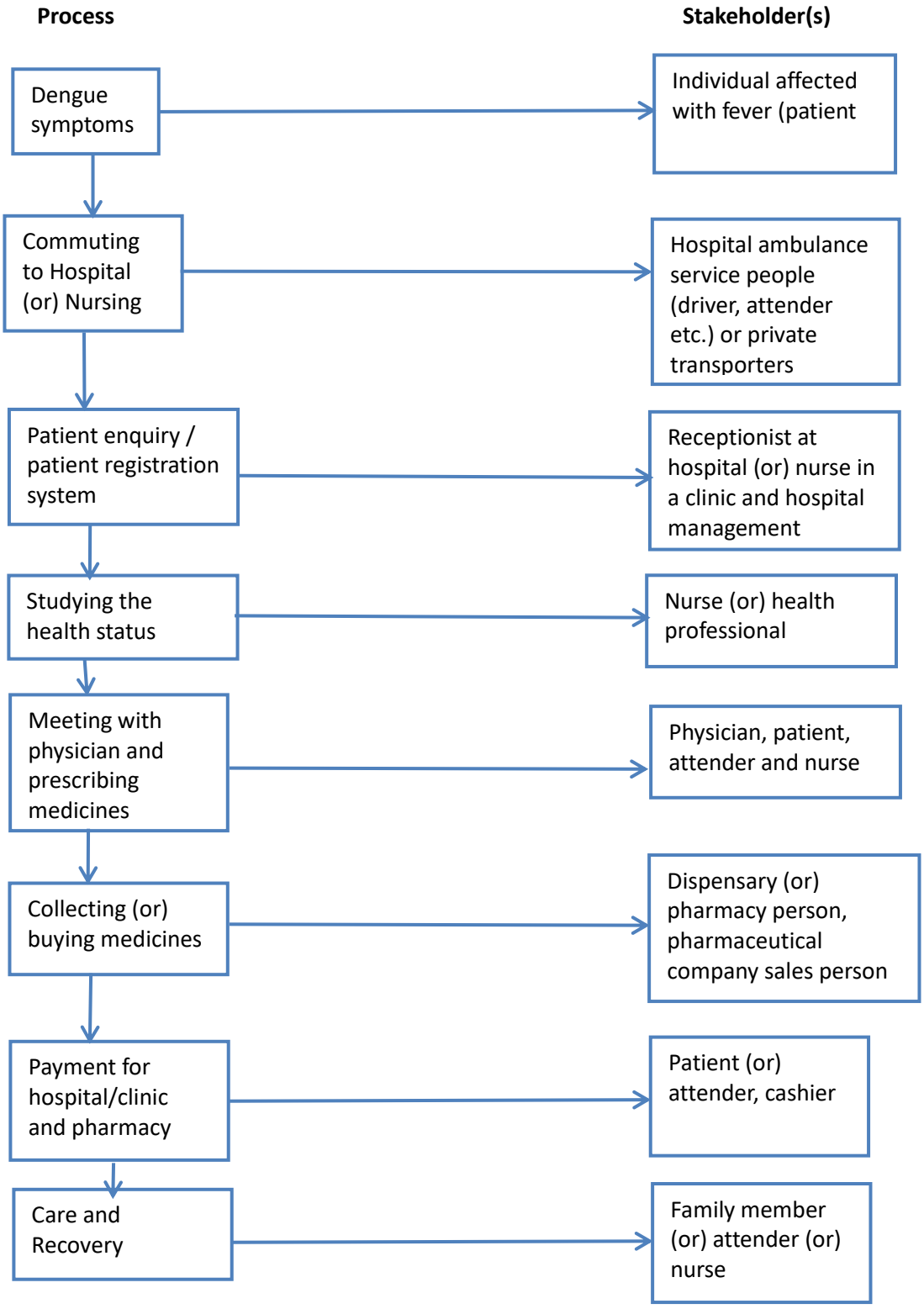


Fig 2.6 Flowchart Method to Identify the Process steps and Map the Stakeholders

Similar to change management process, the stakeholders can be divided into primary, secondary and tertiary. With respect to their association to the change area, they can be divided into internal stakeholders and external stakeholders.

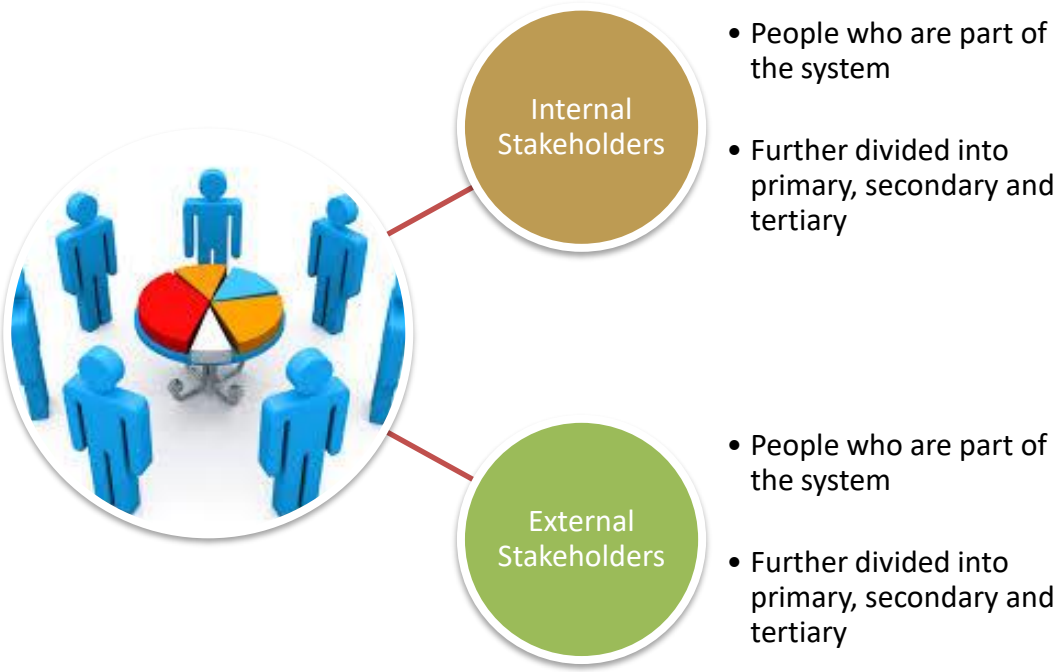


Fig 2.7 Classification of Stakeholder

There are systematic approaches to develop new methods of working. Most important, the change programme also becomes a process of modernising mindsets and changing the way people are motivated.

2.4 Characteristics of Change Leaders

Leading a social change in the current global environment is a tremendously challenging task. However, leadership qualities are necessary at all levels in a society (or) organization. Whether it is a junior, middle or top-level manager, one needs to acquire and develop leadership skills to be effective. It is, therefore, not surprising that leadership has emerged as one of the most important areas for research and training in recent years. The leadership styles can be segregated into multiple ways. However, for the change and community mobilization the leader will have predominantly one of the following characteristics and combination of them. The style of the leader will influence and motivate the team and help in successful implementation.

- Envisioning – Visionary Leader
  - It involves seeing the future, beyond the current constraints and developing an appreciative image or vision of what might be attempted or accomplished.
- Engaging – Committed Leader
  - Engaging involves extending an invitation for involvement in a significant cause. According to Cammock, "it is an invitation that may require great commitment and sacrifice and which often involves intense leader-follower relationships."[i]

- Enacting – Actionable Leader
    - Enactment is about bringing the vision into action. It requires high levels of energy, effort and application over extended periods of time.

The past research identifies six personal characteristics of leadership. These traits are passed on to the team and society for the successful implementation of community change.

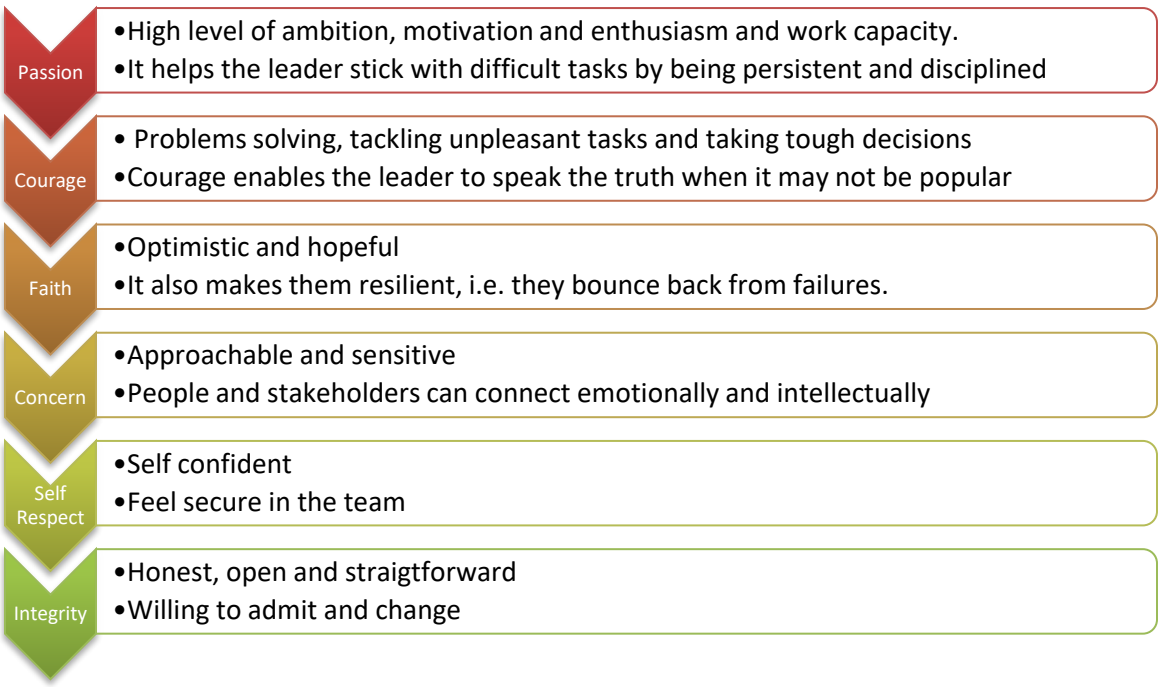


Fig 2.8 Six Personal Characteristics of Leadership

Integrity is probably the most important attribute of a change leader. Integrity means consistency in thought, word and deed. Change leaders have to be people who are consistent in their thoughts, words and behavior. They must practice what they preach. They must live the values that they want their organizations to embrace. While qualities of character and integrity cannot be taught, they can be acquired by discipline and self-development. One needs to work on oneself to develop these qualities.

According to David Hurst, leaders create pathways that direct natural processes to flow along them. He defines leader as a creator, under which self-organization or learning can occur[ii]. The purpose of leadership, according to Hurst, is to build a large-scale loosely connected network of talented individuals who are held together by common values, a shared vision of the future, and a unique sense of who they are as a people. The two most important outputs of these activities are commitment and trust.

Creation and promotion of commitment and trust are central aspects of change leadership. It is the leader's task to create conditions for learning by stimulating meaningful conversations. Meaningful conversations can only take place when relationships are characterized by *trust, commitment and integrity*. Therefore, the challenge of change leadership is promoting trust, integrity and commitment in organizations. Obviously, leaders cannot promote these qualities unless they themselves display the qualities. The most important lesson from leadership research is that change leadership is rooted, *not in charisma, but in character*. Organizational (or) social change requires *value-based* leadership.

The life and work of Mahatma Gandhi provides a powerful example of value-based leadership. Interestingly, he refers to the following as the seven deadly sins:

- Wealth without work
- Pleasure without conscience
- Knowledge without character
- Business without morality
- Science without humanity
- Religion without sacrifice, and
- Politics without principle

Leadership Frameworks in Change Management

The framework describes the key characteristics, attitudes and behaviours to which leaders in change management should aspire.

There are fifteen attributes within the framework, arranged in three clusters:

- Personal Qualities
- Setting Direction, and
- Delivering the Service.

These attributes are defined at different levels of effectiveness, so that it is possible to define or diagnose the level of effectiveness at which an individual is operating at a given time. Different organizations follow different paths to develop a leader. Examples for Leadership Framework can be found below:

1. Infosys Leadership Framework

Infosys, the Indian IT company aspires to be at the forefront of the fast-changing industry in which it operates. The company therefore believes that its leaders require the spirit of learnability and commitment to continuous personal and professional development. To be effective in their leadership roles, individuals need continuous upgradation in specific areas of technology, management, leadership, cultural and communication skills, and other soft skills.

The Infosys framework highlights the following aspects -

- Setting Direction
- Performance Focus
- Relationship Building
- Customer Partnering
- Quality
- Technical / Functional Expertise
- Developing Leaders
- Interpersonal Effectiveness

2. **Tata Leadership Practices**

The Tata Group has developed a common leadership framework for all its 91 businesses operating in different industries such as chemicals, engineering, power, software, steel, tele-services, and hotels. The

framework has been defined in terms of Tata Leadership Practices (TLPs) – a set of behaviours that retain the key elements of the Tata leadership ethos, while taking on the world of tomorrow and the challenges it is likely to throw up. They are called 'practices' to focus on concrete behaviours and actions rather than abstract philosophy. The underlying assumption is that modifying actions is the more effective way to modify values and philosophies. Hence, the TLPs, as they are commonly referred to, are aimed to help shape leaders.

Tata group has three broad themes under which leadership competencies are grouped. The broad themes and the TLPs are given below:

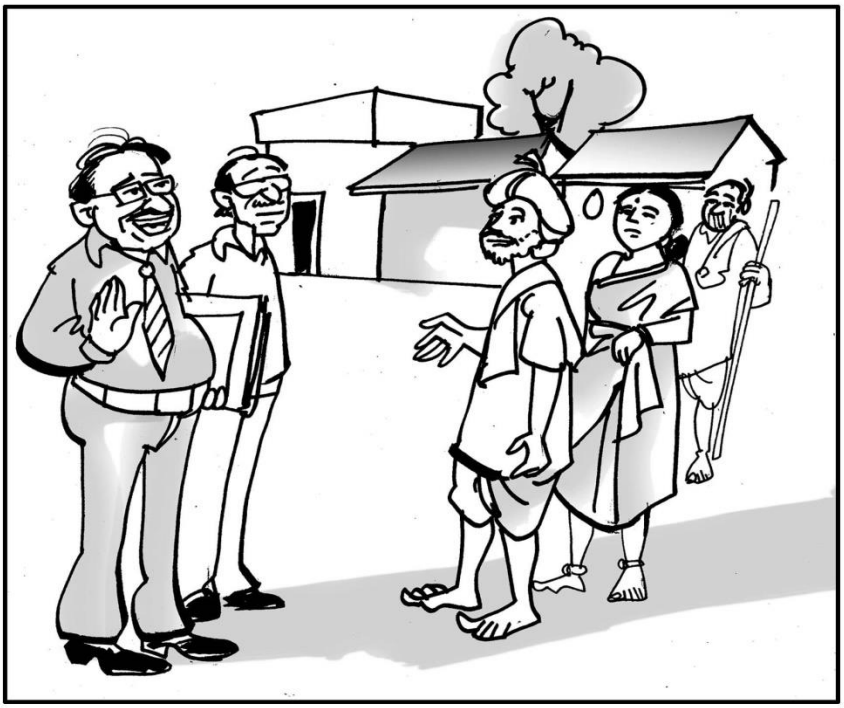
- Delivering value – making money
- Drive for Results
- Timely Decision Making
- Customer Focus
- Innovation Management
- Business leadership
- Managing Vision and Purpose
- Strategic Capability
- Dealing with Ambiguity
- Business Acumen
- Functional Excellence
- People and team leadership
- Taking Ownership
- People Development
- Interpersonal Effectiveness
- Withstanding Pressure
- Building Effective Teams

The Tata Leadership Practices cover different aspects of leadership. Leaders are expected to demonstrate leadership behaviours in each of these areas. TLPs help individuals identify their strengths and also the areas for improvement. They are used for making decisions pertaining to promotion and leadership development.

2.5 Change Communication

The following questions need to be answered for any social (or) organizational level for successful community mobilization (or) change management

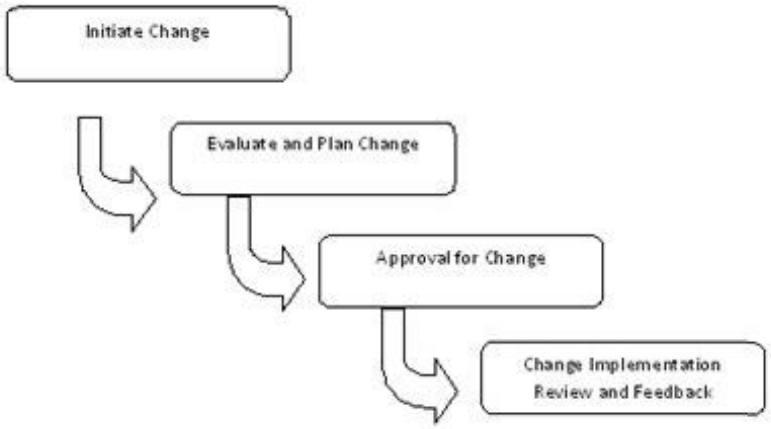
- What can be done to enhance the probability of success of the proposed action plan?
- Are the dates realistic, given other commitments and priorities?
- What can be done to build steps to address key risks and weak spots in the plan?
- Who are the individuals/ groups with whom you have to share the plan?
- How will you communicate with those affected?
- Are there people who should be asked to help with some parts of your project?
- How can you create enthusiasm for the change effort?



These questions bring out clarity to communicate the change. To evolve a workout communication plan, some questions are recommended along with a format for organising the work of communication to different individuals and groups. The questions include:

- What messages should be communicated?
- What are the media through which change should be communicated?

- What is the perceived use of the change initiated?
- Is an ambassador required for nation-wide campaign?
- What are the costs associated with communication?
- Who should receive it?
- What is the appropriate time frame?
- How should the message be communicated?



It was realized that the land acquisition in Delhi would not be easy, and it would get drowned in controversies unless an effective communication campaign and more importantly fair, transparent and customer-oriented policies and processes backed it. This required moving away completely from the precedents for handling this task in the governmental systems. In a similar vein, there had to be an entirely different approach to contractors. The dealings had to be built on bedrock of careful selection based on clear criteria and performance record, trust-based procedures, free & frank sharing of progress and problems, and commitment & mutual support to achieve stretch goals.

Designing appropriate controls and incentives is part of the task of aligning policies and procedures. The change leaders need to be aware that the role of incentives is to *encourage* specific types of behaviour. Incentives alone cannot be expected to create motivation for the desired behaviour. The role of incentives is primarily to facilitate change by reinforcing behaviours that will lead to change.

The need to achieve results and demonstrate competence is a fundamental driving force in all human beings. An incentive system should build on this fundamental need. Therefore, as Herbiniak points out, managers should first ensure that the incentive systems in place do not de-motivate people.[iii] The most effective way to do this in change situations is to first clarify responsibilities and accountabilities.

Summary

This chapter maps the change management processes in terms of team, process mapping, identification of stakeholders etc. The successful implementation of change management depends on planning especially the change agent. The change agent understands and maps every stakeholder's perspective and establishes change objectives. The change communication helps to transform to the new system.

Self Assessment Questions

1. List the key process steps for change management.
2. What are the key characteristics of change leader?
3. What is the importance of change communication?

Further Reading

1. John Kotter, 'Leading Change' , Harvard Business Review Press, 1996
2. William Bridges, 'Managing Transitions: Making the Most of the Change', Da Capo Lifelong Books; 3 edition 2009

Chapter 3
Benefits and Challenges of Community Mobilization

Objectives

1. To understand the key benefits of community mobilization
2. To study Unlearning and learning cycle of a community and an individual
3. To know employment opportunities in rural communities
4. To explore the challenges of community mobilization
5. To adapt and deploy new systems

Structure

3.1 Employment opportunities at Community Level
3.2 Community Learning
3.3 Personality Development and Community Mobilization
3.4 Adapting to New System
3.5 Deployment of Social Change

To Do Activities

1. Do a role play to understand the importance of change communication. The case study on Cooum can be used.
2. Analyze the employment status in your area/region. How can you improve the employment status through community commitments?
3. Form group of 6 and discuss about the personality of everyone and suggest for areas of improvement to become a leader of community/district/state.

3.1 Employment Opportunities at Community Level

According to a general survey done by the National Sample Survey Organization, about 55% of total employment exists in rural sector and only about 35% in urban sector of our country. In India, Below Poverty Line declined to 21.9% of the population in 2011-12 from 29.8% in 2009-10 and 37.2% in 2004-05. In 2011-12, the poverty line had been fixed at Rs 27 spending in rural areas and Rs 33 in urban areas so total poverty is 21.9% at the national level.Government has initiated many employment opportunities to facilitate community mobilization. Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) was launched on February 2, 2005. The Act provides 100 days assured employment every year to every rural household. One-third of the proposed jobs are reserved for women. It aims to initiate community level requirements such as cleaning water resources, clearing landfills, waste separation etc.

The following figure represents the employment benefits of community mobilization:

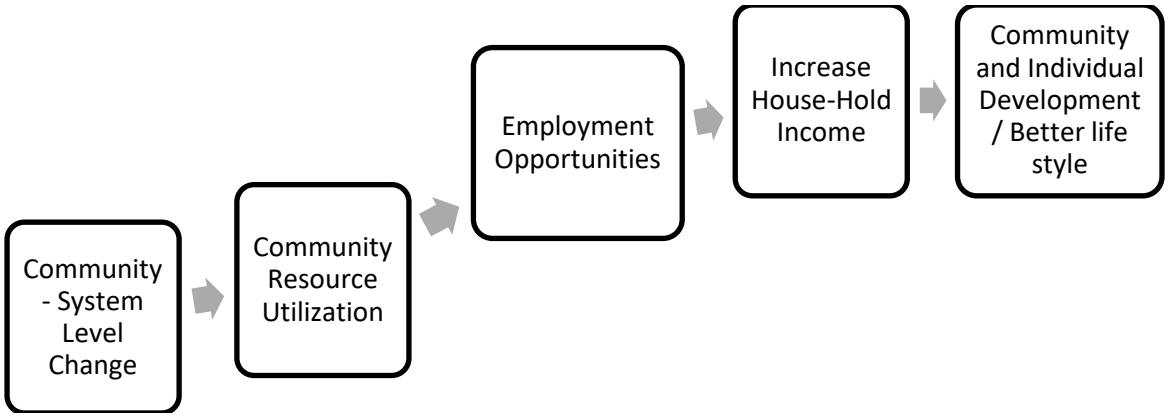


Fig 3.1 Community Mobilization and Employment

Few government initiated employment schemes that benefited in both community mobilization and employment is discussed in this unit.

Integrated Rural Development Programme (IRDP)

The Integrated Rural Development Programme (IRDP), which was introduced in 1978-79 and universalized from 2nd October, 1980, aimed at providing assistance to the rural poor. On 1st April, 1999, the IRDP and allied programmes were merged into a single programme known as Swarnajayanti Gram SwarozgarYojana (SGSY). The SGSY emphasizes on organizing the rural poor into self-help groups, capacity-building, planning of activity clusters, infrastructure support, technology, credit and marketing linkages.

Sampoorna Gramin Rozgar Yojana (SGRY)

The JGSY, EAS and Food for Work Programme were revamped and merged under the new SampoornaGraminRozgarYojana (SGRY) Scheme from 1st September, 2001. The main objective of the scheme continues to be the generation of wage employment, creation of durable economic infrastructure in rural areas and provision of food and nutrition security for the poor.

Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) 2005

MGNREGA was launched on February 2, 2005. The Act provides 100 days assured employment every year to every rural household. One-third of the proposed jobs would be reserved for women. The central government will also establish National Employment Guarantee Funds. Similarly, state governments will establish State Employment Guarantee Funds for implementation of the scheme. Under the program, if an applicant is not provided employment within 15 days s/he will be entitled to a daily unemployment allowance.

Salient features of MGNREGA are:

- Right based framework
- Time bound guarantee of employment
- Labour intensive work
- Women empowerment
- Transparency and accountability

Pradhan Mantri Kaushal VikasYojna (PMKVY)

The cabinet on March 21, 2015 cleared the scheme to provide skill training to 1.4 million youth with an overall outlay of Rs. 1120 crore. This plan is implemented with the help of Ministry of Skill Development and Entrepreneurship through the National Skill Development Corporation. It will focus on fresh entrant to the labour market, especially labour market and class X and XII dropouts.

National Heritage Development and Augmentation Yojna (HRIDAY):

HRIDAY scheme was launched (21 Jan. 2015) to preserve and rejuvenate the rich cultural heritage of the country. This Rs. 500 crore programme was launched by Urban Development Ministry in New Delhi. Initially it is launched in 12 cities: Amritsar, Varanasi, Gaya, Puri, Ajmer, Mathura, Dwarka, Badami, Velankanni, Kanchipuram, Warangal and Amarvati.

These employment schemes play a very crucial role in the development of all sections of society so that the concept of holistic development can be ensured in the real sense. The rural community benefits from the employment and witnesses improved lifestyle.

3.2 Community Learning

Another important aspect of community change program is to learn and improve continuously. Learning requires unlearning. Community should be able to unlearn by giving up old habits, attitudes, assumptions, behaviors and mindset to adapt new systems. Unlearning, however, is a difficult process that has received little attention in the literature on community mobilization.

There is an old story of a person who had come to visit a Zen master. The visitor claimed that he had read widely, but was interested in finding out if he could learn anything more from the master. The master offered him a full cup of tea, but continued to pour more tea into the cup from the tea jug. The visitor was intrigued, and pointed to the tea overflowing from the cup on to the ground. “Just as the cup is too full to hold any more tea, you may be too full to learn anything new”, said the master. ““For new learning to find space within you, you have to first give up the belief that you already know those things”.

Todd Jick described the complex psychological processes of passing through difficult, often conflicting, emotions. He identifies three transition stages:

- Ending phase and letting go - This involves letting go of the previous situation. This may involve dramatic emotions such as pain, confusion and terror. People experience a sharp break with a familiar past that had been taken for granted.
- Neutral zone - This involves completing endings and building energy for beginnings. People may feel adrift and confused. They become ineffective and unproductive. They are disoriented. They need to bury the past. The old mindset needs to be disintegrated. They begin to discover new possibilities.
- New beginnings - This includes new possibilities or alignment with a vision.

These phases take time and cannot be accelerated. If community tries to speed up the process (or) ignores the unlearning and learning process, it risks carrying unfinished psychological "baggage" from one phase to the next. Sufficient time needs to be spent on learning that helps to adapt to new systems. In community mobilization, people move from old practices to new systems. Every new process requires learning and adaptation. People move from discomfort with risks to acceptance in four stages.

The following figure represents community unlearning to learning:

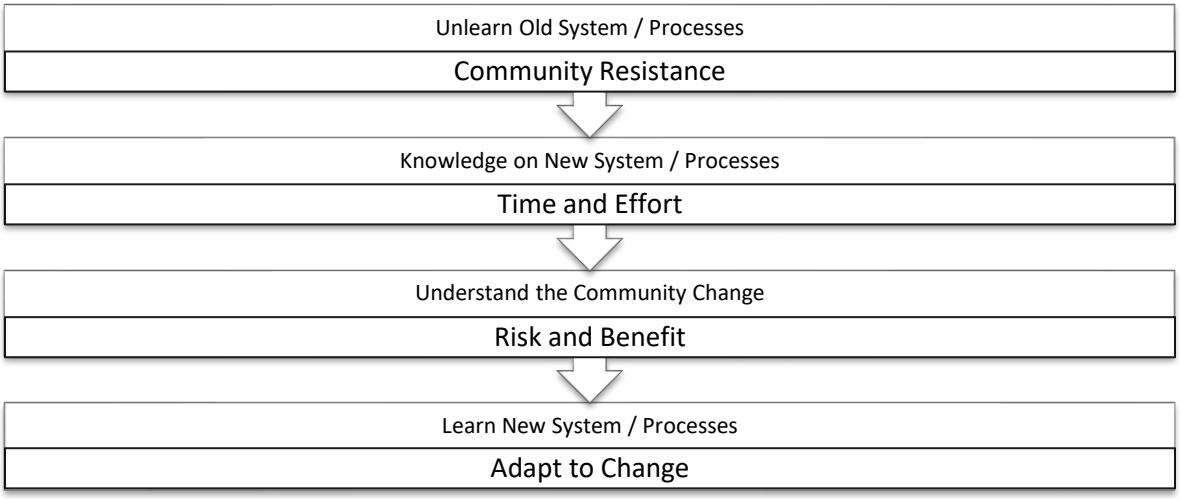


Fig 3.2 Unlearning to Learning in Community Mobilization

In the unlearn phase, people resist the change. They may not have sufficient knowledge about the community change. They feel unsafe, indecisive, and unable to take any action. They may deny that any change is taking place. People still feel uncomfortable and unsafe.

Table 3.1 Community Capability and Benefits

Community Capability	Benefits
Skills	Developing inquiry skills; Building mindsets of systematic problem solving; Getting people in various leadership roles to act as role models to spur learning and innovation

Systems	Building up systems for identifying improvement opportunities, rewarding knowledge sharing, communicating change priorities, filling employee skill gaps, searching for and testing new knowledge, effective action planning etc.
Gender Inequality	Equal ease of access to resources and opportunities regardless of gender, including economic participation and decision-making; and the state of valuing different behaviors, aspirations and needs equally
Structures	Strengthening linkage & integration to bridge organisational 'boundaries'; Enhancing discretion & flexibility; Assigning specific responsibilities for learning initiatives
Strategies	Developing stretch goals and expressing these in a manner that communicates excitement of achievement, progress and contribution; Articulating the capabilities required to effectively execute strategies
Culture	Creating a context characterised by discipline, support, trust, and stretch; Shaping a culture of free & frank dialogue, boundarylessness, risk taking and seeking to be the best

However, with time and effort people eventually come to accept that they have lost something and mourn. They experience both grief and liberation. They begin to take risks and are gradually able to build their confidence.

During adaptation and change period, people feel comfortable with change. There is great energy for risk taking. The change is internalized. People move on and help others to change. They may also become advocates of change.

3.3 Personality Development and Community Mobilization

With an appropriate skill-base, communities are more capable of making quick and effective performance improvements. They develop inquiry skills of questioning, listening, facilitating discussions, creating excitement, constructive conflict management, self-reflection and learning to learn. As a whole the community development process results in individual personality development. The following figure 3.3 represents the community and personality development, as a result of community mobilization:

Fig 3.3 Result of Community Mobilization - Individual and Social Development

Some personality development traits as a result of community mobilization are

- Develop systematic problem solving skills to enable individuals to view situations from multiple perspectives, think systematically and think critically
- Make important skills more broad-based, rather than narrowly concentrated in specialised staff groups or senior leaders
- Get people holding various leadership roles to pay conscious attention
- Clarity about own intentions, values and beliefs
- Respect and give equal importance to opposite gender
- deconstruct the larger challenges and goals into manageable components
- Empower people by enhancing self-efficacy
- Encourage and support innovative behaviour
- Accept mistakes, and act as role models to spur learning and innovation

Dimensions of Change	Theory E	Theory O	Theories E and O Combined
Goals	maximize shareholder value	develop organizational capabilities	explicitly embrace the paradox between economic value and organizational capability
Leadership	manage change from the top down	encourage participation from the bottom up	set direction from the top and engage the people below
Focus	emphasize structure and systems	build up corporate culture: employees' behavior and attitudes	focus simultaneously on the hard (structures and systems) and the soft (corporate culture)
Process	plan and establish programs	experiment and evolve	plan for spontaneity
Reward System	motivate through financial incentives	motivate through commitment—use pay as fair exchange	use incentives to reinforce change but not to drive it
Use of Consultants	consultants analyze problems and shape solutions	consultants support management in shaping their own solutions	consultants are expert resources who empower employees

Systems provide mechanisms to exchange ideas and reach quick and effective decisions. Thoughtful systems (for example, information systems infrastructure, systems for performance measurement, communication and human resource management) ensure that individuals are supported and guided in their efforts to deploy skills effectively. For example, specific systems can be strengthened as outlined below:

- Performance measurement and review systems are designed to help identify problems and improvements, reward knowledge sharing, and use progress reviews to get to root causes of problems faced
- Communication systems help broadcast change priorities and results of successful change efforts to encourage people, and support collaboration between different parts of the organisation,
- Human resource management systems identify and fill skill gaps, provide individuals greater exposure and greater variety of experiences by offering opportunities to work on challenging projects, give incentivesto staff to commit their time and efforts to change priorities, bring people from different work areas together in regular dialogue and discussion, and reward development of new ideas and skills and innovations.
- Search for and test new knowledge through on-going programmes and demonstration projects and utilise best practices or bench marking/ peer comparison studies for feedback and learning.
- Transfer knowledge quickly and effectively through programmes for personnel rotation, reports, education & training, standardisation, knowledge management initiatives, incentives, etc.
- Institute diagnostic and action planning forums where individuals share their difficulties, decision making levels have free & frank conversations with operational levels, priorities are worked out, different alternatives are critically examined, appropriate decisions made, and follow-up initiated.

Structures channel attention to specific concerns and induce capacity for coordinated action. By providing the right behavioural framework, structures can get people into an 'actor' (rather than 'spectator') mode and thus favour learning. Strategies reflect the aspirations and so provide the rationale for capability building. Stretch goals provide the demand for generation of capability.

Culture or mindset represents the bedrock or foundation for capability building efforts to survive and thrive. Without appropriate mindsets, structures and systems may lead to conformity, but not yield committed actions.Few recommendations for community mobilization to help people deal with change. First, they must *not* consider resistance to change as an obstacle or something that needs to be overcome. Resistance must be seen as a natural process of adapting to change. Frequently, strong negative emotions that are evoked by change are labeled as resistance to change. Resistance may also be for rational reasons. Resistance to change needs to be considered as a healthy part of the change process. It must be seen as a positive step toward change. It provides energy to work with and gives information critical to the change process. Resistance must be accepted, acknowledged and managed instead of being brushed aside. Second, need to give emotional first aid to individuals experiencing change. This involves simply listening to their feelings and experiences without being judgmental. They need to be given information about the change, support and counseling. It also involves identifying what is not changing and uncovering the reasons for this. The community must create the capability for change by providing safety and rewards. These efforts will make the smoother community learning process and personality development of individuals and encourage the community mobilization.

3.4 Adapting to New System

The community mobilization results in a process level change (simple) or system level (complex) change. The community has to unlearn the existing practice (or) process and learn the new process. These can be done by setting up newer and creative change routines. Adding creativity to the routines make the people enjoy the change before acknowledging the change results. There are new ways to change the community routine. The following figure gives few ideas to break the barrier of community.

Fig 3.4 Idea Exploration to Adapt New System

After the right ideas have been generated, they need to be generalised for deriving the maximum benefit. This would require routines for moving ideas from one leader to the next, from one geography to another, or from one business unit to another.

Case Study 3:Manthan at Tata Chemicals[1]

Prior to mid-1990s Tata Chemicals thrived in a sellers market within an insulated economy. But the economic liberalization brought the earlier regime of import restrictions and huge tariff barriers to an end, and the nature of the company's business environment changed dramatically. For example, the import duty came down progressively from a high of 150% to 10%. Additionally, the organization was confronted with the adverse impact of overcapacity in the industry, threat from imports and price-cost squeeze. For its sheer survival, new routines had to be instituted for learning and continuous improvement. It was realized that creating these learning routines would be quite challenging in an organization that had been established in 1939 and that functioned as a closely knit community in Mithapur, a small town quite distant and detached from the outside world.

The initiative of bringing in innovation and learning was termed as *Manthan*. Manthan, a Sanskrit term for churning, is a powerful metaphor to describe the processes that ensue when the difficult task of self-evaluation is undertaken. In the Hindu mythology, SamudraManthan (churning of the ocean) was aimed at attaining the nectar of immortality. In Tata Chemicals, it signified churning of minds and ideas to produce fruitful results in terms of significant operational improvements in different areas ranging from manufacturing to purchasing to supply chain management. It was expected that the innovations and improvements would occur with little or no investment of funds.

[1]Refer: http://www.samatvam.co.in/case-studies/Project-Manthan-(Tata-Chemicals)-Mr-B-Sudhakar.pdf

Manthan sought to institute and sustain the following three critical routines for making improvements and innovations through cross-functional teams:

a) A tightly time-based problem solving process oriented to a clear purpose
b) A bottom-up idea generation process with middle management and staff cooperation
c) Stretch targets for cost reduction in each unit and a detailed idea implementation process

As a part of the initiative, small teams were expected to get involved in the process of challenging prevailing assumptions about the 'way we have always done things' and come up with ideas for improvements. More than 100 employees were initially trained on these new routines. In these training workshops, the organizational members were educated on analyzing operational processes, developing databases, working out priorities, reviewing & evaluating ideas, obtaining sign-offs from key actors, planning implementation steps and so on. There were, for example specified routines for categorizing costs into compressible, semi-compressible and non-compressible categories.

The initiative was championed by a steering committee. The steering committee roles and responsibilities were clearly specified. Different teams were constituted to carry out improvement activities, and the coordination of these teams was expected to be carried out by the program leader and program coordinator. They were expected to link the teams with the higher management, select team leaders and facilitators, and actively remove barriers to quick and effective implementation. There were detailed role descriptions for team leaders, senior facilitators and facilitators. Thumb rules were also outlined for selecting the operational issues to work on, target setting etc.

The elaborate role definitions, clear specifications for choosing improvement areas or analyzing costs helped provide clear criteria in terms of *who, what, how and when* at different stages of problem solving to guide thinking and action. They deconstructed the broader goal into specific aspects and provided clear rationale for choices, and thus contributed to speed of decision-making and action. Thus they helped the new routines for learning to take root. In the words of one of the participants, "The project created a new vocabulary that was shared among the team members. The use of business and financial language helped us perceive and deal with aspects that we had not even thought of earlier".

Based on above case study evaluate the following:

1. List the benefits of tools and techniques towards adaptability.
2. What are the ground rules do you think is required for successful new system adaptation.
3. Review the success of "Manthan" project from a team member's perspective.

The clearly defined purpose and well-thought out processes ensured that the approaches followed by team members were appropriate for effective problem solving and their actions added value. The following figure represents the purpose of process effectiveness matrix.

When people are highly preoccupied with processes but don't share a strong sense of common purpose, they become bureaucratic. High sense of purpose, but without corresponding attention to processes leads to well-intended actions, but underutilization of potential resulting from factors like uncoordinated initiatives. When a unit is high on both purpose and processes, people become both 'Trained and Knowledge-Able' and so add value.

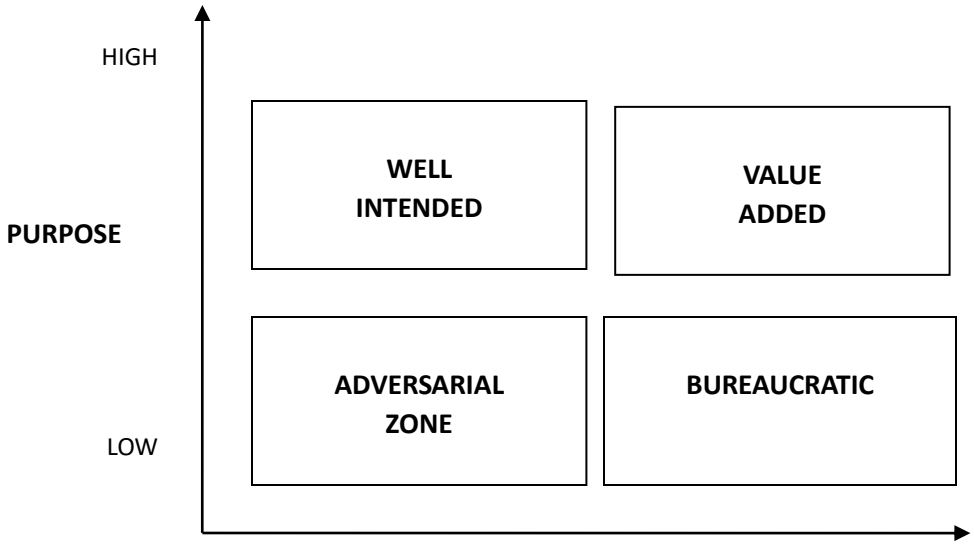


Fig 3.5 Result of System/Processes Change on People

3.5 Deployment of Social Change

Social change process will be implemented in all appropriate and suitable communities. Executing community change requires focus and energy of stakeholders. Change leaders need to sustain focus and energy throughout the organization during the execution phase. Human aspects of change are as important in executing change. Community needs to accept the need for change. Therefore, it is important to build a behavioural climate that emphasises hope and optimism. By initiating actions that sustain hope and optimism, change leaders contribute significantly to addressing the need for control and maintaining sense of competence.

> Community needs to accept the need for change. Therefore, it is important to build a behavioural climate that emphasises hope and optimism. The mind-set of collaborative functioning requires the leaders to set the right context by developing a larger purpose that makes a compelling case for people to work together.

The first task is setting up integration and coordination mechanisms to enable people to work and learn together. The mind-set of collaborative functioning requires the leaders to set the right context by developing a larger purpose that makes a compelling case for people to work together. The context in terms of performance expectations, rewards and skill sets should facilitate cross functional teams to discover pathways to reach the organisational stretch goals that cannot be achieved by the different functions acting on their own without attention to issues of interdependence.

This unit highlights the implementation challenges and explore what can go wrong while implementing the community change.

Lack of understanding of size of change

Community mobilization can be withdrawn because of the perceived nature of the change. Many times the change agents (or) community (or) government make the mistake of attempting to execute complex change with the mindset of simple changes. In such a scenario, community runs into problems. To start with, people at different levels and functions end up having conflicting and confusing interpretations of what has to be done and how, even though the larger direction has been clarified with reasonable clarity. So people start pulling the change in different directions.

Given the level of uncertainty associated with complex change, it is difficult to plan out all the details of execution right at the start. However, change leaders will have to re-align the process and execution to the change objectives. Leaders have to get things started and collect adequate information. There has to be some 'on the job learning and experiential learning'. This would have to be in terms of identifying what the impediments to effective execution are, and taking quick corrective actions.

System Clarity

Any change simple or complex is either part of a system or collection of systems. It is important to understand the holistic system, sub-systems and their components. (Refer Unit 1.5 for better understanding of system representation). Lack of understanding of system either in terms of interaction between sub-systems or missing connection will mislead the implementation.

Sense of Community Mobilization

Communities need worthwhile purposes to direct their energy. For this, goals must be clear, specific and realistic. People must be able to see how their goals contribute to the larger mission of reinvention. As we saw earlier, the goals assigned to cross functional teams challenged the members to think beyond their boundaries and question the traditional ways of doing business. Specific goal-setting enables people to focus on the task rather than groping in the dark. When people are able to visualize the larger picture and yet at the same time be clear about their assigned tasks, they become hopeful and optimistic. This also makes them committed to the reinvention process.

Deconstruction of Change Goals

It is important to break the complex goals down into manageable sub-goals. Individuals tend to get prioritize when the problem is too huge to tackle. To maintain our sense of competence, we must feel that our problems are controllable at every level. The goals can be prioritize with respect to two major objectives: Time (Urgent to not urgent) and level of importance.

Preparing the Community People

People are more hopeful when they feel confident of managing the unexpected. Contingency planning, scenario analysis and alternate courses of action all instil a sense of readiness for multiple possibilities. If people have visualized multiple alternatives for handling the challenges, they feel sure of their decisions and actions. When there is hope and optimism, execution challenges are perceived as opportunities.

Change Leaders

Effective change execution requires a change leader to understand and address these challenges. Organisational change, in its essence is about bringing a change in organisational routines. The routines that are ineffective, inappropriate and dysfunctional need to be identified and changed. This requires exposing people to alternative perspectives to free them the dysfunctional constraints of their mental models. This would happen when people are exposed to customers and people from other functions, and have the possibilities of working together with them. Roadblocks and barriers to modifying existing routines need to be identified and removed. And new routines need to be created to focus the organisational attention on continuous improvement.

During execution, it is also necessary to identify factors obstructing the process of smooth, quick and effective change execution. Sometimes there are structural impediments; at other times, incentive systems may not be aligned to the organisational goal. Change leaders should create a favourable context where even weak signals pertaining to structural and systemic impediments get quickly identified and then actions are taken to minimise and eliminate these.

Finally, change leaders cannot merely restrict their concerns to structures and systems. They should concentrate on people aspects of executing change. There should be a behavioural climate for people that creates and sustains hope and optimism. This would give individuals the much-needed sense of control and competence as they embark on the journey of uncertainty through complex change. Having attended to the strengthening of roles, systems, linkages and procedures, they should create a context that addresses the subjective world of organisational members. It is this subjective world that determines what people see and how they would think and act.

Professor Todd Jick has written extensively on organisational change. His research conducted on change management in 93 organizations identified the following pitfalls in implementation of change:

- Implementation took more time than originally allocated
- Major problems surfaced during implementation
- Coordination of implementation activities was not effective enough
- Competing activities and crises detracted attention from implementation
- Capabilities and skills of employees involved in implementation were not sufficient
- Training and instruction given to lower-level employees were not adequate
- Uncontrollable factors in the environment had an adverse impact on implementation

Thus effective change management involves modifying existing routines, eliminating some old routines and introducing a few new routines. Why do we need to change a routine? An organization may underperform if its routines are dysfunctional or inappropriate.

Summary

This chapter provides overview of the key benefits and challenges of community mobilization. For any system level change the size of the problem should be clearly studied and mapped. This will facilitate smooth transformation of the community by unlearning the old process and learning the new process.

The community mobilization not only improves the environment but also develops skills at community and individual levels. It also provides employment opportunities and increased household income. However, overcoming the change resistance and mind-set to accept the new system are the key challenges of community mobilization. System level understanding, adequate resource planning and risk mitigation plan will enrich the transition.

Self Assessment Questions

1. What is the importance of change communication? Analyse with an example.
2. Identify a social leader of your choice and explore how he transformed the society.
3. Explore the employment schemes in your area. Understand the challenges of successful implementation of the employment scheme.

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2. Wealth from Waste - Agricultural food and chemical Processing Waste by S.C.Bhatia
3. Integrated Solid Waste Management, Engineering Principles and Management Issues by George Teho Banglous Hilary Theisen Samuel A. Vigal
4. Smart Cities - Transforming India - Prof M.P Dube
5. Waste Management Practices by John Pichtel
6. Solid wastes management by Stephen Burnley
7. Eco-Economy: Building an Economy For The Earth by Lester R.Brown
8. Not in My Backyard - Solid Waste Mgmt in Indian Cities by Sunita Narain & Swati Singh Sambyal

Semester I

Part II

Waste Management Logistics
Water Security and Waste Water Management
Community Mobilization and Change Management

PG Diploma in
Waste Management & Environmental Hygiene

Department of Higher Education
Ministry of Human Resource Development, Government of India

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Department of Higher Education

Ministry of Human Resource Development, Government of India

Where there is Rural Wellbeing
there is Universal Prosperity