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URBAN WATER MANAGEMENT

DEM 103

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DEM 103 URBAN WATER MANAGEMENT CR 4

UNIT-1: URBAN WATER USE AND INFRASTRUCTURES

UNIT STRUCTURE

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1.0 OBJECTIVES

After going through this unit, you will be able to:

- discuss urbanization and escalated water use
- discuss the quality, accessibility and availability of water in the urban set-up
- describe the rainwater infiltration process
- discuss rainwater harvesting

1.1 URBANIZATION AND ESCALATED WATER USE:

Demographic changes have significant impacts on water use and its management. Fig.1 shows the past and predicted population growth in Japan and Southeast Asian countries from 1950 to 2025. After going through this unit, you will be able to: It reveals a similarity in urban population growth from 1950 to 1970 in Japan and the coming future of Southeast Asian countries. This means that the early urbanization stage in Japan is being experienced in Southeast Asia; therefore, the history of water management in Japan could be useful to explore better ways of water management for Southeast Asia. A stable water supply and efficient water use have become concerns in mega cities. It is necessary to introduce new concepts, policies and measures for sustainable water use and management. (Wagner et al.,2002,Furumai, 2007).

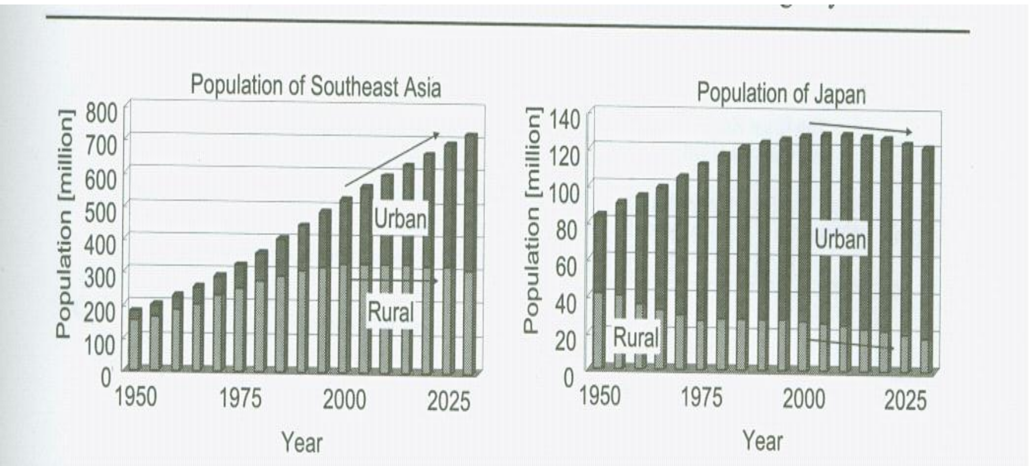


Fig1: Urban and Rural population in Southeast Asia and Japan

Fig.2 shows representative locations with ground subsidence problems and how their cumulative subsidence changes over time. In Tokyo, large scale groundwater pumping started in 1914. In the following years, the number of deep wells with a large diameter increased rapidly. Ground subsidence was first observed in Tokyo in the 1910s, and in Osaka in the 1920s.

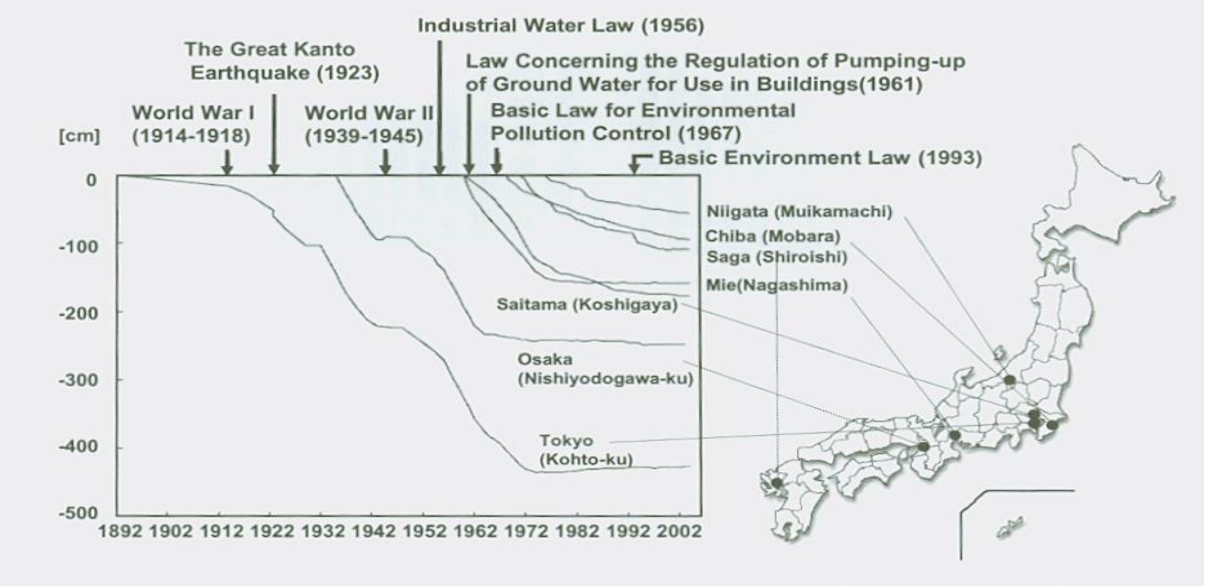


Fig.2: Cumulative change in ground subsidence in typical areas over time

The groundwater level continued to fall due to the extensive pumping to support increased production activities. Ground subsidence caused the destruction of buildings, damage from floods and high tides and rising public concern. By the mid-1940s, the damage to industry from World War II reduced the industrial use of groundwater, thereby halting ground subsidence. With the rapid progress of urbanization due to economic development after World War II, water supply had to catch up with remarkably increased water demand for domestic and industrial purposes. There was a sudden surge in demand for groundwater, and major subsidence took place again, especially in large urban areas.

Counter measures against ground subsidence, e.g., control of ground water pumping rates, were started in the 1960s and there after, the arte of subsidence in metropolitan areas slowed. Nowadays, measures have been introduced to control the abstraction of the water level and to avoid changes in the subsidence levels by optimizing water use and introducing new sources of water.

Urban water consumption has a major impact on the natural water cycle and consequently on the water environment. Therefore, understanding the urban water cycle, the potential of rainwater use and water recycling in urban areas is important for sustainability. In the case of mega cities, the sustainability of urban water use has become important in terms of a stable water supply and efficient water use. The achievement of sustainability is required to ensure a long-term water supply with adequate quality while minimizing adverse economic, social and environmental impacts.

1.2 QUALITY, ACCESSIBILITY AND AVAILABILITY OF WATER IN THE URBAN SETUP

In many countries, water shortages stem from inefficient use, degradation of the available water by pollution and the unsustainable use of underground water. Water can be provided in rural and low-income urban areas through the utilization of low-cost technologies that include hand pumps, gravity-fed systems and rainwater collection, which would be built to serve entire rural villages or urban neighborhoods, rather than bringing indoor plumbing to individual houses. The provisions would include pumps, pipes, the training of workers, and the development and strengthening of water management practices.

1.2.1 INEQUITIES IN WATER ACCESSIBILITY

Access to piped water has been a significant factor in health improvements in most developing regions. As opposed to other water sources, piped water can provide water to homes, plots, and yards and is thought to be the safest drinking water source, provided that the pipes are maintained to ensure water quality. On an average, urban households have more piped water coverage than rural households, but large inequities exist between and within cities.

For example, while wealthy city dwellers may experience a comfortable availability of safe drinking water, 137 million urban inhabitants do not have access to a quality water supply. Water transmits over half of the world's diseases, and 25 million deaths occur annually due to water pollution. The most substantial gaps exist between the richest and the poorest city dwellers of Africa, the Americas, and Asia, but it is also important to consider the inequities that exist along the entire socioeconomic gradient. Though correlations vary between regions, studies indicate that the level of piped water access corresponds to the wealth of those accessing it. In some countries such as Mozambique, this difference is very large, while in other countries, including Morocco, inequities are less notable. Within cities, slums are usually overlooked, and administrative data often refer to existing water sources without taking into account whether or not they are actually usable. Though water systems may be in place, they need to be maintained in order to provide safe and potable water.

1.2.2 WATER SHORTAGES AND POLLUTION

In the larger picture, urban water shortages and water pollution can affect an entire city and its surrounding regions. In poor areas, the only drainage system available is often flushable toilets, so people waste a great deal of water by flushing away dirty water and waste. This leads to significant city water shortages even though it improves sanitation in individual households. Moreover, sanitation, by necessity, uses large volumes of clean water, further contributing to the shortages. Countries could conserve more clean water by separating the water needed for consumption from the water needed for washing, as the latter would still be safe at a lower quality.

Apart from physical water shortages, many shortages occur based on the availability of unpolluted water. In countries with weak piping systems and maintenance, a large proportion of water (up to 70% in some developing countries) leaks through pipes and makes quality water coverage more costly. Many cities face major obstacles in dealing with water pollution from human and domestic waste, poor sewage and water treatment systems, and recycling of water. Waste can also contaminate areas outside of the local environment through groundwater, lakes, and rivers that are used for fresh-water supplies by communities in surrounding areas. In nations that provide frequent treatment, river water is often recycled repeatedly before it reaches the ocean. However, in developing countries that lack adequate treatment service, river water becomes unsafe to use once it is polluted after passing through one city.

1.2.3 URBANIZATION AND THE WATER CRISIS

The consequences of the increasing global water scarcity will largely be felt in the arid and semi-arid areas, in rapidly growing coastal regions and in the megacities of the developing world. Water scientists predict that many of these cities already are, or will be, unable to provide safe, clean water and adequate sanitation facilities for their citizens -- two fundamental requirements for human well being and dignity.

The problem will be magnified by rapid urban growth. In 1950, there were less than 100 cities with a population in excess of 1 million; by 2025, that number is expected to rise to 650. By the year 2000, some 23 cities -- 18 of them in the developing world -- had populations exceeding 10 million. On a global scale, half of the world's people will live in urban areas.

Some of the world's largest cities, including Beijing, Buenos Aires, Dhaka, Lima and Mexico City, depend heavily on groundwater for their water supply, but it is unlikely that dependence on aquifers, which take many years to recharge, will be sustainable. Groundwater from aquifers beneath or close to Mexico City, for example, provides it with more than 3.2 billion liters per day, but already water shortages occur in many parts of the capital.

As urban populations grow, water use will need to shift from agriculture to municipal and industrial uses, making decisions about allocating between different sectors difficult.

Water scarcity is aggravated by six principal factors:

1. Reluctance to treat water as an economic as well as a public good resulting in inefficient water use practices by households, industries and agriculture - Farmers pay too little to cover the whole cost of water resources development; very often in developing countries households pay a lump sum tariff for their water use.

2. Excessive reliance in many places on inefficient institutions for water and wastewater services. There is no incentive to improve their efficiency and reliability under the current organizations.

3. Fragmented management of water between sectors and institutions, with little regard for conflicts between social, economic and environmental objectives; and

4. Inadequate recognition of the health and environmental concerns associated with current practices. Lack of trained engineers, data on water quality, and information dissemination systems further aggravates this problem. International agencies still do not have comprehensive understandings of water quality issues in developing countries as most of the experts are trained in developed, often temperate, countries.

5. Environmental degradation of water sources, in particular, reduced water quality and quantity due to pollution from urban or land-based activities. Too little money and attention are paid to improve such basic infrastructures as water and wastewater systems, while more money is spent for economic growth. Lack of consensus on "who should pay for water and wastewater" very often makes it difficult to build sustainable water and wastewater systems. One of the examples is the sewage treatment systems in Thailand; municipalities often refuse to manage and operate sewage treatment plants because people do not want to pay for their wastewater.

6. Inadequate use of alternative water sources. Alternative water sources other than groundwater and surface water are rarely explored. Desalination is too expensive; and rainwater harvesting is only good for small communities in remote areas. Wastewater reuse may be a future alternative but it requires a better understanding on the risks and benefits of water reuse.

Instead, we must adopt a new approach to water resources management in the new millennium so as to overcome these failures, reduce poverty and conserve the environment -- all within the framework of sustainable development.

1.2.4 THE URBAN WATER STRATEGY

Quite clearly, a concerted strategy for management of water resources in urban areas need to be put in place in order to avoid the crisis outlined above. Developing a framework for urban water management can draw inspiration and guidance from several global agreements and norms, including Agenda 21 itself, and the World water vision.

Preparatory work will have to map out the progress achieved vis-à-vis objectives outlined in Agenda 21, as well as the recommendations made in the World Water Vision. A 'situation report' on the status will have to be developed - urban water-quality, usage and the policy and programme/project environment within which water is managed. Trends of water use and disposal at the community and urban levels will have to be monitored and comparative analyses made to understand the dimensions of the problem.

Water Audits: Water audits provide a comprehensive appraisal of natural and urban water resource base. It assists in water policy assessment and development, investment decisions, monitoring and evaluating program and policy performance; and direct resource management, particularly by local government.

Demand Management: Clearly, the way forward in effective mitigation of the water crisis is demand management - in understanding water usage in urban areas, in developing tools and strategies for a deeper and broader reduction, reuse/recycle of water for different purposes.

Community education and awareness-building is a critical component in water demand management, as is effective stakeholder participation in decision-making and policy development. Water pricing issues are also included here.

Integrated urban water resource management (IUWRM): IUWRM is an emerging concept that covers the entire urban water cycle, including rainwater, desalination, ground and surface water, etc., as well as storage and distribution, treatment, recycling and disposal, and the protection, conservation and exploitation of water resources at their origin. It also covers empowering local communities to decide on the level of access to safe water and hygienic living conditions, the need to produce more food, and the need to create more sustainable livelihoods per unit of water, and the need to manage human water use to conserve the quantity and quality of freshwater and terrestrial ecosystems that provide services to humans and all living things.

Urban watersheds: The issues of managing urban water supply, wastewater and storm water can be viewed in an integrative manner by looking at urban areas as watersheds. Such perspectives incorporate issues such as pollution of water resources, surface run-off, rainwater harvesting from urban structures, etc. It includes the perspective of cities as 'metabolic units' that can be defined in terms of inputs/outputs and material balance as well as life cycle cost.

1.3 RAINWATER INFILTRATION

The infiltration capacity is the maximum rate at which water can enter a particular soil. Different soil types have different infiltration capacities, for example sandy soils are free draining relative to clays, resulting in higher infiltration capacities. High infiltration capacities will reduce run-off and risks of water logging, however very high infiltration capacities, often found in sands, may mean some nutrients are lost from the root zone through leaching into deeper parts of the soil profile.

Infiltration capacities can be altered by soil management practices. As infiltration is related to soil structure, any practice that degrades the structure of the soil will have an adverse effect on infiltration. Therefore, monitoring infiltration rates under different soil management regimes is a good indicator of how the practice will influence the rate at which water can move into the soil.

1.3.1THE INFILTRATION PROCESS:

When rain or irrigation water is supplied to a field, it seeps into the soil. This process is called infiltration. Infiltration can be visualized by pouring water into a glass filled with dry powdered soil, slightly tamped. The water seeps into the soil; the colour of the soil becomes darker as it is wet.

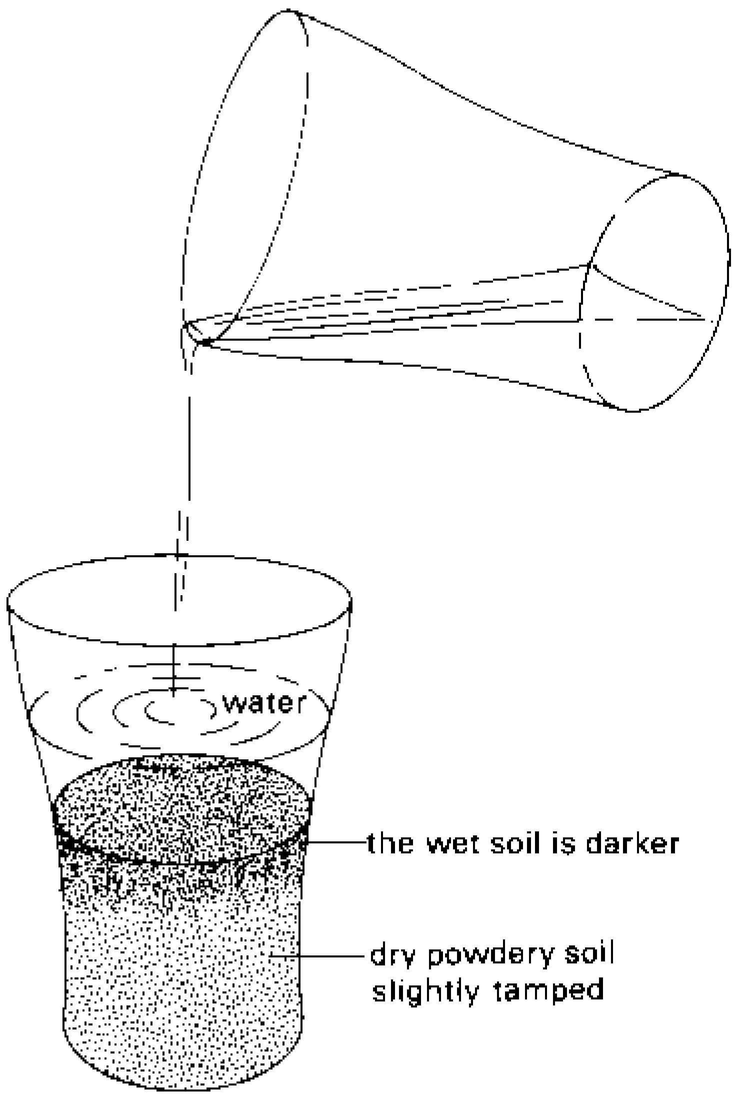
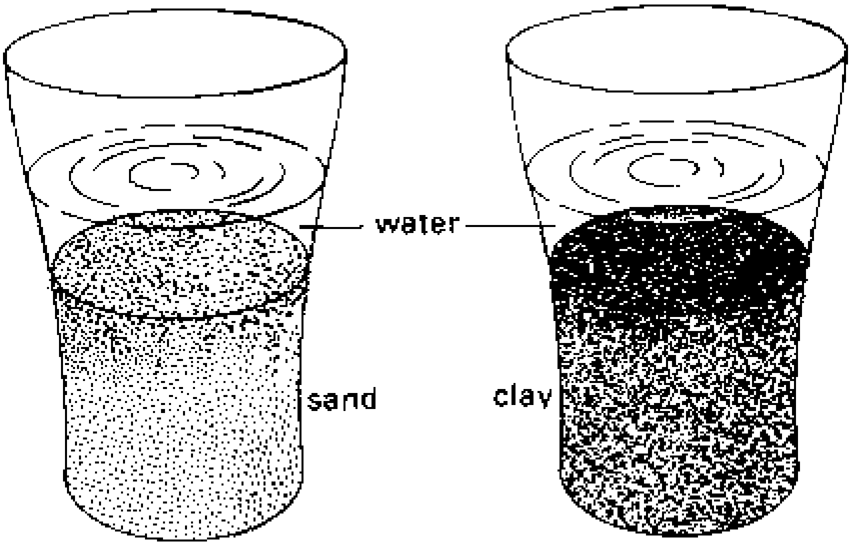


Fig 3. Infiltration of water into the soil

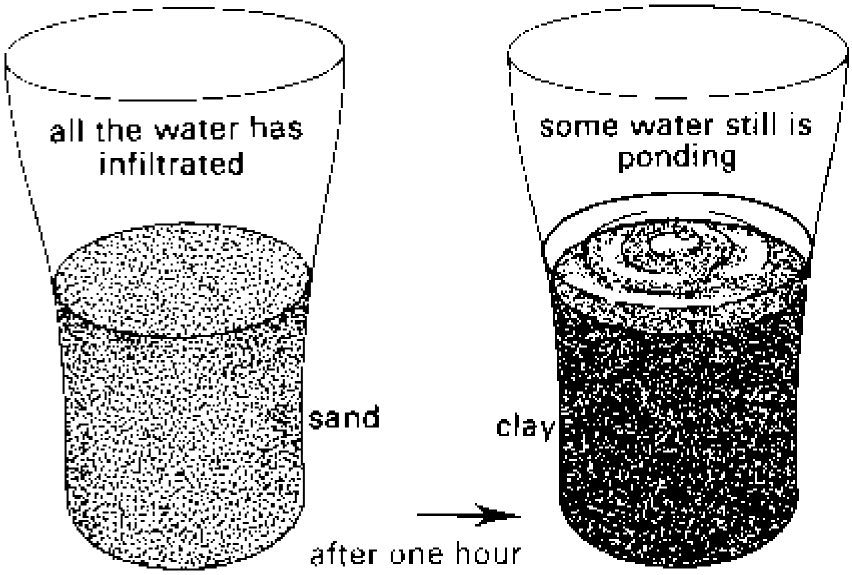
1.3.2 INFILTRATION RATE

Repeat the previous test, this time with two glasses. One is filled with dry sand and the other is filled with dry clay.

The infiltration of water into the sand is faster than into the clay. The sand is said to have a higher infiltration rate.



<u>Fig 4</u>. The same amount of water is supplied to each glass



<u>Fig. 5</u>. After one hour the water has infiltrated in the sand, while some water is still ponding on the clay

The infiltration rate of a soil is the velocity at which water can seep into it. It is commonly measured by the depth (in mm) of the water layer that the soil can absorb in an hour.

An infiltration rate of 15 mm/hour means that a water layer of 15 mm on the surface of the soil will take one hour to infiltrate.

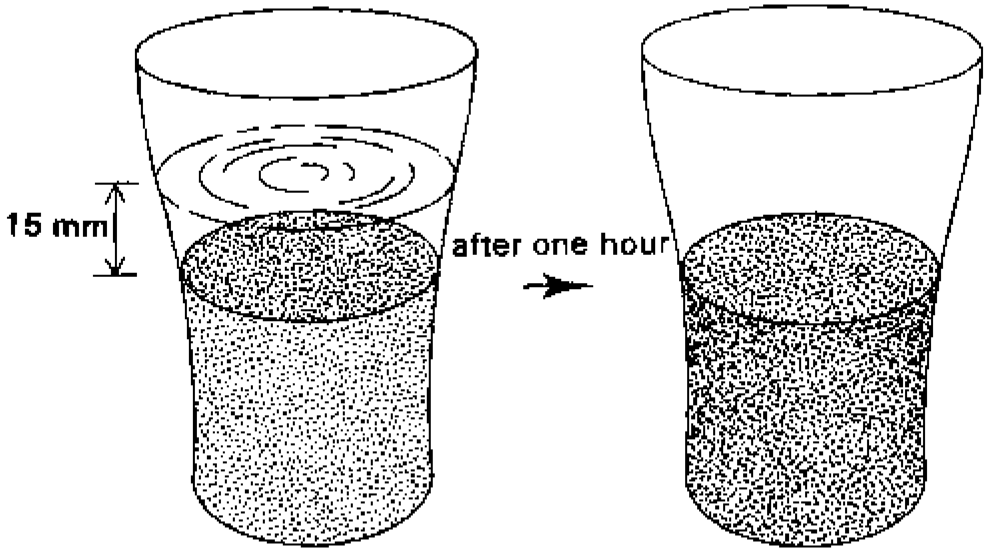


Fig.6. Soil with an infiltration rate of 15 mm/hour

A range of values for infiltration rates is given below:

Low infiltration rate	less than 15 mm/hour
medium infiltration rate	15 to 50 mm/hour
high infiltration rate	more than 50 mm/hour

1.3.3 FACTORS INFLUENCING THE INFILTRATION RATE

The infiltration rate of a soil depends on factors that are constant, such as the soil texture. It also depends on factors that vary, such as the soil moisture content.

i)SOIL TEXTURE

Coarse textured soils have mainly large particles in between which there are large pores.

On the other hand, fine textured soils have mainly small particles in between which there are small pores

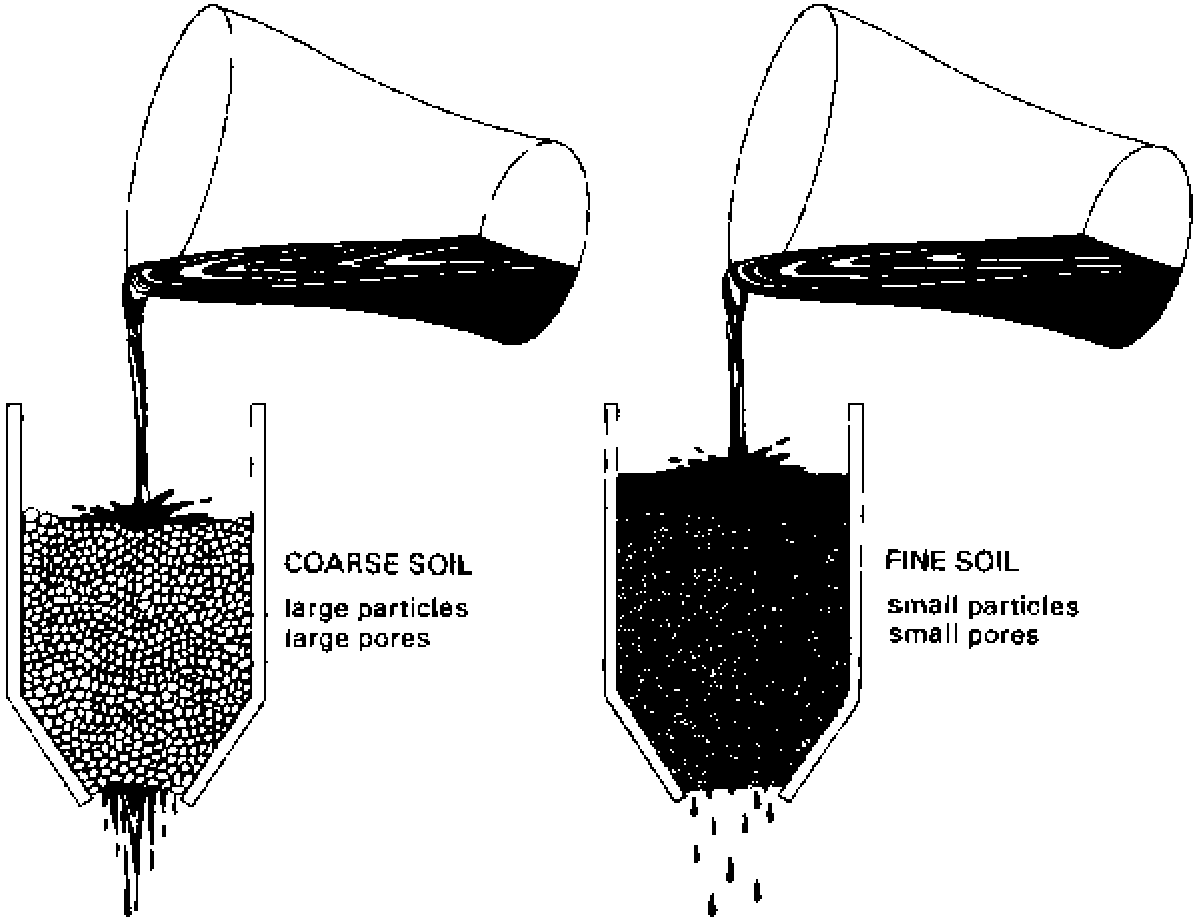


Fig.7: Infiltration rate and soil texture

In coarse soils, the rain or irrigation water enters and moves more easily into larger pores; it takes less time for the water to infiltrate into the soil. In other words, infiltration rate is higher for coarse textured soils than for fine textured soils.

ii) THE SOIL MOISTURE CONTENT

The water infiltrates faster (higher infiltration rate) when the soil is dry than when it is wet . As a consequence, when irrigation water is applied to a field, the water at first infiltrates easily, but as the soil becomes wet, the infiltration rate decreases.

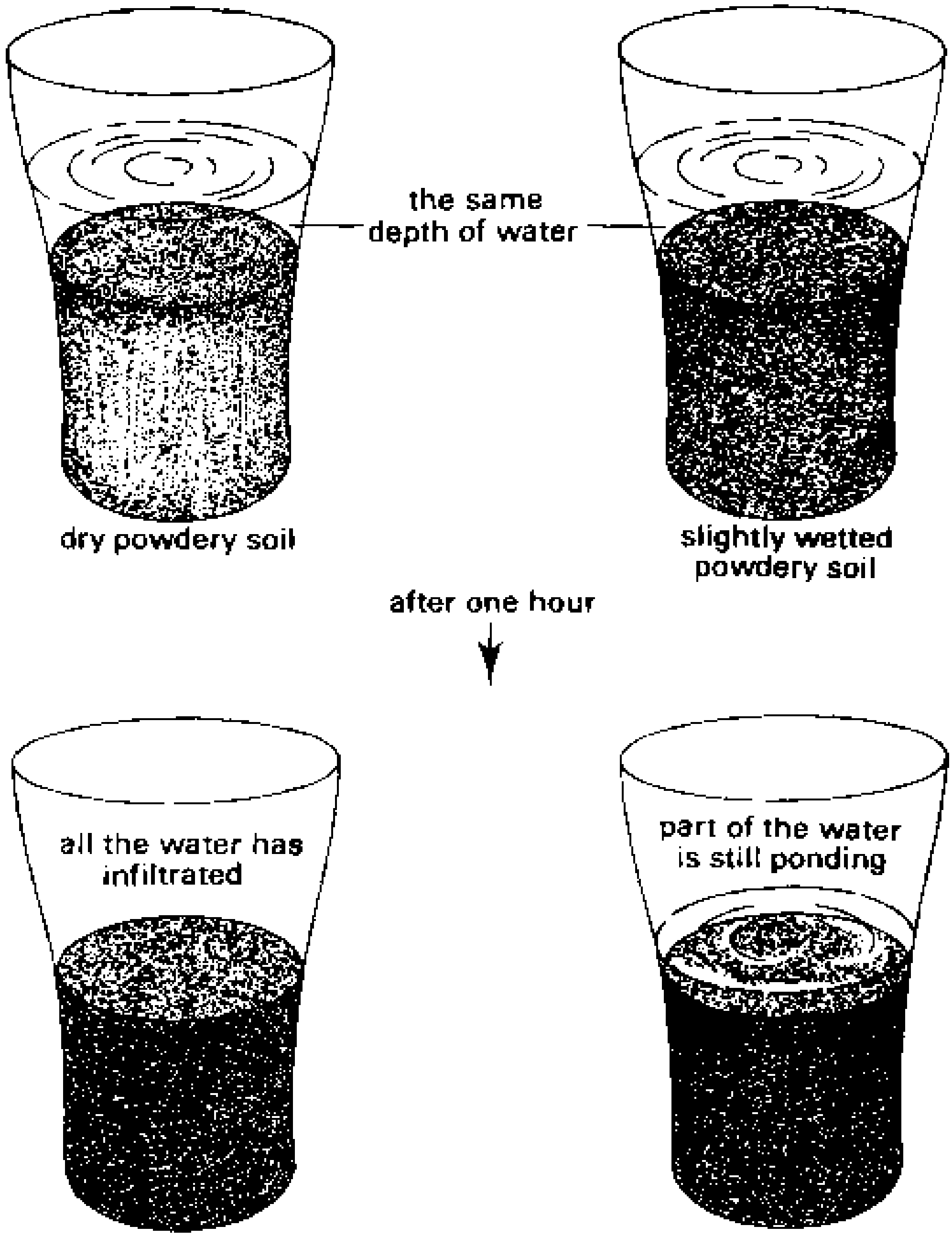


Fig.8: Infiltration rate and soil moisture content

iii) THE SOIL STRUCTURE

Generally speaking, water infiltrates quickly (high infiltration rate) into granular soils but very slowly (low infiltration rate) into massive and compact soils.

Because the farmer can influence the soil structure (by means of cultural practices), he can also change the infiltration rate of his soil.

1.4 RAIN WATER HARVESTING

In the present scenario management and distribution of water has become centralized. People depend on government system, which has resulted in disruption of community participation in water management and collapse of traditional water harvesting system.

As the water crisis continues to become severe, there is a dire need of reform in water management system and revival of traditional systems. Scientific and technological studies need to be carried out to assess present status so as to suggest suitable mitigative measures for the revival to traditional system/wisdom. Revival process should necessarily be backed by people's initiative and active public participation.

Living creatures of the universe are made of five basic elements, viz., Earth, Water, Fire, Air and Sky. Obviously, water is one of the most important elements and no creature can survive without it. Despite having a great regard for water, we seem to have failed to address this sector seriously. Human beings could not save and conserve water and it sources, probably because of its availability in abundance. But this irresponsible attitude resulted in deterioration of water bodies with respect to quantity and quality both. Now, situation has arrived when even a single drop of water matters. However, " better late than never", we have not realized the seriousness of this issue and initiated efforts to overcome those problems.

In the present scenario management and distribution of water has become centralized. People depend on government system, which has resulted in disruption of community participation in water management and collapse of traditional water harvesting system.

Rain is the ultimate source of fresh water. With the ground area around houses and buildings being cemented, particularly in cities and towns, rainwater, which runs off from terraces and roofs, was draining into low-lying areas and not percolating into the soil. Thereby, precious rainwater is squandered, as it is drained into the sea eventually. Rain water harvesting is a system by which, the rainwater that collects on the roofs and the area around the buildings is directed into open wells through a filter tank or into a percolation chamber, built specifically for this purpose. Rainwater is collected directly or recharged into the ground to improve ground water storage. Water that is not extracted from ground during rainy days is the water saved.

1.4.1 NEED FOR RAIN WATER HARVESTING

i) Major parts of our country have been facing continuous failure of monsoon and consequent deficit of rainfall over the last few years.

ii) Due to ever increasing population of India, the use of ground water has increased drastically leading to constant depletion of ground water level causing the wells and tube wells to dry up.

iii) In some places, excessive heat waves during summer create a situation similar to drought.

iv) It is imperative to take adequate measures to meet the drinking water needs of the people in the country besides irrigation and domestic needs.

v) Out of 8760 hours in a year, most of the rain in India falls in just 100 hours.

1.4.2 TYPES OF RAINWATER HARVESTING

Broadly there are two ways of harvesting rainwater:

(i) Surface runoff harvesting

(ii) Roof top rainwater harvesting

(i) SURFACE RUNOFF HARVESTING

In urban area rainwater flows away as surface runoff. This runoff could be caught and used for recharging aquifers by adopting appropriate methods.

(ii)ROOF TOP RAINWATER HARVESTING

It is a system of catching rainwater where it falls. In rooftop harvesting, the roof becomes the catchments, and the rainwater is collected from the roof of the house/building. It can either be stored in a tank or diverted to artificial recharge system. This method is less expensive and very effective and if implemented properly helps in augmenting the ground water level of the area.

1.4.3 RAIN WATER HARVESTING TECHNIQUES

There are two main techniques of rain water harvestings.

a)Storage of rainwater on surface for future use.

b)Recharge to ground water.

The storage of rain water on surface is a traditional techniques and structures used were underground tanks, ponds, check dams, weirs etc. Recharge to ground water is a new concept of rain water harvesting and the structures generally used are:

i) PITS : Recharge pits are constructed for recharging the shallow aquifer. These are constructed 1 to 2 m.wide and to 3 m. deep which are back filled with boulders, gravels, coarse sand.

ii) TRENCHES: These are constructed when the permeable stram is available at shallow depth. Trench may be 0.5 to 1 m. wide, 1 to 1.5m. deep and 10 to 20 m. long depending up availability of water. These are back filled with filter materials.

iii) DUG WELLS: Existing dug wells may be utilized as recharge structure and water should pass through filter media before putting into dug well.

iv) HAND PUMPS : The existing hand pumps may be used for recharging the shallow/deep aquifers, if the availability of water is limited. Water should pass through filter media before diverting it into hand pumps.

v) RECHARGE WELLS : Recharge wells of 100 to 300 mm. diameter are generally constructed for recharging the deeper aquifers and water is passed through filter media to avoid choking of recharge wells.

vi) RECHARGE SHAFTS : For recharging the shallow aquifer which are located below clayey surface, recharge shafts of 0.5 to 3 m. diameter and 10 to 15 m. deep are constructed and back filled with boulders, gravels & coarse sand.

vii) LATERAL SHAFTS WITH BORE WELLS: For recharging the upper as well as deeper aquifers lateral shafts of 1.5 to 2 m. wide & 10 to 30 m. long depending upon availability of water with one or two bore wells are constructed. The lateral shafts are back filled with boulders, gravels & coarse sand.

viii) SPREADING TECHNIQUES: When permeable strata starts from top then this technique is used. Spread the water in streams/Nalas by making check dams, nala bunds, cement plugs, gabion structures or a percolation pond may be constructed.

1.4.4. COMPONENTS OF A RAINWATER HARVESTING SYSTEM

A rainwater harvesting system comprises components of various stages - transporting rainwater through pipes or drains, filtration, and storage in tanks for reuse or recharge. The common components of a rainwater harvesting system involved in these stages are illustrated here.

i) CATCHMENTS: The catchment of a water harvesting system is the surface which directly receives the rainfall and provides water to the system. It can be a paved area like a terrace or courtyard of a building, or an unpaved area like a lawn or open ground. A roof made of reinforced cement concrete (RCC), galvanised iron or corrugated sheets can also be used for water harvesting.

ii) COARSE MESH: At the roof to prevent the passage of debris

iii) GUTTERS: Channels all around the edge of a sloping roof to collect and transport rainwater to the storage tank. Gutters can be semi-circular or rectangular and could be made using:

- Locally available material such as plain galvanised iron sheet (20 to 22 gauge), folded to required shapes.
- Semi-circular gutters of PVC material can be readily prepared by cutting those pipes into two equal semi-circular channels.
- Bamboo or betel trunks cut vertically in half.

The size of the gutter should be according to the flow during the highest intensity rain. It is advisable to make them 10 to 15 per cent oversize.

Gutters need to be supported so they do not sag or fall off when loaded with water. The way in which gutters are fixed depends on the construction of the house; it is possible to fix iron or timber brackets into the walls, but for houses having wider eaves, some method of attachment to the rafters is necessary.

iv) CONDUITS

Conduits are pipelines or drains that carry rainwater from the catchment or rooftop area to the harvesting system. Conduits can be of any material like polyvinyl chloride (PVC) or galvanized iron (GI), materials that are commonly available.

v) FIRST-FLUSHING

A first flush device is a valve that ensures that runoff from the first spell of rain is flushed out and does not enter the system. This needs to be done since the first spell of rain carries a relatively larger amount of pollutants from the air and catchment surface.

vi) FILTER UNIT

The filter unit is a container or chamber filled with filter media such as coarse sand, charcoal, coconut fiber, pebbles and gravels to remove the debris and dirt from water that enters the tank. The container is provided with a perforated bottom to allow the passage of water. The filter unit is placed over the storage tank. Commonly used filters are of two types. One is a ferro-cement filter unit, which is comparatively heavy and the other is made of either aluminum or plastic bucket. The latter is readily available in market and has the advantage of ease in removing, cleaning and replacing. Another simple way of filtering the debris and dust particles that came from the roof along with rainwater is to use a fine cloth as filter media. The cloth, in 2 or 3 layers, can be tied to the top of a bucket or vessel with perforations at the bottom.

vii) STORAGE FACILITY

There are various options available for the construction of these tanks with respect to the shape, size and the material of construction.

Shape: cylindrical, rectangular and square.

Material of construction: Reinforced cement concrete, (RCC), ferrocement, masonry, plastic (polyethylene) or metal (galvanised iron) sheets are commonly used. **POSITION OF TANK:** Depending on space availability these tanks could be constructed above ground, partly underground or fully underground. Some maintenance measures like cleaning and disinfection are required to ensure the quality of water stored in the container

vii) COLLECTION PIT

A small pit is dug in the ground, beneath the tap of the storage tank and constructed in brick masonry to make a chamber, so that a vessel could be conveniently placed beneath the tap for collecting water from the storage tank. A small hole is left at the bottom of the chamber, to allow the excess water to drain-out without stagnation. Size of collection pit shall be 60 cm x 60 cm x 60 cm.

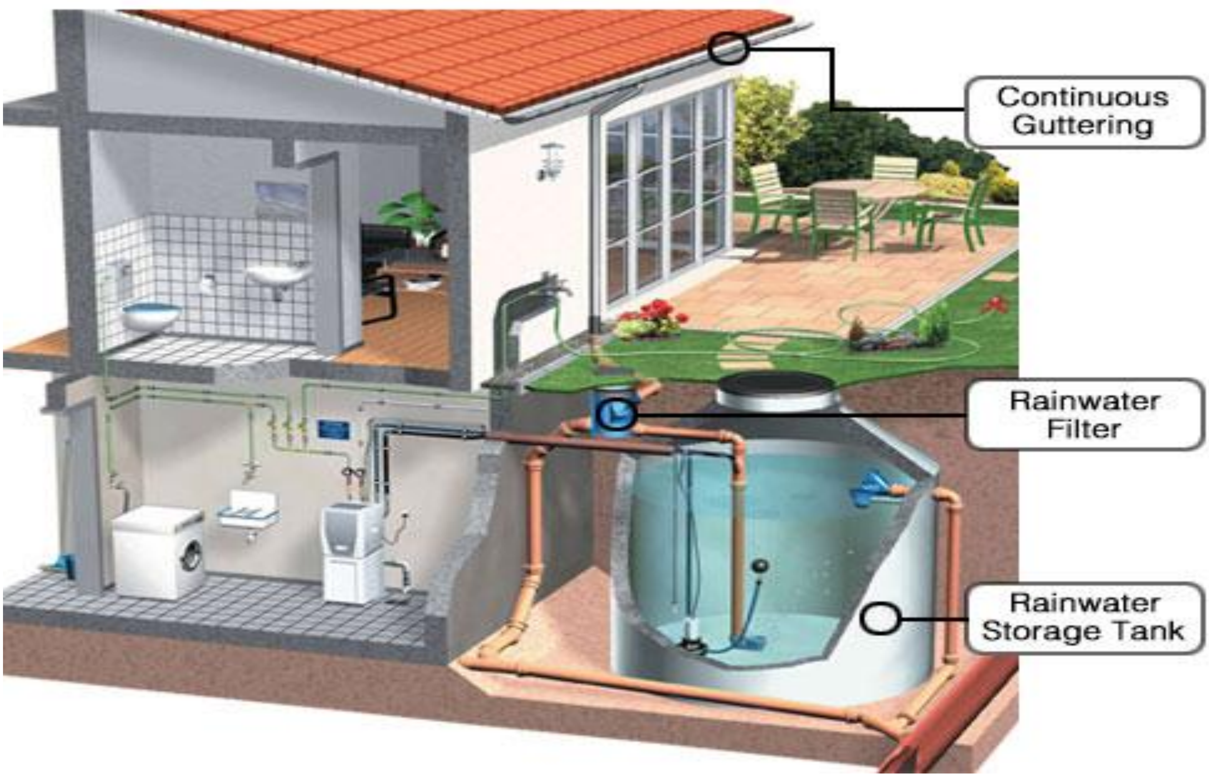


Fig.9: Rain water harvesting system(source: Solus, renewable energy)

1.4.5 THE ADVANTAGES OF RAINWATER HARVESTING

The advantages of rainwater harvesting are:

i)Saves money by reducing your water usage.

ii)A volume of water is kept out of the storm-water management system thereby helping to reduce flooding risks.

iii)Gains Eco-homes rating points for your property.

iv) Rainwater is better for your garden as it has a balanced ph and is free of chemicals such as chlorine.

v) Sustains and safeguards existing water table through recharge.

vi) Increases water availability and improves water quality.

vii) Arrests sea-water intrusion and prevents salination of ground water.

1.4.6 COLLECTION OF RAINWATER

The quantity of rainwater that can be harvested from a roof area of 1000 sq. ft for 100 mm of average annual rainfall and with a surface run off coefficient of 0.6 would be :

0.1 x 100 x 0.6 x 0.9295 = 5.577 m^3 or 5570 litres /annum.

100 mm of rain falling on 1 hectare of land means 1 million litres of water. Even if 50 % of this water is collected, it can provide 15 litres of water/day to 91 persons for a whole year.

1.4.7 DO'S AND DON'TS

Harvested rainwater is used for direct usage or for recharging aquifers. It is most important to ensure that the rainwater caught is free from pollutants. Following precautionary measures should be taken while harvesting rainwater:-

- Roof or terraces uses for harvesting should be clean, free from dust, algal plants etc.
- Roof should not be painted since most paints contain toxic substances and may peel off.
- Do not store chemicals, rusting iron, manure or detergent on the roof.
- Nesting of birds on the roof should be prevented.
- Terraces should not be used for toilets either by human beings or by pets.
- Provide gratings at mouth of each drainpipe on terraces to trap leaves debris and floating materials.
- Provision of first rain separator should be made to flush off first rains.
- Do not use polluted water to recharge ground water.
- Ground water should only be recharged by rainwater.
- Before recharging, suitable arrangements of filtering should be provided.
- Filter media should be cleaned before every monsoon season.
- During rainy season, the whole system (roof catchment, pipes, screens, first flush, filters, tanks) should be checked before and after each rain and preferably cleaned after every dry period exceeding a month.
- At the end of the dry season and just before the first shower of rain is anticipated, the storage tank should be scrubbed and flushed off all sediments and debris.

1.5 SUMMARY

Rainwater harvesting can ensure an independent water supply during water restrictions, though somewhat dependent on end-use and maintenance, usually of acceptable quality for household needs and renewable at acceptable volumes, despite forecasted climate change (CSIRO, 2003). It produces beneficial externalities by reducing peak storm water runoff and processing costs. In municipalities with combined sewer systems, reducing storm runoff is especially important, because excess runoff during heavy storms leads to the discharge of raw sewage from outfalls when treatment plant capacity cannot handle the combined flow. Rainwater harvesting systems are simple to install and operate. Running costs are negligible, and they provide water at the point of consumption. Rainwater harvesting in urban communities has been made possible by various companies. Their tanks provide an attractive yet effective solution to rainwater catchment.

Infiltration tests on a natural hillside slope indicated that rainfall infiltration was too large for the prevailing soil character and was influenced by the macropores existing in the surface soil layer. In the urban area, the infiltration rate was nearly equal to the value derived from the hydraulic conductivity of the surface soil and the macropores were negligible. Based on these results, numerical simulation models of rainfall infiltration and runoff were investigated. From the calculated results, it was clarified that the increase of rainfall runoff due to urbanization is brought about by the decrease of infiltration due to the destruction of macro pores and the increase of impervious areas, and by decrease of concentration time of rainfall due to the decrease of roughness.

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1.8 QUESTIONS WITH ANSWERS

Q.Why is rooftop rainwater harvesting very useful for schools?

Ans: Many schools presently do not have a reliable source of water for drinking and other use. The school rooftop rainwater harvesting system seeks to provide a source of water for all purposes such as toilet flushing, cooking, washing hands and feet before eating and after toilet use, hygiene and finally if the rainwater is treated well for drinking purpose.

This is especially important in areas where there is Fluoride, Nitrate, iron or salt in the groundwater and therefore it is unfit for consumption. In these places the rainwater harvesting tank can provide mineral free water for consumption.

Q. What is the effect urbanization on surface run off ?

Ans: Urbanization increases surface runoff, by creating more impervious surfaces such as pavement and buildings, that do not allow percolation of the water down through the soil to the aquifer. It is instead forced directly into streams or storm water runoff drains, where erosion and siltation can be major problems, even when flooding is not. Increased runoff reduces groundwater recharge, thus lowering the water table and making droughts worse, especially for farmers and others who depend on the water wells.

When anthropogenic contaminants are dissolved or suspended in runoff, the human impact is expanded to create water pollution. This pollutant load can reach various receiving waters such as streams, rivers, lakes, estuaries and oceans with resultant water chemistry changes to these water systems and their related ecosystems.

Q.Is catchment water clean enough to drink?

Ans: A residential water supply that collects rainwater stored in a catchment tank can be much safer and more reliable than most municipal water sources. Many large cities and towns are built on rivers or other rain-fed water sources. Unfortunately, pharmacutical residue and other contaminants cannot be completely removed from our municipal water supply with any present water treatment systems. Even with chemical additives, trace amounts of drugs and biological contaminants can be found in ground and municipal water supplies.

Q. Why is inflow and infiltration a problem?

Ans: Sanitary sewer systems are designed to carry wastewater from toilets, dishwashers, sinks, or showers in homes or businesses. Inflow and infiltration add clear water to sewer systems increasing the load on the systems. Clear water belongs in stormwater sewers or on the surface of the ground, and not in the sanitary sewers. A stormwater sewer is a pipe system designed to carry rainwater away. Stormwater sewers are normally much larger than sanitary sewer systems because they are designed to carry much larger amounts of water. Drainage ditches also act the same way in many neighborhoods. When clear water enters sanitary sewer systems, it must be transported and treated like sanitary waste water. During dry weather the impact of inflow and infiltration can vary from minimal impact to a significant portion of the sewer pipe flow. Wet weather magnifies existing inflow and infiltration sources. As a rain or snow melt event begins the inflow and infiltration sources start filling the sanitary sewer systems with clear water, eventually filling the sewer systems to capacity. Once the sanitary sewer systems have reached capacity or becomes overloaded, wastewater flows at much higher water level than normal and if sanitary fixtures or drains are below this overload level, water will flow backward through the sanitary sewer pipe, flooding basements or households and causing manholes to pop open releasing wastewater onto the street.

Overflow occurrences put public health at risk and violate state and federal environmental regulations. Sanitary sewer overflows release wastewater and potential pathogens onto streets, into waterways, and basements increasing potential health risks. As wastewater overflows into creeks, rivers, lakes, and streams it contaminates all bodies of water fed by the waterways and all creatures/plants coming in contact with the polluted water. Sewer overflows also contribute to beach advisories and closures due to contamination.

1.9 PROBABLE QUESTIONS

Q. What are the advantages and benefits of rainwater harvesting?

Q. Describe the role of soil type in rain water infiltration rate.

Q. What are typical rainwater harvesting system components?

Q. What types of soil allows the greatest amount of rainfall to soak in?

UNIT-2: URBAN WATER SUPPLY

UNIT STRUCTURE

OBJECTIVES
1. INTRODUCTION
    1.1STATUS IN INDIA
2. HISTORICAL DEVELOPMENT OF WATER SUPPLY SYSTEMS
3. SOURCE OF WATER POLLUTION
    3.1 COMMON SOURCES
    3.2 POINT AND NON-POINT SOURCES
    3.3 CONTINUOUS AND INSTANTANEOUS SOURCES
4. WATER MONITORING AND WATER QUALITY GUIDELINES
    4.1 OBJECTIVES
    4.2 WATER QUALITY MONITORING INVOLVES 8 STEPS AS EXPLAINED BELOW:
5. CHARACTERISTICS OF WATER RESOURCES IN TROPICAL COUNTRIES
6. CONCEPT OF 'NEW' WATER OR (RECLAIMED WASTEWATER) AS A RESOURCE
    6.1 TYPES OF WASTEWATER RECLAMATION AND REUSES
    6.2 TREATMENT OF WASTE WATER
    6.3 WORLDWIDE APPLICATIONS AND ACCEPTANCE
    6.4 BENEFITS
7. SUMMARY

OBJECTIVES

After going through this unit, you will be able to:

- discuss the status and historical development of urban water supply in India
- list the sources of water pollution
- list the guidelines of water monitoring and water controlling
- discuss the characteristics of water resources in tropical countries
- illustrate the benefits of 'new' water as a resource

1. INTRODUCTION

Water supply is the provision of water by public utilities, commercial organisations, community endeavours or by individuals, usually via a system of pumps and pipes.

The urban water supply and sanitation sector in the country is suffering from inadequate levels of service, an increasing demand-supply gap, poor sanitary conditions and deteriorating financial and technical performance.

According to Central Public Health Engineering Organisation (CPHEEO) estimates, as on 31

March 2000, 88 per cent of urban population has access to a potable water supply. But this supply is highly erratic and unreliable. Transmission and distribution networks are old and poorly maintained, and generally of a poor quality. Consequently physical losses are typically high, ranging from 25 to over 50 per cent. Low pressures and intermittent supplies allow back siphoning, which results in contamination of water in the distribution network. Water is typically available for only 2-8 hours a day in most Indian cities. The situation is even worse in summer when water is available only for a few minutes, sometimes not at all.

1.1STATUS IN INDIA

According to a World Bank study, of the 27 Asian cities with populations of over 1,000,000, Chennai and Delhi are ranked as the worst performing metropolitan cities in terms of hours of water availability per day, while Mumbai is ranked as second worst performer and Calcutta fourth worst (Source: Background Paper - International Conference on New Perspectives on Water for Urban & Rural India - 18-19 September, 2001, New Delhi). In most cities, centralised water supply systems depend on surface water sources like rivers and lakes. Chennai, for instance, has to bring in water from a distance of 200 km whereas Bangalore gets its water from the Cauvery river, which is 95 km away. Where surface water sources fail to meet the rising demand, groundwater reserves are being tapped, often to unsustainable levels.

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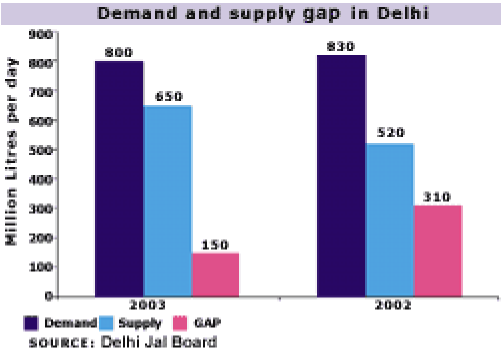
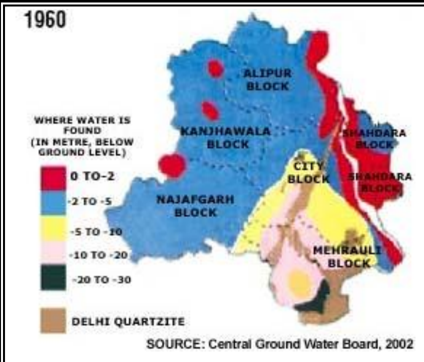
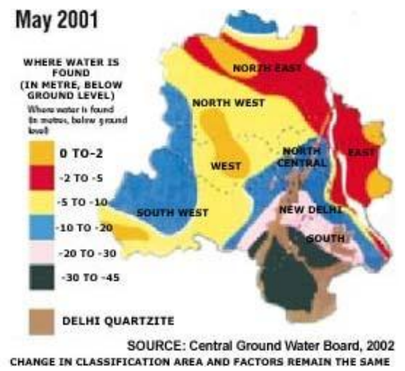
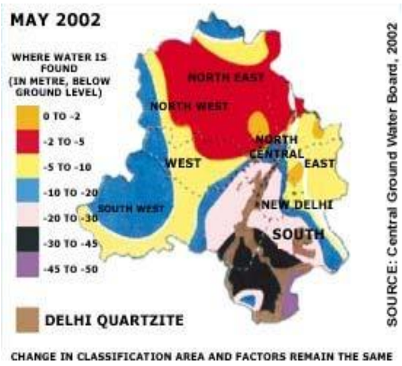


Delhi: The nation's capital is perpetually in the grip of a water crisis, more so during the dry season, when the situation gets particularly worse. As the demand-supply gap widens, more groundwater is being exploited. Of the water supplied by the municipality, approximately 11 per cent comes from groundwater reserves and remaining from the Yamuna river. It is, however, difficult to establish the total quantity of groundwater extracted because a large number of tubewells (owned by individuals, industries and bottled water companies) remain unregistered.

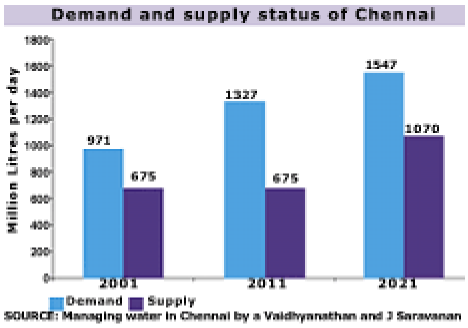


In Delhi approximately 13 per cent (Source: Zerah., M Helene, 2000, *Water - Unreliable Supply in Delhi*, French Research Institute of India) households do not receive water every day and in Rajkot, Gujarat, water availability in April 2000 was only for 30 minutes every alternate day.

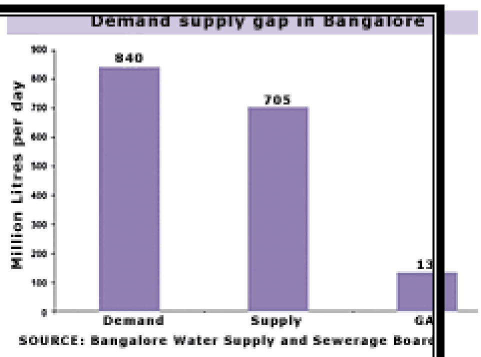




Chennai: The main sources of public water supply in the city are the three reservoirs - Poondi, Redhills and Cholavaram - with an aggregate storage capacity of 175 MCM. Even when the reservoirs are not full, they get inflows from intermittent rains, which is then drawn. On the other hand, losses due to evaporation from the reservoirs result in the effective availability being lower than the storage. The other major resource is groundwater from the well fields in the Araniar-Kortaliyar basin and the southern coastal aquifer, and a large number of wells and tubewells spread all across the city. Over-extraction of groundwater in the north western coastal belt resulted in a rapid ingress of seawater, which extended from 3 km inshore in 1969 to 7 km in 1983 and 9 km in 1987. Groundwater levels within the city also fell and brackish water began to appear even in localities which earlier had good quality groundwater sources.



Bangalore: With a population of 5,686,000, Bangalore is India's fifth largest city. As per the estimates of the Bangalore Water Supply and Sewerage Board (BWSSB), the total demand of water is 840 million litres per day (MLD) . The demand works out to be 1200 MLD,at the standard rate of 200 lpcd set by the Bureau of Indian Standards[BIS] for water supply in urban areas). Corresponding demand supply gaps are 135 and 495 MLD



2. HISTORICAL DEVELOPMENT OF WATER SUPPLY SYSTEMS

Evidence of activity concerned with human health and water supply found in civilizations throughout human history. The human search for pure water supplies must have begun pre-historic times. Thousands of years passed before our more recent ancestors learned to build cities and the convenience of water piped to the home and drains for water-carried wastes as shown in table 1.

TABLE:1

4000 BC	Water supply tunnels in Middle East
2000 BC	Water purification in Egypt and Iraq- they learn the benefits of filtration
312 BC	Roman aqueducts built (Aqua Appia, 18km) they learn that lead in water is toxic.
300 BC	Storage cisterns used in cities (e.g. Istanbul)
1100 AD	Polluted water supplies in Europe=plagues
1183	Paris aqueduct built
1235	Uses lead pipes
1619	London provides house connections
1804	Sand filters used in Scotland, 4 millenia after Mesopotamia
1835	Charles Storrow writes Treatise on Water-works
1850s	Polluted water again, major cholera outbreaks in London
1860	Hamilton water works
1890	Chlorine disinfection
1993	Cryptosporidium infects 400000, Milwaukee

Throughout history people have devised systems to make getting and using water more convenient. Early Rome had indoor plumbing, meaning a system of aqueducts and pipes that terminated in homes and at public wells and fountains for people to use. London water supply infrastructure developed over many centuries from early mediaeval conduits, through major 19th century treatment works built in response to cholera threats, to modern large scale reservoirs. Water towers appeared around the late 19th century, as building height rose, and steam, electric and diesel-powered water pumps became available. As skyscrapers appeared, they needed rooftop water towers. The technique of purification of drinking water by use of compressed liquefied chlorine gas was developed in 1910 by U.S. Army Major (later Brig. Gen.) Carl Rogers Darnall (1867–1941), Professor of Chemistry at the Army Medical School. Shortly thereafter, Major (later Col.) William J. L. Lyster (1869–1947) of the Army Medical Department used a solution of calcium hypochlorite in a linen bag to treat water. For many decades, Lyster's method remained the standard for U.S. ground forces in the field and in camps, implemented in the form of the familiar Lyster Bag (also spelled Lister Bag). Darnall's work became the basis for present day systems of municipal water '***purification***'.Desalination appeared during the late 20th century, and is still limited to a few areas.During the beginning of the 21st Century, especially in areas of urban and suburban population centres, traditional centralized infrastructure have not been able to supply sufficient quantities of water to keep up with growing demand. Among several options that have been managed are the extensive use of desalination technology, this is especially prevalent in coastal areas and in "dry" countries like Australia. Decentralization of water infrastructure has grown extensively as a viable solution including Rainwater harvesting and Stormwater harvesting where policies are eventually tending towards a more rational use and sourcing of water incorporation concepts such as "Fit for Purpose".

Q.1. Describe briefly the history of water supply system.

3. SOURCE OF WATER POLLUTION

3.1 COMMON SOURCES

There are many causes for water pollution but two general categories exist: direct and indirect contaminant sources.

Direct sources include effluent outfalls from factories, refineries, waste treatment plants etc.. that emit fluids of varying quality directly into urban water supplies. In the United States and other countries, these practices are regulated, although this doesn't mean that pollutants can't be found in these waters.

Indirect sources include contaminants that enter the water supply from soils/groundwater systems and from the atmosphere via rain water. Soils and groundwaters contain the residue of human agricultural practices (fertilizers, pesticides, etc..) and improperly disposed of industrial wastes. Atmospheric contaminants are also derived from human practices (such as gaseous emissions from automobiles, factories and even bakeries).

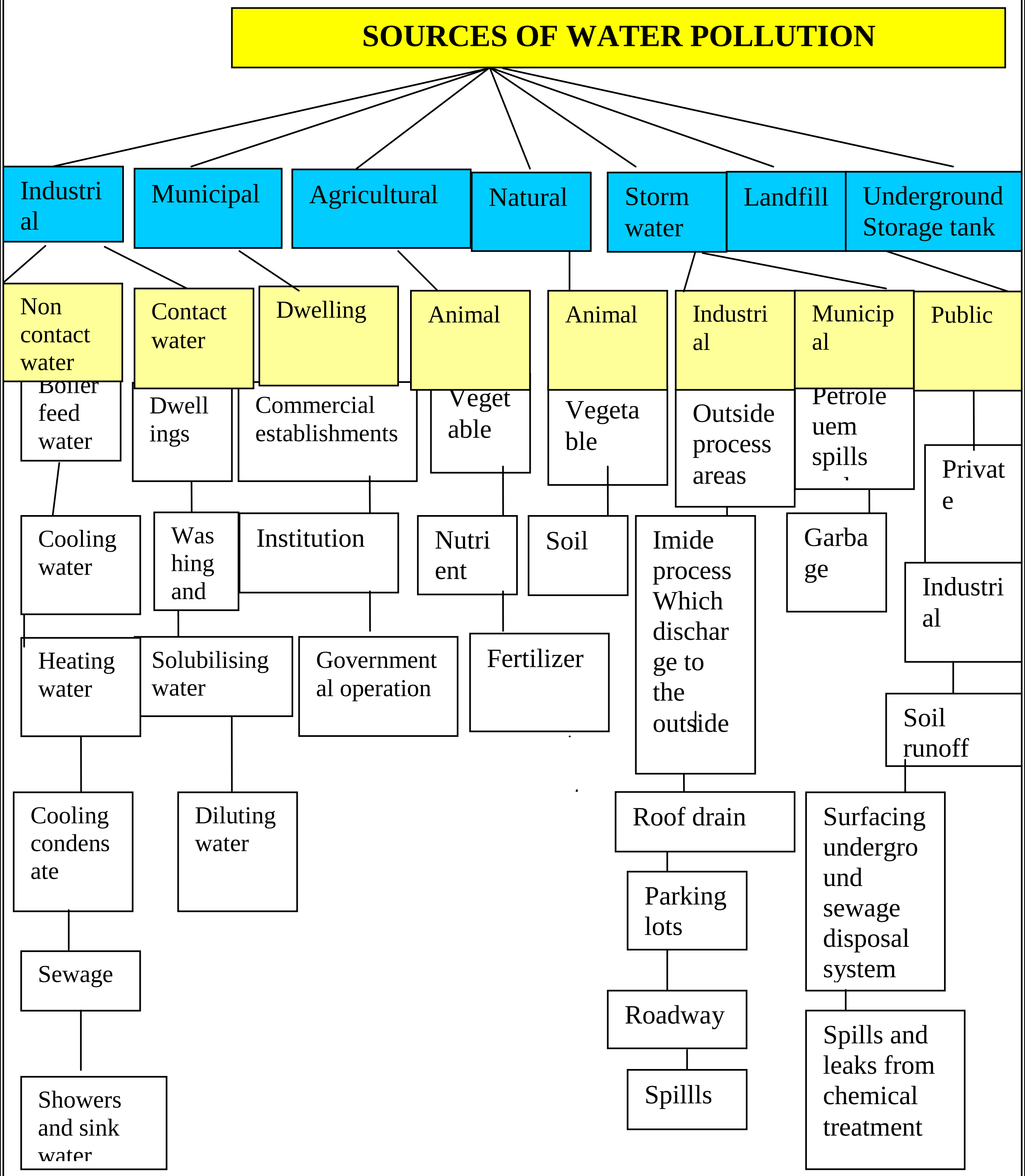


Fig 1: ***The most common sources of pollution of the streams and rivers***

3.2 POINT AND NON-POINT SOURCES

From spatial perspective, the sources of pollution can be divided as **point** and **non-point** sources.

Point source pollution represents those activities where wastewater is routed directly into receiving water bodies by, for example, discharge pipes, where they can be easily measured and controlled. Examples of point sources include discharges from municipal wastewater treatment plants and industrial facilities and spills that occur due to accidents.

Mass loading, for example, may be estimated by measuring the flow and solute concentration associated with a plant's effluent:

$$W = Q_e . C_e$$

where:

- W mass loading rate (M/T)
- Q_e volumetric flow rate for the point source
- C_e solute concentration in the effluent

In contrast, non-point source water pollution, once known as "diffuse" source pollution, arises from a broad group of human activities for which the pollutants have no obvious point of entry into receiving watercourses. *Table 2 outlines the classes of non-point sources and their relative contributions to pollution loadings*.

Table 2. ***Classes of non-point source pollution (International Joint Commission, 1974)***

Agriculture	Animal feedlots Irrigation Cultivation Pastures Dairy farming Orchards Aquaculture	Runoff from all categories of agriculture leading to surface and groundwater pollution. In northern climates, runoff from frozen ground is a major problem, especially where manure is spread during the winter. Vegetable handling, especially washing in polluted surface waters in many developing countries, leads to contamination of food supplies. Growth of aquaculture is becoming a major polluting activity in many countries. Irrigation return flows carry salts, nutrients and pesticides. Tile drainage rapidly carries leachates such as nitrogen to surface waters.
Forestry		Increased runoff from disturbed land. Most damaging is forest clearing for urbanization.
Liquid waste disposal		Disposal of liquid wastes from municipal wastewater effluents, sewage sludge, industrial effluents and sludges, wastewater from home septic systems; especially disposal on agricultural land, and legal or illegal dumping in watercourses.
Urban areas	Residential Commercial Industrial	Urban runoff from roofs, streets, parking lots, etc. leading to overloading of sewage plants from combined sewers, or polluted runoff routed directly to receiving waters; local industries and businesses may discharge wastes to street gutters and storm drains; street cleaning; road salting contributes to surface and groundwater pollution.
Rural sewage systems		Overloading and malfunction of septic systems leading to surface runoff and/or direct infiltration to groundwater.
Transportation		Roads, railways, pipelines, hydro-electric

		corridors, etc.
Mineral extraction		Runoff from mines and mine wastes, quarries, well sites.
Recreational land use		Large variety of recreational land uses, including ski resorts, boating and marinas, campgrounds, parks; waste and "grey" water from recreational boats is a major pollutant, especially in small lakes and rivers. Hunting.
Solid waste disposal		Contamination of surface and groundwater by leachates and gases. Hazardous wastes may be disposed of through underground disposal.
Dredging		Dispersion of contaminated sediments, leakage from containment areas.
Deep well disposal		Contamination of groundwater by deep well injection of liquid wastes, especially oilfield brines and liquid industrial wastes.
Atmospheric deposition		Long-range transport of atmospheric pollutants (LRTAP) and deposition of land and water surfaces. Regarded as a significant source of pesticides (from agriculture, etc.), nutrients, metals, etc., especially in pristine environments.

An example of a non-point source is agricultural runoff that enters a stream as overland flow. During precipitation events, runoff from cultivated fields may contain pesticide residues and fertiliser, as well as suspended sediments that sorb contaminants. Loading due to this type of non-point source is represented by the **lateral inflow** terms in the general transport equation. Obviously, non-point source pollution is much more difficult to identify, measure and control than point sources.

3.3 CONTINUOUS AND INSTANTANEOUS SOURCES

The sources of pollution and loading rates also vary with respect to time. Sources may be roughly classified according to their duration - **continuous** and **instantaneous** sources.

Continuous sources introduce contaminants to the streams for extended periods of time. An example of a continuous source is the effluent from wastewater treatment plant. Although mass-loading rates may vary in time, many of these plants continuously discharge effluent into receiving waters, resulting in a continuous addition of solutes to the stream.

Instantaneous sources add contaminants to the streams over very short time periods. Although truly instantaneous sources do not exist, situation do arise in which contaminants are added to the stream over time intervals, which are short relative to the time-scales of interest. An example of this kind of source is an accidental spill, where contaminants enter a stream in a matter of minutes. This loading can be viewed as the instantaneous addition of mass at a discrete point in time.

Table 3: Lists *municipal* sources of water in terms of average flows per day and biological strength in BOD_5.

Classification	**Remarks**	**Average flow/ person/day**	**BOD_5 person/day**
Municipality	Residential	380 l	0.10 kg
Subdivision	Residential	380 l	0.10 kg
Hospitals	Per bed	760 l	0.20 kg
Schools, high	With cafeteria & showers	100 l	0.03 kg
Factory or office	With showers/shift	130 l	0.03 kg
Motels	Per unit	380 l	0.06 kg
Ordinary restaurants (not 24 hours)	Per seat	130 l	0.10 kg
Curb service	Per car space	190 l	0.14 kg
Country clubs	Per member	190 l	0.10 kg

Source: Municipal sources of wastewater (Water Quality control Handbook)

The United States Environmental Protection Agency (US-EPA, 1994) identified *agriculture* as the leading cause of water quality impairment of rivers and lakes in the United States and third in importance for pollution of estuaries (Table 4)

Table 4*: Leading sources of water quality impairment in the United States (US-EPA, 1994)*

Rank	**Rivers**	**Lakes**	**Estuaries**
1	**Agriculture**	**Agriculture**	Municipal point sources
2	Municipal point sources	Urban runoff/storm sewers	Urban runoff/storm sewers
3	Urban runoff/storm sewers		**Agriculture**
4	Resource extraction	Municipal point sources	Industrial point sources
5	Industrial point sources	On-site wastewater	Resource extraction

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Table 5:*Agricultural impacts on water quality (FAO,1990)*

Agricultural activity	**Impacts**
	Surface water
Tillage/ploughing	Sediment/turbidity: sediments carry phosphorus and

	pesticides adsorbed to sediment particles; siltation of river beds and loss of habitat, spawning ground, etc.
Fertilizing	Runoff of nutrients, especially phosphorus, leading to eutrophication causing taste and odour in public water supply, excess algae growth leading to deoxygenation of water and fish kills.
Manure spreading	Carried out as a fertilizer activity; spreading on frozen ground results in high levels of contamination of receiving waters by pathogens, metals, phosphorus and nitrogen leading to eutrophication and potential contamination.
Feedlots/animal corrals	Contamination of surface water with many pathogens (bacteria, viruses, etc.) leading to chronic public health problems. Also contamination by metals contained in urine and faeces.
Irrigation	Runoff of salts leading to salinization of surface waters; runoff of fertilizers and pesticides to surface waters with ecological damage, bioaccumulation in edible fish species, etc. High levels of trace elements such as selenium can occur with serious ecological damage and potential human health impacts.
Clear cutting	Erosion of land, leading to high levels of turbidity in rivers, siltation of bottom habitat, etc. Disruption and change of hydrologic regime, often with loss of perennial streams; causes public health problems due to loss of potable water.
Silviculture	Broad range of effects: pesticide runoff and contamination of surface water and fish; erosion and sedimentation problems.
Aquaculture	Release of pesticides (e.g. TBT (Tributyltin)) and high levels of nutrients to surface water and groundwater through feed and faeces, leading to serious eutrophication.

The ranking of agriculture as a major polluter is highlighted by the statistics of Table 6.4. Fully 72% of assessed river length and 56% of assessed lakes are impacted by agriculture.

Table.6*Percent of assessed river length and lake area impacted (US-EPA, 1994)*

Source of pollution	**Rivers (%)**	**Lakes (%)**	**Nature of pollutant**	**Rivers (%)**	**Lakes(%)**
Agriculture	72	56	Siltation (sediment)	45	22
Municipal point sources	15	21	Nutrients	37	40
Urban runoff/storm sewers	11	24	Pathogens	27	
Resource extraction	11		Pesticides	26	
Industrial point sources	7		Organic enrichment DO	24	24
Silviculture	7		Metals	19	47

Hydrologic/habitat modification	7	23	Priority organic		20
On-site wastewater disposal		16			
Flow modification		13			

Areas unaffected by human activity can still pollute receiving streams due to *stormwater* runoff, which can be classified into animal, vegetable and soil sources. Stormwater transports industrial and municipal water pollutants to a receiving stream or an underground water supply. Public, private and industrial *landfills* can be a source of stormwater pollution because of runoff from the surface and underground leachate.

Questions

Q.1 What are the sources of water pollution and its impact in the environment?

Q.2 What is point and non-point source of pollution?

4. WATER MONITORING AND WATER QUALITY GUIDELINES

4.1 OBJECTIVES

The main objectives for water quality monitoring for Surface and Groundwater Agencies under the HP were identified as:

i) Monitoring for establishing baseline water quality

ii) Observing trend in water quality changes

iii) Calculation of flux of water constituents of interest

iv) Surveillance for irrigation use

v) Control and management of water pollution (for groundwater only)

4.2 WATER QUALITY MONITORING INVOLVES 8 STEPS AS EXPLAINED BELOW:

Step-1 Setting Water Quality Monitoring Objectives

↓

Step-2 Assessment of Resources Availability
- Laboratory facilities and competence
- Transport
- Manpower-adequate number and competence

↓

Step-3 Reconnaissance Survey
- Map of the area
- Background information
- Human activities
- Potential polluting sources
- Water abstractions and users
- Hydrological information
- Water regulation

↓

Step-4 Network Design
- Selection of sampling locations
- Optimum number of locations
- Parameters to be measured
- Component to be samples- water, sediment or biota

↓

Step-5 Sampling
- Representative sampling
- Field testing
- Sample preservation and transport

↓

Step-6 Laboratory Work
- Laboratory procedures
- Physical, chemical analysis
- Microbiological and biological analysis

↓

Step-7 Data Management
- Storage
- Statistical analysis
- Presentation
- Interpretation
- Reporting

↓

Step-8 Quality Assurance
- Production of reliable data
- Quality control
- Internal AQC
- External AQC

Question

Q.1. What are the various methods of monitoring and control of water pollution?

5 CHARACTERISTICS OF WATER RESOURCES IN TROPICAL COUNTRIES

Many arid and semi-arid countries water is becoming an increasingly scarce resource and planners are forced to consider any sources of water which might be used economically and effectively to promote further development. At the same time, with population expanding at a high rate, the need for increased food production is apparent. The potential for irrigation to raise both agricultural productivity and the living standards of the rural poor has long been recognized. Irrigated agriculture occupies approximately 17 percent of the world's total arable land but the production from this land comprises about 34 percent of the world total. This potential is even more pronounced in arid areas, such as the Near East Region, where only 30 percent of the cultivated area is irrigated but it produces about 75 percent of the total agricultural production. In this same region, more than 50 percent of the food requirements are imported and the rate of increase in demand for food exceeds the rate of increase in agricultural production.

Whenever good quality water is scarce, water of marginal quality will have to be considered for use in agriculture. Although there is no universal definition of 'marginal quality' water, for all practical purposes it can be defined as water that possesses certain characteristics which have the potential to cause problems when it is used for an intended purpose. For example, brackish water is a marginal quality water for agricultural use because of its high dissolved salt content, and municipal wastewater is a marginal quality water because of the associated health hazards. From the viewpoint of irrigation, use of a 'marginal' quality water requires more complex management practices and more stringent monitoring procedures than when good quality water is used. This publication deals with agricultural use of municipal wastewater, which is primarily domestic sewage but possibly contains a proportion of industrial effluents discharged to public sewers.

Expansion of urban populations and increased coverage of domestic water supply and sewerage give rise to greater quantities of municipal wastewater. With the current emphasis on environmental health and water pollution issues, there is an increasing awareness of the need to dispose of these wastewaters safely and beneficially. Use of wastewater in agriculture could be an important consideration when its disposal is being planned in arid and semi-arid regions. However it should be realized that the quantity of wastewater available in most countries will account for only a small fraction of the total irrigation water requirements. Nevertheless, wastewater use will result in the conservation of higher quality water and its use for purposes other than irrigation. As the marginal cost of alternative supplies of good quality water will usually be higher in water-short areas, it makes good sense to incorporate agricultural reuse into water resources and land use planning.

Properly planned use of municipal wastewater alleviates surface water pollution problems and not only conserves valuable water resources but also takes advantage of the nutrients contained in sewage to grow crops. The availability of this additional water near population centres will increase the choice of crops which farmers can grow. The nitrogen and phosphorus content of sewage might reduce or eliminate the requirements for commercial fertilizers. It is advantageous to consider effluent reuse at the same time as wastewater collection, treatment and disposal are planned so that sewerage system design can be optimized in terms of effluent transport and treatment methods. The cost of transmission of effluent from inappropriately sited sewage treatment plants to distant agricultural land is usually prohibitive. Additionally, sewage treatment techniques for effluent discharge to surface waters may not always be appropriate for agricultural use of the effluent.

Many countries have included wastewater reuse as an important dimension of water resources planning. In the more arid areas of Australia and the USA wastewater is used in agriculture, releasing high quality water supplies for potable use. Some countries, for example the Hashemite Kingdom of Jordan and the Kingdom of Saudi Arabia, have a national policy to reuse all treated wastewater effluents and have already made considerable progress towards this end. In China, sewage use in agriculture has developed rapidly since 1958 and now over 1.33 million hectares are irrigated with sewage effluent. It is generally accepted that wastewater use in agriculture is justified on agronomic and economic grounds (see Example 1) but care must be taken to minimize adverse health and environmental impacts. The purpose of this document is to provide countries with guidelines for wastewater use in agriculture which will allow the practice to be adopted with complete health and environmental security.

Q.1 What is the status of water resources in tropical countries?

6. CONCEPT OF ‘NEW’ WATER OR (RECLAIMED WASTEWATER) AS A RESOURCE

Reclaimed water or **recycled water**, is wastewater (sewage) that is treated to remove solids and certain impurities, and used in sustainable landscaping irrigation or to recharge groundwater aquifers. The purpose of these processes is sustainability and water conservation, rather than discharging the treated water to surface waters such as rivers and oceans. Water utilities around the world are under growing pressure to combat the water shortage issues caused by severe droughts, uneven distribution of water resources and population growth. There are only two options available, one to reduce the water demand and the other to increase the water supply. Having exploited possible existing water supplies and explored all the possible water conservation and demand management, several municipalities in the world have been considering the ***reclaimed wastewater as a resource not to be wasted***..

6.1 TYPES OF WASTEWATER RECLAMATION AND REUSES

i) Unplanned Indirect Potable Water Reuse (UIPR) : Unplanned indirect portable use occurs when a water supply is abstracted for portable purposes from a natural source (surface or groundwater) that is fed in part by the discharge/disposal of treated or non-treated wastewater effluent. The subsequent portable use of the wastewater was not an intentional part of the effluent disposal plan and therefore, the waste water discharged is not treated to a much higher degree as it is with the planned indirect portable reuse. This type of indirect portable reuse occurs whenever an upstream water users discharges waste water into a water source that serve as a water supply for a downstream user.

ii) **Planned Indirect Portable Reuse (PIPR)** Planned indirect portable water reuse involves intentional augmentation of natural water supply sources such as river, lake, reservoir of underground aquifer for subsequent abstraction, treatment and distribution of water for drinking purposes. As shown in fig.2, the wastewater discharged will be subjected to very high degree of treatments with multiple barriers to remove the contaminants before disposal into the natural water supply sources. With planned of unplanned indirect portable reuse, the storage provided between treatment and consumption allows time for mixing, dilution and natural, physical, chemical, biological processes to purify the water.

iii) **Direct Potable Reuse (DPR)**

Direct portable reuse refers to the introduction of highly treated wastewater with extensive processing beyond usual wastewater treatment directly into a water distribution system without intervening storage. Direct use of reclaimed wastewater for portable reuse without the added protection by storage in the environment is not considered as a viable option in Australia

6.2 TREATMENT OF WASTE WATER

Sewage can be treated close to where it is created, a decentralised system, (in septic tanks, biofilters or aerobic treatment systems), or be collected and transported via a network of pipes and pump stations to a municipal treatment plant, a centralised system, (see sewerage and pipes and infrastructure). Sewage collection and treatment is typically subject to local, state and federal regulations and standards. Industrial sources of wastewater often require specialized treatment processes (see Industrial wastewater treatment).

Sewage treatment generally involves three stages, called primary, secondary and tertiary treatment.

- ***Primary treatment*** consists of temporarily holding the sewage in a quiescent basin where heavy solids can settle to the bottom while oil, grease and lighter solids float to the surface. The settled and floating materials are removed and the remaining liquid may be discharged or subjected to secondary treatment.
- ***Secondary treatment*** removes dissolved and suspended biological matter. Secondary treatment is typically performed by indigenous, water-borne micro-organisms in a managed habitat. Secondary treatment may require a separation process to remove the micro-organisms from the treated water prior to discharge or tertiary treatment.
- ***Tertiary treatment*** is sometimes defined as anything more than primary and secondary treatment in order to allow rejection into a highly sensitive or fragile ecosystem (estuaries, low-flow rivers, coral reefs). Treated water is sometimes disinfected chemically or physically (for example, by lagoons and microfiltration) prior to discharge into a stream, river, bay, lagoon or wetland, or it can be used for the irrigation of a golf course, green way or park. If it is sufficiently clean, it can also be used for groundwater recharge or agricultural purposes.

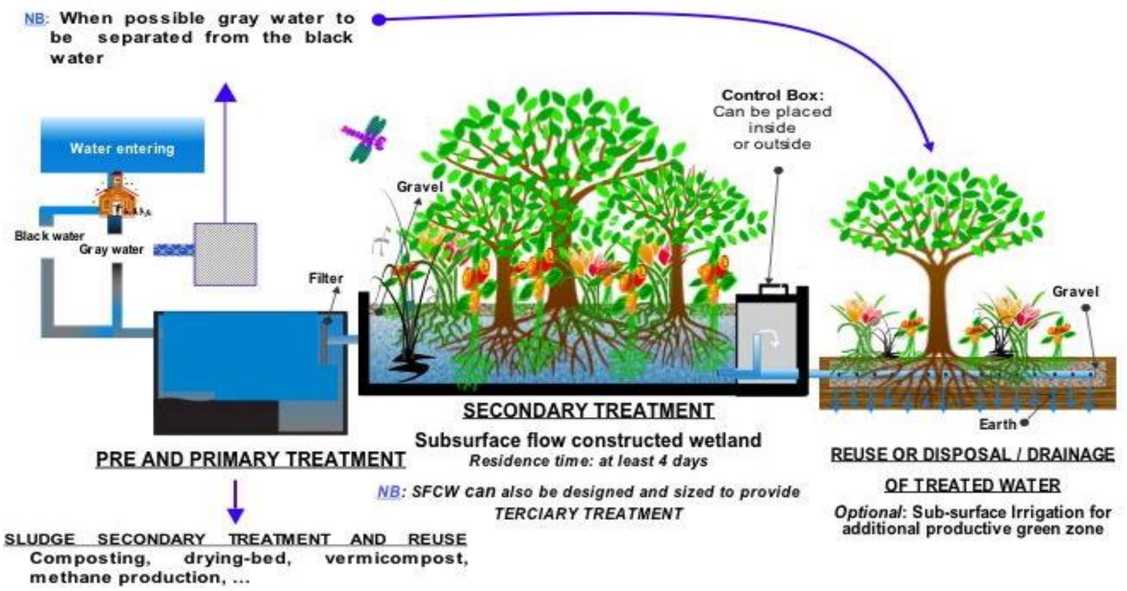

Fig:2 Typical treatment plant via Subsurface Flow Constructed Wetlands (SFCW)

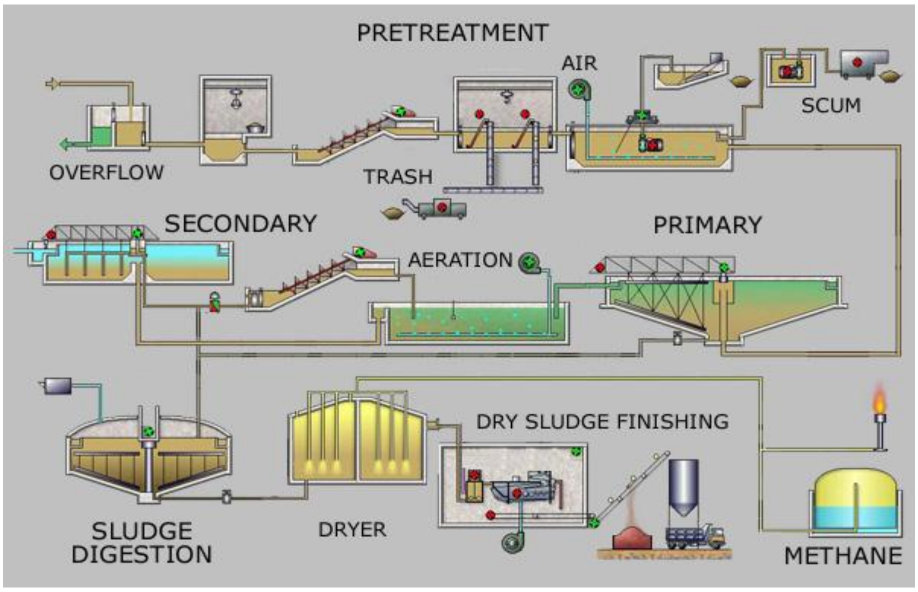

Fig 3: Typical large-scale treatment plant

6.3 WORLDWIDE APPLICATIONS AND ACCEPTANCE

The leaders in use of reclaimed water in the U.S. are **Florida and California**, with **Irvine Ranch Water District** as one of the leading developers. They were the first district to approve the use of reclaimed water for in-building piping and use in flushing toilets. As **Australia** continues to battle the 7–10-year drought, nationwide, reclaimed effluent is becoming a popular option. Two major capital cities in Australia, **Adelaide and Brisbane**, have already committed to adding reclaimed effluent to their dwindling dams. Brisbane has been seen as a leader in this trend, and other cities and towns will review the **Western Corridor Recycled Water Project** once completed. **Goulbourn, Canberra, Newcastle, and Regional Victoria, Australia** are already considering building a reclaimed effluent process. According to an EU-funded study, "**Europe and the Mediterranean countries** are lagging behind" **California, Japan, and Australia** "in the extent to which reuse is being taken up." According to the study "the concept (of reuse) is difficult for the regulators and wider public to understand and accept.

As of 2010**, Israel** treats 80% of its sewage (400 billion liters a year), and 100% of the sewage from the Tel Aviv metropolitan area is treated and reused as irrigation water for agriculture and public works. The remaining sludge is currently pumped into the Mediterranean, however a new bill has passed stating a conversion to treating the sludge to be used as manure. Only 20% of the treated water is lost (due to evaporation, leaks, overflows and seeping). The recycled water allows farmers to plan ahead and not be limited by water shortages. There are many levels of treatment, and many different ways of treating the water—which leads to a big difference in the quality of the end product. The best quality of reclaimed sewage water comes from adding a gravitational filtering step, after the chemical and biological cleansing. This method uses small ponds in which the water seeps through the sand into the aquifer in about 400 days, then is pumped out as clear purified water. This is nearly the same process used in the space station water recycling system, which turns urine and feces into purified drinking water, oxygen and manure. To add to the efficiency of the Israeli system - the reclaimed sewage water may be mixed with reclaimed sea water (Plans are in action to increase the desalinization program up to 50% of the countries usage by 2013 - 600 billion liters of drinkable sea water a year), along with aquifer water and fresh sweet lake water - monitored by computer to account for the nationwide needs and input. This action reduced the outdated risk of salt and mineral percentages in the water. Plans to implement this overall usage of reclaimed water for drinking are discouraged by the psychological preconception of the public for the quality of reclaimed water, and the fear of its origin. As of today, all the reclaimed sewage water in Israel is used for agricultural and land improvement purposes. The second largest waste reclamation program in the world is in **Spain,** where 12% of the nation's waste is treated.

6.4 BENEFITS

In urban areas, reclaimed waster water has been used mainly for non-potable applications such as:

i) Irrigation of public parks, recreation centre, athletic fields, school yards and playing fields and edges and central reservation of highways.

ii) Irrigation of landscape areas surrounding public, residential, commercial and industrial buildings.

iii) Irrigation of golf courses

iv) Ornamental landscapes and decorative water features, such as fountains, reflecting pools and waterfalls.

v) Fire protection

Portable urban reuse can be performed directly or indirectly

i) Utilities providing reclaimed water for non-potable uses do not treat the water to drinking water standards.

ii) Varying amounts of pathogens, pharmaceutical chemicals (e.g., hormones from female hormonal contraception) and other trace chemicals are able to pass through the treatment and filtering process, potentially causing danger to humans. Modern technologies such as reverse osmosis may help to somewhat overcome this problem. An experiment by the University of New South Wales reportedly showed a reverse osmosis system removed ethinylestradiol and paracetamol from the wastewater, even at 1000 times the expected concentration. iii) Drinking water standards were developed for natural ground water, and are not appropriate for identifying contaminants in reclaimed water. In addition to pathogens, and organic and endocrine disrupting chemicals, a large number of compounds may be present in reclaimed water. They cannot all be tested for, and there is a paucity of toxicity information on many of the compounds

Assess Your Progress

Q.1. What is reclaimed waste water and what are different types of reclaimed waste water?

Q.2 What is sewage treatment plan and how it is treated?

Q.3. What are the advantages and disadvantages of using reclaimed waste water?

7. SUMMARY

More than 90% of the urban population has access to drinking water, and more than 60% of the population has access to basic sanitation. However, access to reliable, sustainable, and affordable water supply and sanitation (WSS) service is lagging behind. Water quality has deteriorated in most receiving bodies and in shallow groundwater as a result of uncontrolled discharge of raw domestic and industrial waste-water. Most households, forced to cope with poor quality water supply and sanitation service, spend time and money on expensive and unsafe substitutes, costing much higher than their monthly water bills. The inefficiencies in services and costs are passed on to customers, with the poor suffering the most. Poor managerial and financial autonomy, limited accountability, weak cost recovery, perverse incentives and limited capacity has led to poor services to customers across the country. Simply creating infrastructure (normally focusing on augmentation but neglecting the distribution network) and not addressing management of service does not lead to sustainable services. Further, the easy access to financing coupled with overlapping responsibility of policy making, planning, financing, implementation, maintenance and regulation, generally vested in the State Engineering Department, results in lack of incentive for accountable and efficient services. Hardly any State has a well-defined WSS Service Improvement Program supported by sound sector policies and institutional development plan. number of programs have been launched to increase ‘access’ to WSS ‘infrastructure’, including the centrally supported Accelerated Urban WSS Program and recent programs like Jawaharlal Nehru National Urban Renewal Mission (JNNURM) and the Urban Infrastructure Development Scheme for Small and Medium Towns (IDSSMT). The seven year JNNURM program started in November 2005 and provides up to 80% grant financing to participating cities, with grant component smaller in the larger cities at 50%. The WSS sector has been a big beneficiary of the JNNURM program with more than 60% of total funds allocated for water and sanitation infrastructure. The Ministry of Urban Development (MoUD) also launched the National Urban Sanitation Policy (NUSP) in 2008 with the goal of making all Indian cities totally healthy and sanitized. The policy, for the first time articulated the importance of total sanitation, the need for integrated and pro poor city wide sanitation planning, with attention to operations and maintenance and achievement of outcomes. It is mandated that all states need to develop state sanitation strategies by 2011 and cities to develop city sanitation plans by 2011. To raise awareness and promote competition amongst cities, the MoUD undertook a Sanitation Rating of 423 Class I cities in 2010 and, along with bilateral donors, is supporting the preparation of City Sanitation Plans (CSPs) in 140 cities. The city sanitation planning "process" is intended to help cities articulate their sanitation requirements in an integrated manner, addressing the total cycle of sanitation (access, collection, conveyance and treatment/disposal), while also making choices that are compatible with the technical and financial capacity of the city.

While funding infrastructure creation and promoting institutional improvements, these programs are still work-in-progress and do not provide strong incentives for improving reliable and sustainable services to the beneficiary population. Hardly any State has a well-defined WSS Policy and Institutional Development Program. ***The true challenge is not only to increase access to infrastructure but to increase access to reliable, sustainable, and affordable service***

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DEM 103 URBAN WATER MANAGEMENT CR 4

UNIT-3: WATER TREATMENT TECHNOLOGIES

UNIT STRUCTURE

3.0 OBJECTIVES
3.1 INTRODUCTION
3.2 PRIMARY, SECONDARY, AND TERTIARY WASTEWATER TREATMENT
3.2.1 PRIMARY TREATMENT
3.2.1.1 AERATION:
3.2.1.2 COAGULATION AND SEDIMENTATION PROCESSES:
3.2.1.2.1 SEDIMENTATION
3.2.1.2.2 COAGULATION
3.2.1.2.3 FLOCCULATION
3.3 MEMBRANE FILTRATION
3.3.1 MICROFILTRATION AND ULTRAFILTRATION
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3.3.3 ELECTRODIALYSIS:
3.4 ADVANCED WATER TREATMENT
3.5 DESIGN AND MAINTENANCE OF WATER SUPPLY
3.5.1 MAINTENANCE OF WATER SUPPLY
3.5.1.1 MAINTENANCE OF WATER STORAGE FACILITIES
3.5.2 PRIVATE SECTOR PARTICIPATION
3.5.3 PUBLIC WATER SERVICE PROVISION
3.5.4 PRICING OF WATER SUPPLY
3.6 SUMMARY
SUGGESTED READINGS

3.0 OBJECTIVES

After going through this unit, you will be able to:

- discuss primary, secondary and tertiary wastewater treatment
- describe membrane filtration
- get an idea of advanced water treatment
- discuss the design and maintenance of water supply

3.1 INTRODUCTION

Water is a precious commodity. Most of the earth water is sea water. About 2.5% of the water is fresh water that does not contain significant levels of dissolved minerals or salt and two third of that is frozen in ice caps and glaciers. In total only 0.01% of the total water of the planet is accessible for consumption.

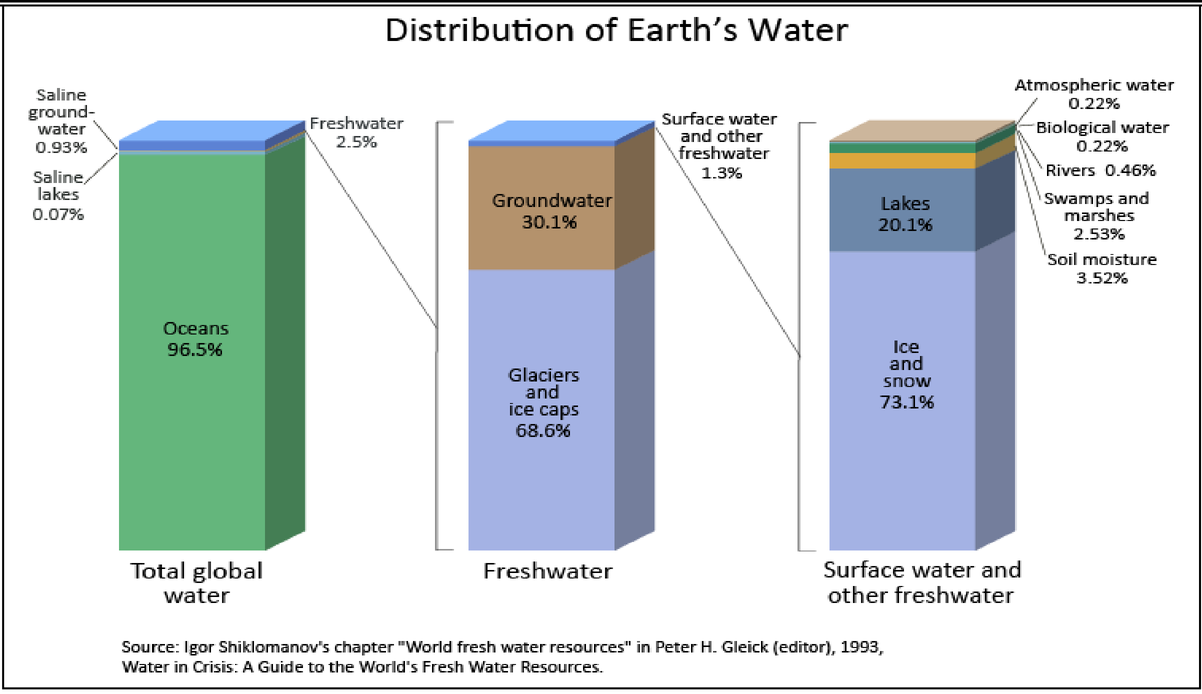


Fig 3.1 Earth's distribution of water

Clean drinking water is a basic human need. Unfortunately, more than one in six people still lack reliable access to this precious resource in developing world.

India accounts for 2.45% of land area and 4% of water resources of the world but represents 16% of the world population. With the present population growth-rate (1.9 per cent per year), the population is expected to cross the 1.5 billion mark by 2050.The Planning Commission, Government of India has estimated the water demand increase from 710 BCM (Billion Cubic Meters) in 2010 to almost 1180 BCM in 2050 with domestic and industrial water consumption expected to increase almost 2.5 times. Urbanization in India is causing stress on civic authorities to provide basic requirement such as safe drinking water, sanitation and infrastructure. The rapid growth of population has exerted the portable water demand, which requires exploration of raw water sources, developing treatment and distribution systems.

Three basic purpose of Water Treatment Plant are as follows:

1. To produce water that is safe for human consumption

2. To produce water that is appealing to the consumer

3. To produce water - using facilities which can be constructed and operated at a reasonable cost.

Primary water quality criteria for designated best classes (for drinking water, outdoor bathing, propagation of wildlife & fisheries, irrigation, industrial cooling) have been developed by the Central Pollution Control Board. The limits for criteria pollutants are given at Table 3.1.

Table 3.1: Primary Water Quality Criteria for Designated Best Use Classes

S.no.	Designated best use		Criteria
1.	Drinking Water Source without conventional treatment but after disinfection	A	1. Total Coliform organism MPN / 100 ml shall be 50 or less 2. pH between 6.5 and 8.5 3. Dissolved Oxygen 6 mg/l or more 4. Biochemical Oxygen Demand 5 days 20°C, 2 mg/l or less
2.	Outdoor bathing (organized)	B	1.Total Coliform organism MPN / 100 ml shall be 500 or less 2.pH between 6.5 and 8.5 3.Dissolved Oxygen 5 mg/l or more 4.Biochemical Oxygen Demand 5 days 20°C, 3 mg/l or less
3.	Drinking water source after conventional treatment and disinfection	C	1.Total Coli form organism MPN / 100 ml shall be 5000 or less 2.pH between 6 and 9 3.Dissolved Oxygen 4 mg/l or more 4.Biochemical Oxygen Demand 5 days 20°C, 3 mg/l or less
4.	Propagation of wild life and fisheries	D	1.pH between 6.5 and 8.5 2.Dissolved Oxygen 4 mg/l or more 3.Free ammonia (as N)1.2 mg/l or less
5.	Irrigation, industrial cooling, controlled waste disposal	E	1.pH between 6.5 and 8.5 2. Electrical Conductivity at 25°C micro mhos /cm Max. 2250 3.Sodium absorption ratio max 26 4. Boron max. 2 mg/l

3.2 PRIMARY, SECONDARY, AND TERTIARY WASTEWATER TREATMENT

Many industrial treatment plants were constructed in the 1970s and 1980s. Discharge criteria required the installation of facilities that performed what is now called primary treatment of wastewater. This involved using screens and sedimentation tanks to remove most of the materials in the wastewater that float or settle. As subsequent discharge criteria were tightened, secondary treatment became necessary. Secondary treatment is accomplished by bringing together waste, bacteria and oxygen in trickling filters or the activated sludge process. Bacteria are used to consume the organic parts of the wastewater. Tertiary treatment facilities were subsequently installed to remove recalcitrant organic compounds, as well as excess nutrients such as nitrogen and phosphorus etc.

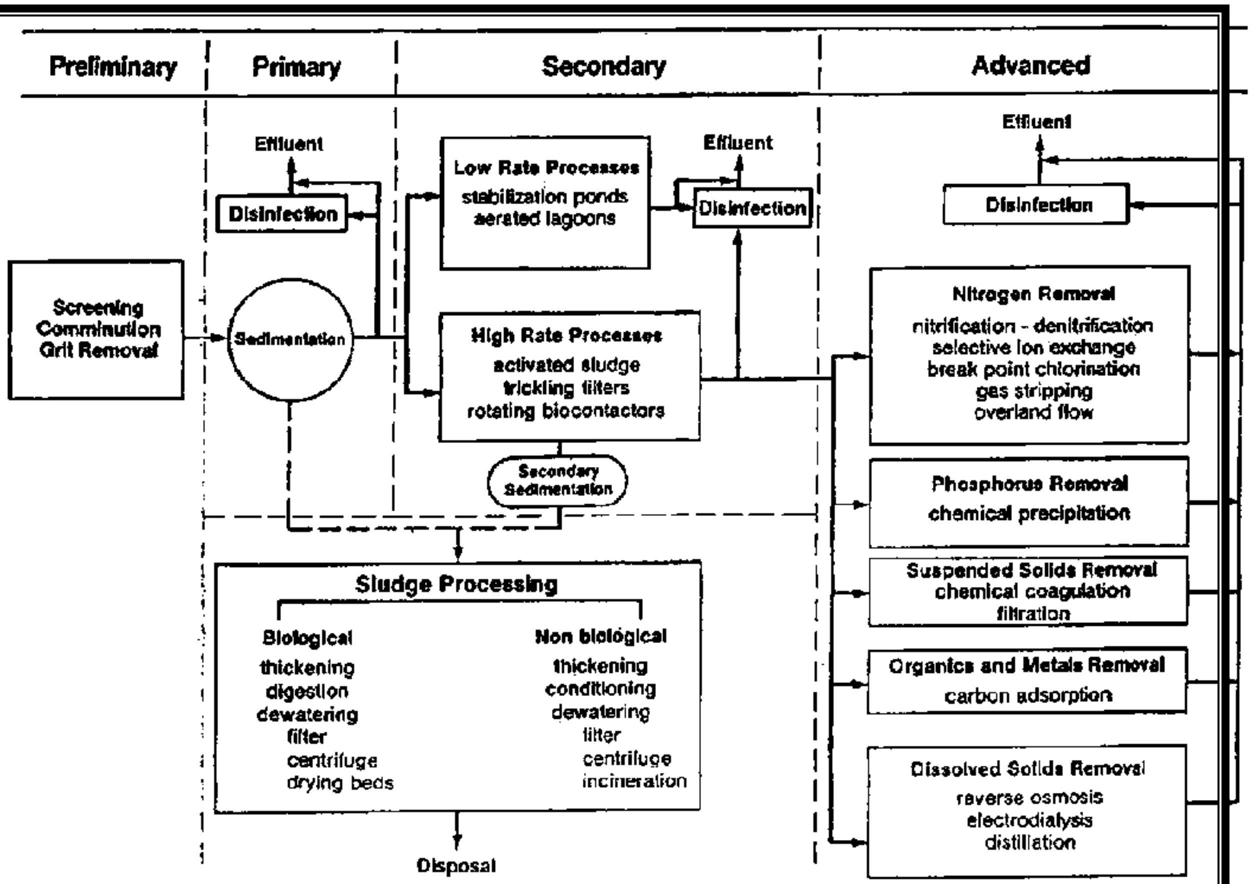


Fig 3.2 Primary, secondary and tertiary treatment

3.2.1 PRIMARY TREATMENT

3.2.1.1 AERATION: Aeration involves bringing air or other gases in contact with water to strip volatile substances from the liquid to the gaseous phase and to dissolve beneficial gases into the water. Purposes of aeration in water treatment are:

- to reduce the concentration of taste and odor causing substances, such as hydrogen sulfide and various organic compounds, by volatilization / stripping or oxidation,
- to oxidize iron and manganese, rendering them insoluble,
- to dissolve a gas in the water (ex.: addition of oxygen to groundwater and addition of carbon dioxide after softening), and
- to remove those compounds that may in some way interfere with or add to the cost of subsequent water treatment (ex.: removal of hydrogen sulfide before chlorination and removal of carbon dioxide prior to softening)

3.2.1.2 COAGULATION AND SEDIMENTATION PROCESSES: All waters, especially surface waters, contain both dissolved and suspended particles. Coagulation and flocculation processes are used to separate the suspended solids portion from the water

3.2.1.2.1 SEDIMENTATION

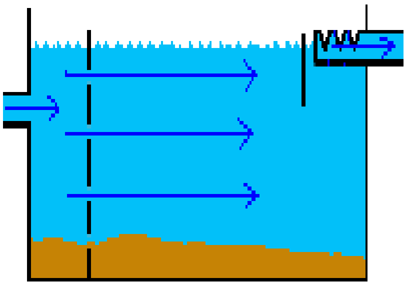
Sedimentation is a treatment process in which the velocity of the water is lowered below the suspension velocity and the suspended particles settle out of the water due to gravity. The process is also known as settling or clarification. Most water treatment plants include sedimentation in their treatment processes. However, sedimentation may not be necessary in low turbidity water of less than 10 NTU.

The most common form of sedimentation follows coagulation and flocculation and precedes filtration. This type of sedimentation requires chemical addition (in the coagulation/flocculation step) and removes the resulting floc from the water. Sedimentation at this stage in the treatment process should remove 90% of the suspended particles from the water, including bacteria. The purpose of sedimentation here is to decrease the concentration of suspended particles in the water, reducing the load on the filters.

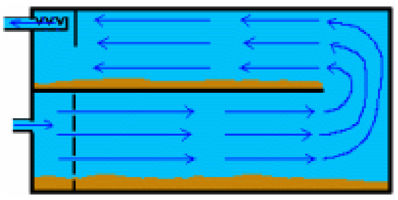
Sedimentation can also occur as part of the pretreatment process, where it is known as **presedimentation**. Presedimentation can also be called **plain sedimentation** because the process depends merely on gravity and includes no coagulation and flocculation. Without coagulation/flocculation, plain sedimentation can remove only coarse suspended matter (such as grit) which will settle rapidly out of the water without the addition of chemicals. This type of sedimentation typically takes place in a reservoir, grit basin, debris dam, or sand trap at the beginning of the treatment process.

Types of Basins

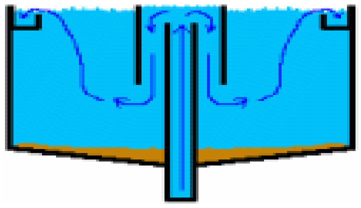
Three common types of sedimentation basins are shown below (Fig 3.3):



1. Rectangular basins are the simplest design, allowing water to flow horizontally through a long tank. This type of basin is usually found in large-scale water treatment plants. Rectangular basins have a variety of advantages - predictability, cost-effectiveness, and low maintenance. In addition, rectangular basins are the least likely to short-circuit, especially if the length is at least twice the width. A disadvantage of rectangular basins is the large amount of land area required.



2. Double-deck rectangular basins are essentially two rectangular sedimentation basins stacked one atop the other. This type of basin conserves land area, but has higher operation and maintenance costs than a one-level rectangular basin.



3. Square or circular sedimentation basins with horizontal flow are often known as **clarifiers**. This type of basin is likely to have short-circuiting problems.

Coagulation and flocculation occur in successive steps intended to overcome the forces stabilizing the suspended particles, allowing particle collision and growth of floc. If step one is incomplete, the following step will be unsuccessful.

3.2.1.2.2 COAGULATION

The first step destabilizes the particle's charges. Coagulants with charges opposite those of the suspended solids are added to the water to neutralize the negative charges on dispersed non-settlable solids such as clay and color-producing organic substances. Once the charge is neutralized, the small suspended particles are capable of sticking together. The slightly larger particles formed through this process and called microflocs, are not visible to the naked eye. The water surrounding the newly formed microflocs should be clear. If it is not, all the particles' charges have not been neutralized, and coagulation has not been carried to completion. More coagulant may need to be added.

A high-energy, rapid-mix to properly disperse the coagulant and promote particle collisions is needed to achieve good coagulation. Over-mixing does not affect coagulation, but insufficient mixing will leave this step incomplete. Coagulants should be added where sufficient mixing will occur.

3.2.1.2.3 FLOCCULATION

Following the first step of coagulation, a second process called flocculation occurs. Flocculation, a gentle mixing stage, increases the particle size from submicroscopic microfloc to visible suspended particles.

The microflocs are brought into contact with each other through the process of slow mixing. Collisions of the microfloc particles cause them to bond to produce larger, visible flocs called pinflocs. The floc size continues to build through additional collisions and interaction with inorganic polymers formed by the coagulant or with organic polymers added. Macroflocs are formed. High molecular weight polymers, called coagulant aids, may be added during this step to help bridge, bind, and strengthen the floc, add weight, and increase settling rate. Once the floc has reached it optimum size and strength, the water is ready for the sedimentation process.

Coagulant selection

The choice of coagulant chemical depends upon the nature of the suspended solid to be removed, the raw water conditions, the facility design, and the cost of the amount of chemical necessary to produce the desired result. Considerations must be given to required effluent quality, effect upon down stream treatment process performance, cost, method and cost of sludge handling and disposal, and net overall cost at the dose required for effective treatment.

Inorganic Coagulants

Inorganic coagulants such as aluminum and iron salts are the most commonly used. When added to the water, they furnish highly charged ions to neutralize the suspended particles. The inorganic hydroxides formed produce short polymer chains which enhance microfloc formation. Inorganic coagulants usually offer the lowest price per pound, are widely available, and, when properly applied, are quite effective in removing most suspended solids. They are also capable of removing a portion of the organic precursors which may combine with chlorine to form disinfection by-products. They produce large volumes of floc which can entrap bacteria as they settle. However, they may alter the pH of the water since they consume alkalinity. When applied in a lime soda ash softening process, alum and iron salts generate demand for lime and soda ash. They require corrosion-resistant storage and feed equipment. The large volumes of settled floc must be disposed of in an environmentally acceptable manner.

Inorganic Coagulant Reactions Common coagulant chemicals used are alum, ferric sulfate, ferric chloride, ferrous sulfate, and sodium aluminate. The first four will lower the alkalinity and pH of the solution while the sodium aluminate will add alkalinity and raise the pH. The reactions of each follow:

ALUM

$A1_2(SO_4)_3$ + 3 $Ca(HCO_3)_2$ ------------> 2 $Al(OH)_3$ + $3CaSO_4$ + 6 CO_2

Aluminum + Calcium gives Aluminum + Calcium + Carbon

Sulfate Bicarbonate Hydroxide Sulfate Dioxide

FERRIC SULFATE

$Fe_2(SO4)_3$ + 3 $Ca(HCO_3)_2$ ------------> 2 $Fe(OH)_3$ + $3CaSO_4$ + 6 CO_2

Ferric + Calcium gives Ferric + Calcium + Carbon

Sulfate Bicarbonate Hydroxide Sulfate Dioxide

FERRIC CHLORIDE

2 Fe Cl_3 + 3 $Ca(HCO_3)_2$ ------------> 2 $Fe(OH)_3$ + $3CaCl_2$ + $6CO_2$

Ferric + Calcium gives Ferric + Calcium + Carbon

Chloride Bicarbonate Hydroxide Chloride Dioxide

FERROUS SULFATE

$FeS0_4$ + $Ca(HCO_3)_2$ ------------> $Fe(OH)_2$ + $CaS0_4$ + $2CO_2$

Ferrous + Calcium gives Ferrous + Calcium + Carbon

Sulfate Bicarbonate Hydroxide Sulfate Dioxide

SODIUM ALUMINATE

2 $Na_2A1_2O_4$ + $Ca(HCO_3)_2$ ------------> 8 $Al(OH)_3$ + 3 Na_2CO_3 + 6 H_20

Sodium + Calcium gives Aluminum + Sodium + Water

Aluminate Carbonate Hydroxide Carbonate

Case Study 1:
Alum is being added as coagulant in almost all Water Treatment Plants, however, recently water treatment plant at Nasik and Pune have started using PAC instead of alum, which is in liquid form. The water treatment plant personal appeared to prefer PAC as no solution is to be prepared, as in case of alum. Bhandup water treatment complex, Mumbai is using aluminium ferric sulphate, which is one of the biggest water treatment plants in India.

3.3 SAND FILTRATION AND MEMBRANE FILTRATION

3.3.1 SAND FILTRATION

Sand filtration is one of the oldest wastewater treatment technologies known. If properly designed, constructed, operated and maintained, a sand filter produces a very high quality effluent. Wastewater applied to the sand filter should be pretreated, such as in a septic tank. Sand filters are beds of granular material, or sand, drained from underneath so that pretreated wastewater can be treated, collected and distributed to the land application system. They are normally used to polish effluent from septic tanks or other treatment processes before it is distributed on the land. Slow sand filters operate by two methods: a deep sand bed, and a surface coating filter which processes the water biologically.

The typical sand filter is a lined watertight box, generally concrete- or plastic-lined, and filled with a specific sand material. Types of sand filters include:

- **Intermittent sand filter**, in which wastewater is applied periodically to a 24- to 36-inch-deep bed of sand that is under drained to collect and discharge the effluent. The bed is underlain by graded gravel and collecting tile. Wastewater is applied intermittently to the bed's surface through distribution pipes.
- **Recirculating intermittent sand filter**, which filters wastewater by mixing filtrate with incoming septic tank effluent and recirculating it several times through the filter media before discharging it to a final land application system. This filter's components are similar to the intermittent sand filter components.

Treatment

A sand filter purifies the water in three ways:

- Filtration, in which particles are physically strained from the incoming wastewater;
- Chemical sorption, in which contaminants stick to the surface of the sand and to the biological growth on the sand surface; and
- Assimilation, in which aerobic microbes eat the nutrients in the wastewater. The success of treating wastewater depends on these microbes. Air must be available for these microbes to live.

3.3 MEMBRANE FILTRATION

The application of membrane filtration for drinking-water applications has increased markedly in recent years, with a membrane option considered for most water treatment applications. The increase in uptake has been driven by a number of factors, from lowering unit capital and operating costs, to the emergence of low-pressure membrane technology (reducing power demands), and a greater emphasis on correct pretreatment selection. In addition, advantages offered by advanced materials and low footprint designs have given membrane options additional weight when compared with traditional treatment approaches. These recent developments have been aided by the emergence of further, legitimate evidence supporting membrane filtration as a secure means to eliminate pathogenic organisms from the water supply, in particular, the protozoan species *Cryptosporidium* and *Giardia*.

Fundamentals of membrane filtration

There are four principal classes of membrane filtration that apply to drinking-water treatment:

• microfiltration (MF)
• ultrafiltration (UF)
• nanofiltration (NF)
• reverse osmosis (RO).

3.3.1 MICROFILTRATION AND ULTRAFILTRATION

MF and UF are characterized by their ability to remove suspended or colloidal particles via a sieving mechanism based on the size of the membrane pores in the membrane, relative to that of the particulate matter.

Each membrane has a distribution of pores, which will vary according to the membrane material and manufacturing process. There are two ways to represent pore size:

• nominal, the average pore size
• absolute, the maximum pore size.

MF membranes are generally considered to have a pore range of 0.1-0.2 μm (nominally 0.1 μm), although there are exceptions, with some MF membranes marketed with pore sizes up to 10 μm.

For UF, pore sizes generally range from 0.01 - 0.05 μm (nominally 0.01 μm) or less. With UF, classification in terms of pore size becomes inappropriate, due to the other mechanisms/phenomena that take place at the membrane surface. In terms of pore size, the lower cut off for a UF membrane is approximately 0.005 μm.

Some UF membranes are categorised in terms of their molecular weight cut-off (MWCO) rather than a particular pore size. The concept of MWCO, expressed in Daltons (a unit of mass) is a measure of the removal characteristic of a membrane in terms of atomic weight (or mass) rather than size. Therefore, UF membranes with a specified MWCO are presumed to act as a barrier to compounds or molecules with a molecular weight exceeding the MWCO.

3.3.2. NANOFILTRATION AND REVERSE OSMOSIS

NF and RO comprise a class of membrane processes that provide a higher degree of removal of contaminants compared with MF/UF. They are specified less frequently in drinking-water applications.

NF/RO remove dissolved contaminants, as represented by measurements of total dissolved solids (TDS) or conductivity (μS/cm). The typical range of MWCO is less than 100 Daltons for RO membranes, and between 200 and 1,000 for NF membranes.

Reverse osmosis: In the reverse osmosis process, demineralization water is produced by forcing water through semi permeable membranes at high pressure. In ordinary osmosis, if a vessel is divided by a semi permeable membrane (one that is permeable to water but not the dissolved material), and one compartment is filled with water and other with concentrated salt solution, water diffused through the membrane towards the compartment containing salt solution until the difference in water levels on the two sides of the membrane creates a sufficient pressure to counteract the original water flow.

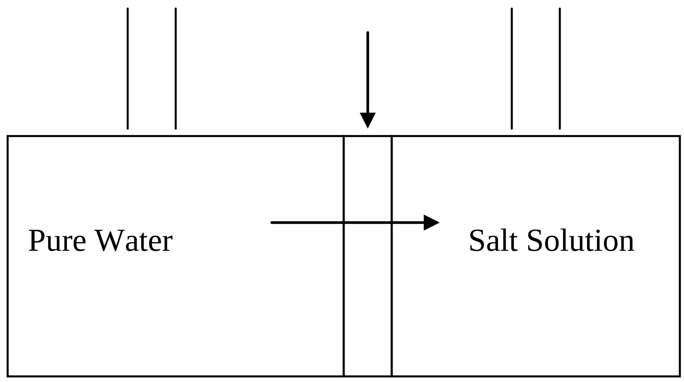


Fig 3.4 Osmosis

The process can be reversed by applying sufficient pressure to the concentrated solution to overcome the osmotic pressure force the net flow of water through the membrane towards the dilute phase. The solute concentration (impurity) builds up on one side of the membrane while relatively pure water passes through the membrane. In order to obtain adequate solvent (water) flux through the membrane, pressures of the order of 4000 to 7000 kN/m^2 are required.

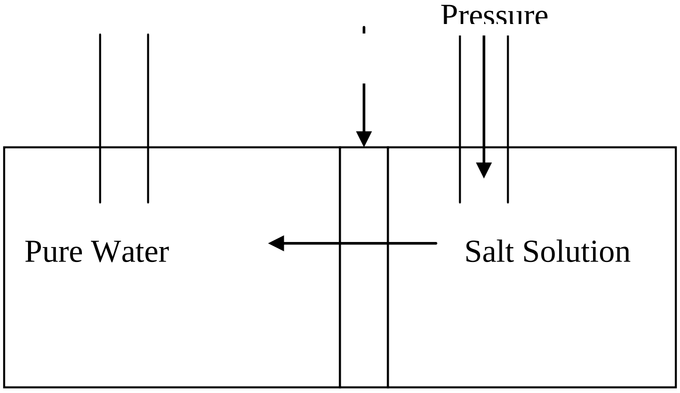


Fig 3.5 Reverse Osmosis

3.3.3 ELECTRODIALYSIS: Electrodialysis uses ion-selective membranes and an electrical potential difference to separate anions and cations in solution.

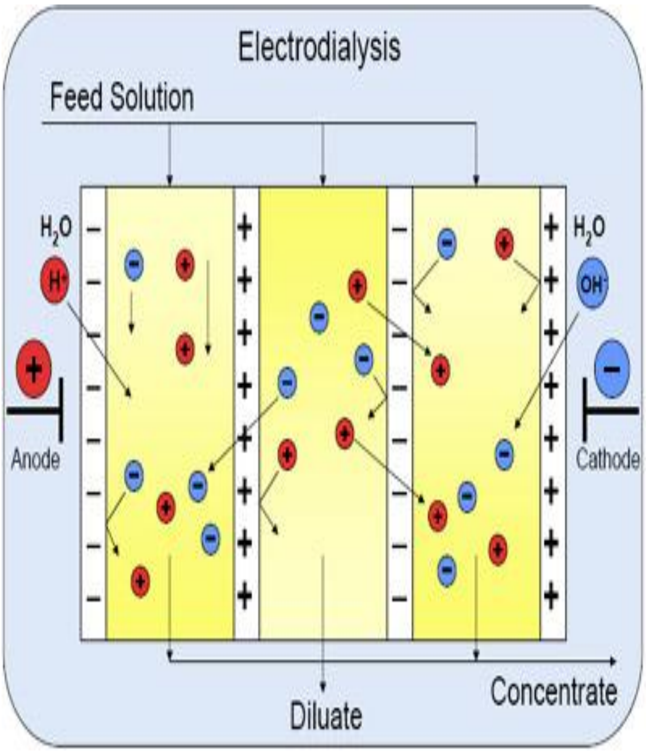


Fig. 3.7 shows a simple dialysis cell in which waste water may be deionised. As shown in the figure two types of membranes (anionic and cationic) are arranged alternatively to form many compartments between the electrodes placed at the two ends. When the voltage is applied across the cell containing mineralized water, the anions migrate to the positive electrode and the cations migrate to the negative electrode. This causes solution in alternate compartments to become more concentrated while that in the remaining becomes more dilute. The electric power requirement is proportional to the number of ions removed from the water.

Fig 3.6 Electrodialysis

In the past electrodialysis was most often used for purifying brackish water, but it is now finding a role in hazardous waste treatment.

In the electrodialysis process, organic molecules are not removed and they can collect on and clog the membranes. Another disadvantage of this method is that it still leaves concentrated waste water to be disposed of by some appropriate scheme. The process does not require any chemical additives and has low energy requirements and as such it can be an economically feasible means of demineralisation.

3.4 ADVANCED WATER TREATMENT

Different methods are used in advanced waste treatment to satisfy any of the several specific goals, which include the removal of (1) suspended solids (2) BOD (3) plant nutrients (4) dissolved solids and (5) toxic substances.

Removal of Suspended Solids:

This treatment implies the removal of those materials that have been carried over from a secondary treatment settler. Many methods were proposed of which two methods were commonly used. The two methods are micro staining and chemical coagulation followed by settling and mixed media filtration.

Micro straining: It is a special type of filtration procedure which makes use of filters oven from stainless steel wires with opening only 60-70 μm across to remove very small particles. High flow rates and low back pressures are normally achieved.

Removal of dissolved solids:

The dissolved solids are of both organic and inorganic types. A number of methods have been investigated for the removal of inorganic constituents from waste water. Three methods which are finding wide application in advanced waste treatment are ion-exchange, electrodialysis and reverse osmosis. For the removal of soluble organics from waste water the most commonly used method is adsorption on activated carbon

Ion exchange: The process takes advantage of the ability of certain natural and synthetic materials to exchange one of their ions. A number of naturally occurring minerals have ion exchange properties. Among them the notable ones are aluminium silicate minerals, which are called zeolites. Synthetic zeolites have been prepared using solutions of sodium silicate and sodium aluminate. Alternatively synthetic ion-exchange resins composed of organic polymer with attached functional groups such as $–SO_3^-H^+$ (strongly acidic cation exchange resins), or $–COO^-H^+$(weakly acidic cation exchange resins) or $-N^+(CH_3)_3OH^-$ (strongly basic anion exchange resins) can be used.

In the water softening process, the hardness producing elements such as calcium and magnesium are replaced by sodium ions. A cation exchange resin in sodium form is normally used. The water-softening capability of cation exchange can be seen when sodium ion in the resin is exchanged for calcium ion in solution.

$$\mathbf{2ResSO_3^-Na^+ + Ca^{2+} \rightarrow (ResSO_3^-)_2 Ca^{2+} + 2Na^+}$$

(Where "Res" represents resin phase)

The product water thus has high sodium content, which is not likely to be troublesome unless the original water is very hard. When the exchanger is saturated, it has to be regenerated to allow reuse of expensive resin. Regeneration can be achieved by sodium chloride solution which removes Ca2+ and Mg2+ ions from the resin.

$$(ResSO_3^-)_2\ Ca^{2+} + 2Na^+ + 2Cl^- \rightarrow 2Na^+(ResSO_3^-) + Ca^{2+} + 2Cl^-$$

Since for regeneration large amounts of NaCl has to be used, appreciable amounts of sodium chloride can be introduced into sewage by this route. This problem can be overcome by using weakly acidic cation exchange resin such $ResCOO^-H^+$. These cation exchangers having -COOH as functional group are useful for removing alkalinity along with hardness. Alkalinity is generally manifested by bicarbonate ion.

Removal of nitrogen:

Nitrogen compounds may be removed in waste water in two ways. Even after secondary treatment, most of nitrogen exists as ammonia. Increasing the pH produces the reaction,

$NH_4^+ + OH^- \rightarrow NH_3\uparrow + H_2O$

Much of the dissolved ammonia gas may then be expelled from the water into the atmosphere. The ammonium ion in the waste water may also be oxidized to nitrate by bacteria like nitrobacter and nitrosomonas, in a process called nitrification.

$2NH_4^+ + 3O_2$ ------------ > $2NO_2^- + 2H_2O + 4H^+$ (in presence of nitrosomonas bacteria)

$2NO_2^- + 3O_2$ ------------- > $2\ NO_3^-$

Once the ammonia has been oxidized to nitrate, it may be reduced by anaerobic bacteria like pseudomonas. This denitrification requires a source of carbon and methanol is often used for that purpose.

$6\ NO_3^- + CH_3OH$ ------------- > $2CO_2 + 6NO_2^- + 4H_2O$

$6\ NO_2^- + 3\ CH_3OH$ ------------- > $3N_2 + 3\ CO_2 + 3H_2O + 6OH^-$

Phosphate removal (chemical treatment):

Phosphate may be removed chemically or biologically. The most popular chemical methods use lime, $Ca(OH)_2$ and alum, $Al_2(SO_4)_3$.Under alkaline conditions, the calcium will combine with phosphate to form calcium hydroxyapatite, a white insoluble precipitate that is settled out and removed from waste water. Insoluble calcium carbonate is also formed and removed.

$5Ca(OH)_2 + 3HPO_4^{2-}$ -------------- > $Ca_5OH(PO_4)_3 + 3H_2O + 6OH^-$

The aluminium ion from alum precipitates as very slightly soluble aluminium phosphate,

$Al^{3+} + PO_4^{3-}$ ------------- > $AlPO_4$

$Al^{3+} + 3OH^-$ ------------- > $Al(OH)_3$ and also forms aluminium hydroxide which forms sticky flocs that help to settle out phosphates.

Phosphate removal (biological treatment)

Biological phosphorous removal does not require the addition of chemicals. In this process, the aeration tank in the activated sludge system is subdivided into zones, some of which are not aerated. In these zones, the aerobic microorganisms become solely stressed because of the lack of oxygen. If these microorganisms are then transferred to an aerated zone, they try to make up for lost time and assimilate organic matter (as well as phosphorous) at a rate much higher than they ordinarily would. Once the microorganisms have adsorbed the phosphorous, they are removed as waste activated sludge, thus carrying with them high concentrations of phosphorous. Using such sequencing of nonaerated and aerated zones, it is possible to remove as much as 90% of the phosphorous.

Removal of dissolved organic compounds:

Adsorption: One of the most commonly used techniques for removing organics involves the process of adsorption, which is the physical adhesion of chemicals on to the surface of the solid. The most commonly used adsorbent is a very porous matrix of granular activated carbon, which has an enormous surface area (~ 1000 m2/g). Adsorption on activated carbon is perhaps the most economical and technically attractive method available for removing soluble organics such as phenols, chlorinated hydrocarbons, surfactants, and colour and odour producing substances from waste water.

Granular activated carbon treatment systems consist of a series of large vessels partially filled with adsorbent. Contaminated water enters the top of each vessel, trickles down through granulated activated carbon, and is released at the bottom. After a period of time, the carbon filter becomes clogged with adsorbed contaminants and must be either replaced or regenerated. Regeneration of the carbon is accomplished by heating it to 950^{o}C in a steam air atmosphere. This process oxidizes surface, with an approximately 10% loss of carbon.

Fluoride & arsenic and removal techniques

De- fluorination Several methods have been suggested for removing excessive fluorides in drinking water. These may be broadly divided into two types.

1) Those based upon exchange process or adsorption

2) Those based upon addition of chemicals during treatment.

- The material used in contact beds includes processed bone, natural or syntheti tricalcium phosphate, hydroxy apatite magnesia, activated alumina, activated carbon and io exchanger.
- Chemical treatment methods include the use of lime either alone or with magnesium an aluminium salts again either alone or in combination with coagulant aid. Other methods includ addition to fluoride water of material like Magnesia, calcium phospate, bentonite and fuller' earth, mixing and their separation from water by settling and filtration.

Box 2

Defluoridation of water using Nalgonda technique : After extensive testing of many materials and processes including activated alumina since 1961, National Environment Engineering Research Institute (NEERI), Nagpur has evolved an economical and simple method for removal of fluoride which is referred to as Nalgonda Technique.

Nalgonda Technique involves addition of aluminium salts, lime and bleaching powder followed by rapid mixing, flocculation, sedimentation, filtration and disinfection. Aluminium salt may be added as aluminium sulphate or aluminium chloride or combination of these two. Aluminium salt is only responsible for removal of fluoride from water. The dose of aluminium salt increases with increase in the fluoride and alkalinity levels of the raw water. The selection of either aluminium sulphate or aluminium chloride also depends on sulphate and chloride contents of the raw water to avoid them exceeding their permissible limits. The dose of lime is empirically 1/20th that of the dose of aluminium salt. Lime facilitates forming dense floc for rapid settling. Bleaching powder is added to the raw water at the rate of 3 mg/l for disinfection.

Arsenic removal Plants: Arsenic Removal Plants have been designed by various organizations using different technologies and some of these are installed in the Arsenic affected areas in the State of West Bengal.

1) Plants developed by the All India Institute of Hygiene and Public Health, Kolkata

This system based on coagulation-flocculation-sedimentation-filtration method. Water is treated using bleaching powder at the rate 2 mg/l and alum at the rate of 40 mg/l. Bleaching powder is added for oxidation of As (+3) to As(+5). The system comprises circular tanks with a capacity of 1000 litre. Finally, the water passes through a tank (sand media) containing gravels of 5 mm thick to remove suspended particles. The volume of water treated is 10,000 - 12,000 litre in 12 hours. The dosing of bleaching and alum solution is continuous. Dosing of chemicals is continuous but intake of water is not continuous and therefore, there may be chances of over dosing resulting enhancement of chlorine. As claimed by institute, this will not happen due to 1000 litre of capacity of tank which would minimize accumulation of excess chlorine. The operation cost of this unit is Rs. 1.10 per litre.

2) Plants developed by School Of Environmental Studies(SOES), Jadavpur University, Kolkata and CSIR, New Delhi

School of Environmental Studies (SOES), Jadavpur University, Kolkata in collaboration with CSIR has developed table and filter candle. The main ingredient of the candle is fly ash. Use of fly ash makes the filter candle hard. The filter in combination with a chemical tablet can remove almost 100 percent both AS (+3) and As (+5) from ground water. The system is cost effective, durable and meant for daily use. The complete system consists of mud jars, filter candle and tablet. This can be used for one year at the cost of Rs. 200/- (Two hundred) only. The system was tried in affected districts for studying its efficiency. According to the report, arsenic compound accumulated on the filter candle is washed and washing of the filter along with some cow dung would not contaminate the soil since microorganisms present in the cow dung would convert the inorganic arsenic to methylated form which would be released in to the air.

Disinfection:

Disinfection, using chemical and physical methods is the final step in drinking water purification. The finished water is disinfected often with chlorine. It kills the remaining microorganisms in the water, some of which will be pathogenic. It is a very efficient oxidizing, bleaching and disinfecting agent. In water chlorine reacts as follows:

$Cl_2 + H_2O$ < ------ > $H^+ + Cl^- + HOCl$

The hypochlorous acid (HOCl) is the prime disinfecting agent. Its dissociation in pH dependent yielding less effective hypochlorite ions (OCl-) at higher pH values:

HOCl <------ > $H^+ + Cl^-$

Together, HOCl and OCl- are called the free available chlorine.

A principal advantage of chlorination over other forms of disinfection is that a chlorine residual is created that can protect the treated water after leaving the treatment plant. This guard against possible contamination that might occur in water distribution system. To increase the lifetime of the residual, some systems add ammonia to the treated water, forming chloramines.

Chlorine may have adverse secondary effects. It has the potential to combine with trace amounts of organic substances to form trihalomethanes (THMs) such as the carcinogen chloroform. Some studies have shown an association between bladder and rectal cancer and consumption of chlorinated drinking water. One approach to reducing THMs is to remove more of the organics before any chlorination takes place, which can be accomplished by adsorption on activated carbon.

Ozonization: Ozone is a very powerful disinfectant that is even more effective against cysts and viruses than chlorine, and it has the added advantage of having no taste or odour problems. Ozone has been used extensively in Europe for disinfection and for taste and odor control in water supplies. In addition to its use as a disinfectant, pre ozonation is also used for (a) removal of taste and odor, (b) removal of colour, (c) removal of iron and manganese, (d) enhanced removal of organic matters and (e) oxidation and volatilization of organics.

Ozone is an unstable gas; therefore, it has to be generated on site. In addition, ozone cannot be used as a secondary disinfectant, because an adequate residual in water can be maintained for only a short period of time. Because of its high oxidation potential, ozone requires certain contact time between the dissolved ozone and water. As a micro flocculation aid, ozone is added during or before rapid mix followed by coagulation.

3.5 DESIGN AND MAINTENANCE OF WATER SUPPLY

A water supply system or water supply network is a system of engineered hydrologic and hydraulic components which provide water supply. A water supply system typically includes:

1. A drainage basin
2. A raw (untreated) water collection point (above or below ground) where the water accumulates, such as a lake, a river, or groundwater from an underground aquifer.
3. Water purification facilities. Treated water is transferred using water pipes (usually underground).
4. Water storage facilities such as reservoirs, water tanks, or water towers. Smaller water systems may store the water in cisterns or pressure vessels. (Tall buildings may also need to store water locally in pressure vessels in order for the water to reach the upper floors.)
5. Additional water pressurizing components such as pumping stations may need to be situated at the outlet of underground or above ground reservoirs or cisterns.
6. A pipe network for distribution of water to the consumers.

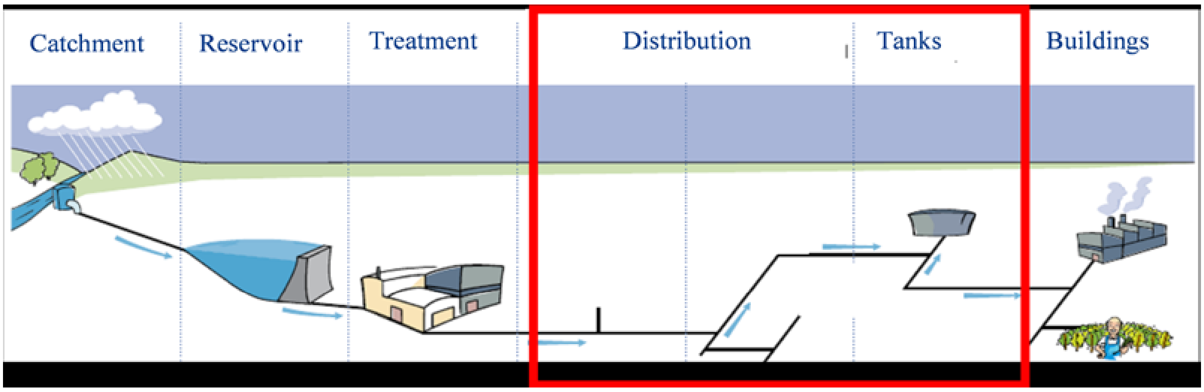


Figure 3.7: Illustration of water supply from source to tap with focus on distribution

(http://www.techneau.org/fileadmin/files/Publications/Publications/Deliverables/D5.6.7.pdf)

For design and maintenance in the distribution system the integrity of the system is important.

3.5.1 The integrity of the distribution system can briefly be divided into the following three groups according to:

1) Physical integrity,

2) Hydraulic integrity and

3) Water quality integrity.

Physical integrity refers to the distribution system as a physical barrier preventing external contamination to occur. Examples of physical barriers in distribution system are water tanks and pipes. These barriers should be operated and maintained for safeguarding the condition of the barrier. E.g. barrier is maintained when minimizing external and internal corrosion. Internal corrosion might be reduced by introducing efficient flushing and cleansing of the network. If the physical barrier is compromised the drinking water supply will become exposed to contamination. This means that it is very important with good practices for installation, repair and rehabilitation.

Hydraulic integrity refers to maintaining adequate water pressure in the network. Low or no pressure might result from pipe breaks, large leakages, pressure surge/water hammer, pump or valve failures etc. These events might increase the risk of contamination from ingress. An important factor related to hydraulic integrity is water age since this influence the level of sedimentation in the network.

Water quality integrity refers to maintaining treated water delivered into the network by preventing internally deterioration of the water quality (biofilm growth, internal corrosion, leaching from pipe material etc).

3.5.1 MAINTENANCE OF WATER SUPPLY

a) Inspect all structures periodically for cracks or structural defects.

b) Measure the depth of the suction well to determine the accumulation of silt and sand. Dredge these accumulations as necessary.

c) When ice conditions endanger the structure or clog the intake opening, take protective measures. Install log booms or bubble compressed air into the water at critical points to prevent freezing. Frazil ice can form in supercooled water and may cause complete blockage of intakes.

d) Remove any material on screens that is not removable by ordinary operations. Lubricate and repair any accessory equipment to movable screens.

3.5.1.1 MAINTENANCE OF WATER STORAGE FACILITIES

Ground Storage Reservoirs

a) Covered reservoirs or tanks should be vented to allow the passage of air to and from the reservoir as the water level changes. Use fine screens on the vents to prevent entrance of animals and insects, and keep the screens in good repair. Keep access manhole covers in place to prevent accidents and contamination. Slope the ground away from the reservoir in all directions so no surface water can flow towards it. Leaks in the cover or walls that permit the entrance of surface water or shallow groundwater are dangerous. Repair leaks at once.

b) In freezing areas, inspect vent screens frequently to keep them clear of ice and frost. Where ground storage tanks are used only for fire protection, operate fire pumps and recirculate tank contents as frequently as required to prevent or reduce ice formation. The construction of earth banks around storage tanks will help insulate the tanks and prevent freezing. Where these measures do not stop freezing, install steam or hot water coils or paint the tanks a dark, energy-absorbent color.

Underground Reservoirs

If storage tanks are constructed below ground level, or are surrounded by an earthen embankment, the inspection and repair includes only the interior walls, roofs, appurtenances, and embankment. If the earthen embankment, surrounding soil, or interior of the tank shows evidence of tank leakage, the earth may need to be excavated and repairs made on the walls.

Elevated Storage

Freezing Prevention: Cover the elevated-tank riser pipe with insulating material to guard against frozen water. In climates where insulation alone may not give adequate protection, install steam coils in the riser and pipe stream into the coils from a nearby boiler plant. Alternatively, connect a circulating hot-water heater to the rise to take water about 15 to 20 feet (5 to 6 m) above the riser base and return it near the base. In the latter case, adding a small recirculating pump is desirable because it provides a large amount of recirculation with limited heat rise.

Inspect vent screens frequently throughout the winter and keep them clear of frost.

3.5.2 PRIVATE SECTOR PARTICIPATION

Under these arrangements the public entity that is legally responsible for service provision delegates certain or all aspects of service provision to the private service provider for a period typically ranging from 4 to 30 years. The public entity continues to own the assets. These arrangements are common in France and in Spain. Only in few parts of the world water supply systems have been completely sold to the private sector (privatization), such as in England and Wales as well as in Chile. The largest private water companies in the world are Suez and Veolia Environnement from France; Aguas de Barcelona from Spain; and Thames Water from the UK, all of which are engaged internationally

3.5.3 PUBLIC WATER SERVICE PROVISION

Under this provision the state or local authorities, or also by collectives or cooperatives run without an aim for profit but are based on the ethos of providing a common good considered to be of public interest. In most middle and low-income countries, these publicly-owned and managed water providers can be inefficient as a result of political interference, leading to over-staffing and low labour productivity. Ironically, the main losers from this institutional arrangement are the urban poor in these countries. Because they are not connected to the network, they end up paying far more per litre of water than do more well-off households connected to the network who benefit from the implicit subsidies that they receive from loss-making utilities. We are still so far from achieving universal access to clean water and sanitation shows that public water authorities, in their current state, are not working well enough.

Yet some are being very successful and are modelling the best forms of public management. As Ryutaro Hashimoto, former Japanese Prime Minister, notes: “Public water services currently provide more than 90 per cent of water supply in the world. Modest improvement in public water operators will have immense impact on global provision of services."

3.5.4 PRICING OF WATER SUPPLY

It has been universally acknowledged that adequate attention has not been paid to pricing of water in the developing countries. Since the provision of water for drinking and domestic uses is a basic need, the pricing of water for this purpose is subsidized. It has been assessed through extensive studies that the rich people are paying less for the quantum of water they consume compared to the poor. Therefore, the objectives of pricing policy consider the following, keeping in view the crucial role played by water pricing policy, in providing incentives for efficient use and conservation of the scarce resource:

- ❖ Determine the water charges (water tariff) based on the average incremental cost of production & supply of water in a water supply system and implement the same in the city by enacting suitable byelaws.
- ❖ Wherever no meter supply is effective, a flat rate may be levied based on the average cost of production and supply of water.
- ❖ For welfare of the urban poor, water may be supplied to them at a subsidized rate. However, minimum charge may be collected from them at a flat rate, instead of free supply so that they can realize the importance of treated water supply. But charge the affluent sections of the society at a higher rate based on metered quantity including free supply, if the consumption is more than the prescribed limit.
- ❖ Water charges may be revised upwards such that these reflect the social cost of the water use. Introduce pollution tax may addresses the issues in water conservation and environmental protection.
- ❖ Where metering is not possible, flat-water charges could be linked as percentage of property tax.
- ❖ Avoid undue discrimination to subsidize particular users as a principle of redistribution of income and to ensure that even the poorest members of the community are not deprived access to safe water.
- ❖ Subsidize a minimum level of service on public health grounds. Discourage wastage and extravagant use of water and to encourage user economy by designing the tariff with multi-tier system incorporating incentives for low consumption.

3.6 SUMMARY

The raw water quality available in India varies significantly, resulting in modifications to the conventional water treatment scheme consisting of aeration, chemical coagulation, flocculation, sedimentation, filtration and disinfection. The backwash water and sludge generation from water treatment plants are of environment concern in terms of disposal.

Therefore, optimization of chemical dosing and filter runs carries importance to reduce the rejects from the water treatment plants. Also there is a need to study the water treatment plants for their operational status and to explore the best feasible mechanism to ensure proper drinking water production with least possible rejects and its management. The public private partnership and water pricing should be implemented in such a way that the urban poor do not face discrimination and wastage and extravagant use of water must be discouraged and to encourage user economy by designing the tariff with multi-tier system incorporating incentives for low consumption.

Questions

- How does sedimentation fit into the water treatment process?
- What zones are present in a sedimentation basin?
- How is sedimentation sludge disposed of?
- What are the principles of the activated sludge process and the factors that influence them?
- What is the difference between osmosis and reverse osmosis?
- Do you think pricing of water supply is necessary for the proper operation and maintenance of water supply system? Justify your answer with suitable explanation.
- What are the advantages and disadvantages of chlorination technique in disinfection?
- Describe the coagulation process in detail.

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DEM 103 URBAN WATER MANAGEMENT CR 4

UNIT-4: FATE OF WATER RELATED PATHOGENS IN URBAN WATER SYSTEMS

UNIT STRUCTURE

4.0 OBJECTIVES
4.1 BASICS OF SANITATION AND WATERBORNE DISEASE
 4.1.1 INTRODUCTION
 4.1.2 DIMENSION OF THE PROBLEM
 4.1.3 TRANSMISSION
 4.1.4 PREVENTION
4.2. HISTORY OF MICROBIOLOGY AND EPIDEMIOLOGY
4.3. REMOVAL OF PATHOGENS IN WATER
 4.3.1 TREATMENT
 4.3.2 FILTRATION
4.4. WATER SUPPLY AND WASTE WATER TREATMENT
 4.4.1 AN INTRODUCTION TO THE PROBLEM
 4.4.2 CONVENTIONAL WASTE WATER TREATMENT PROCESSES
 4.4.3 NATURAL BIOLOGICAL TREATMENT SYSTEMS
4.5. RISK MANAGEMENT

4.0 OBJECTIVES

After going through this unit, you will be able to:

- discuss the basics of sanitation and waterborne disease; its dimension, transmission and prevention
- discuss the history of microbiology and epidemiology
- learn how to remove pathogens in water
- learn about wastewater treatment

4.1. BASICS OF SANITATION AND WATERBORNE DISEASE

4.1.1 INTRODUCTION

More than one billion people in the developing world have no safe drinking water, or water for washing their food, hands and utensils before eating. 2.4 billion also have no adequate sanitation. This leads to:

- water-borne diseases (e.g. cholera, typhoid)
- water-related diseases (e.g. malaria, yellow fever, river blindness, sleeping sickness)
- water-based diseases (e.g. guinea worm and bilharzias)
- water-scarce diseases (trachoma and scabies)
- diarrhoea – a leading killer of children in sub-Saharan Africa

Improving access to clean water and sanitation would dramatically reduce illness and death in poor countries: a clean water supply reduces diarrhoea-related death by up to 25%, while improved sanitation reduces it by 32%. Where proper sanitation facilities are lacking, water-borne diseases can spread rapidly. Untreated excreta carrying disease organisms wash or leach into freshwater sources, contaminating drinking water and food. The extent to which disease organisms occur in specific freshwater sources depends on the amount of human and animal excreta that they contain. Diarrheal disease, the major water-borne disease, is prevalent in many countries where sewage treatment is inadequate. Instead, human wastes are disposed of in open latrines, ditches, canals, and water courses or they are spread on cropland. Using contaminated sewage for fertilizer can result in epidemics of such diseases as cholera. These diseases can even become chronic where clean water supplies are lacking. In the early 1990s, for example, raw sewage water that was used to fertilize vegetable fields caused outbreaks of cholera in Chile and Peru. Toxic substances that find their way into freshwater are another cause of water-borne diseases. Increasingly, agricultural chemicals, fertilizers, pesticides, and industrial wastes are being found in freshwater supplies Such chemicals, even in low concentrations, can build up over time and, eventually, can cause chronic diseases such as cancers among people who use the water. Health problems from nitrates in water sources are becoming a serious problem almost everywhere. In over 150 countries nitrates from fertilizers have seeped into water wells, fouling the drinking water. Excessive concentrations of nitrates cause blood disorders. Also, high levels of nitrates and phosphates in water encourage growth of blue-green algae, leading to deoxygenating (eutrophication). Oxygen is required for metabolism by the organisms that serve as purifiers, breaking down organic matter, such as human wastes, that pollute the water. Therefore the amount of oxygen contained in water is a key indicator of water quality. Pesticides such as DDT and heptachlor, which are used in agriculture, often wash off in irrigation water. Their presence in water and food products has alarming implications for human health because they are known to cause cancer and also may cause low sperm counts and neurological disease. In Dhaka, Bangladesh, heptachlor residues in water sources have reached levels as high as .789 micrograms per liter as or more than 25 times the WHO-recommended maximum of .03 micrograms per liter. The seepage of toxic pollutants into ground and surface water reservoirs used for drinking and household use causes health problems in industrialized countries as well. In Europe and Russia the health of some 500 million people is at risk from water pollution. For example, in northern Russia half a million people on the Kola Peninsula drink water contaminated with heavy metals, a practice that helps to explain high infant mortality rates and endemic diarrheal and intestinal diseases reported there .

4.1.2 DIMENSION OF THE PROBLEM

In developing countries four-fifths of all the illnesses are caused by water-borne diseases, with diarrhoea being the leading cause of childhood death. The global picture of water and health has a strong local dimension with some 1.1 billion people still lacking access to improved drinking water sources and some 2.4 billion to adequate sanitation. Today we have strong evidence that water-, sanitation and hygiene-related diseases account for some 2,213,000 deaths annually and an annual loss of 82,196,000 Disability Adjusted Life Years (DALYs) (R. Bos, Dec. 2004).

WHO estimates indicate that worldwide over 2 billion people are infected with schistosomes and soil transmitted helminthes and 300 million of these suffer serious illness as a result. Malaria kills over a million people every year, and a large percentage of them are under five as well, mainly in Africa South of the Sahara. In 2001 the estimated global burden of malaria amounted to 42.3 million DALYs, constituting 10 % of Africa's overall disease burden. Malaria causes at least 396.8 million cases of acute illness each year. Pregnant women are the main adult risk group. As one of the major public health problems in tropical countries, it has been claimed that malaria has reduced economic growth in African countries by 1.3 % each year over the past 30 years .An estimated 246.7 million people worldwide are infected by schistomiasis, and of these 20 million suffer severe consequences of the infection, while 120 million suffer milder symptoms. An estimated 80% of transmission takes place in Africa south of the Sahara. Diarrhoea occurs worldwide and causes 4% of all deaths and 5% of the health loss to disability. In Bangladesh alone, some 35 million people are exposed, on a daily basis, to elevated levels of arsenic in their drinking water, which will ultimately threaten their health and shorten their life expectancy.

4.1.3 TRANSMISSION

Water borne diseases are spread by contamination of drinking water systems with the urine and faeces of infected animal or people. This is likely to occur where public and private drinking water systems get their water from surface waters (rain, creeks, rivers, lakes etc.), which can be contaminated by infected animals or people. Runoff from landfills, septic fields, sewer pipes, residential or industrial developments can also sometimes contaminate surface water. This has been the cause of many dramatic outbreaks of faecal-oral diseases such as cholera and typhoid. The germs in the faeces can cause the diseases by even slight contact and transfer. This contamination may occur due to floodwaters, water runoff from landfills, septic fields, and sewer pipe

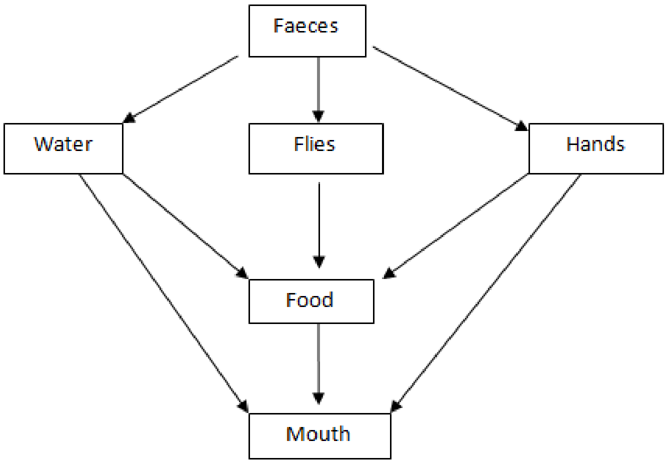

Figure 1 *The faecal-oral routes of diseases transmission***.**

The only way to break the continued transmission is to improve the people's hygienic behaviour and to provide them with certain basic needs: drinking water, washing and bathing facilities and sanitation. Malaria transmission is facilitated when large numbers of people sleep outdoors during hot weather, or sleep in houses that have no protection against invading mosquitoes. Malaria mosquitoes, tropical black flies, and bilharzias snails can all be controlled with efficient drainage because they all depend on water to complete their life cycles.

Prevention

Clean water is a pre –requisite for reducing the spread of water – borne diseases. It is well recognized that the prevalence of water borne diseases can be greatly reduced by provision of clean drinking water and safe disposal of faeces. Water is disinfected to kill any pathogens that may be present in the water supply and to prevent them from growing again in the distribution systems. Disinfection is then used to prevent the growth of pathogenic organisms and to protect public health and the choice of the disinfect depends upon the individual water quality and water supply system .Without disinfection, the risk from waterborne disease is increased. The two most common methods to kill microorganisms in the water supply are: oxidation with chemicals such as chlorine, chlorine dioxide or ozone, and irradiation with Ultra-Violet (UV) radiation.

Source:

4. 2. HISTORY OF MICROBIOLOGY AND EPIDEMIOLOGY

.An English scientist named Robert Hooke made key observations of the micro organism. He is reputed to have observed strands of fungi among the specimens of cells he viewed. In the 1670s and the decades thereafter, a Dutch merchant named Anton van Leeuwenhoek made careful observations of microscopic organisms, which he called animalcules. Until his death in 1723, van Leeuwenhoek revealed the microscopic world to scientists of the day and is regarded as one of the first to provide accurate descriptions of protozoa, fungi, and bacteria.

After van Leeuwenhoek died, the study of microbiology did not develop rapidly because microscopes were rare and the interest in microorganisms was not high. In those years, scientists debated the theory of spontaneous generation, which stated that microorganisms arise from lifeless matter such as beef broth. This theory was disputed by Francesco Redi, who showed that fly maggots do not arise from decaying meat (as others believed) if the meat is covered to prevent the entry of flies. An English cleric named John Needham advanced spontaneous generation, but Lazzaro Spallanzani disputed the theory by showing that boiled broth would not give rise to microscopic forms of life.

Louis Pasteur worked in the middle and late 1800s. He performed numerous experiments to discover why wine and dairy products became sour, and he found that bacteria were to blame. Pasteur called attention to the importance of microorganisms in everyday life and stirred scientists to think that if bacteria could make the wine “sick,” then perhaps they could cause human illness. Pasteur had to disprove spontaneous generation to sustain his theory, and he therefore devised a series of swan-necked flasks filled with broth. He left the flasks of broth open to the air, but the flasks had a curve in the neck so that microorganisms would fall into the neck, not the broth. The flasks did not become contaminated (as he predicted they would not), and Pasteur's experiments put to rest the notion of spontaneous generation. His work also encouraged the belief that microorganisms were in the air and could cause disease. Pasteur postulated the germ theory of disease, which states that microorganisms are the causes of infectious disease.

Pasteur's attempts to prove the germ theory were unsuccessful. However, the German scientist Robert Koch provided the proof by cultivating anthrax bacteria apart from any other type of organism. He then injected pure cultures of the bacilli into mice and showed that the bacilli invariably caused anthrax. The procedures used by Koch came to be known as Koch's postulates (Figure 1).

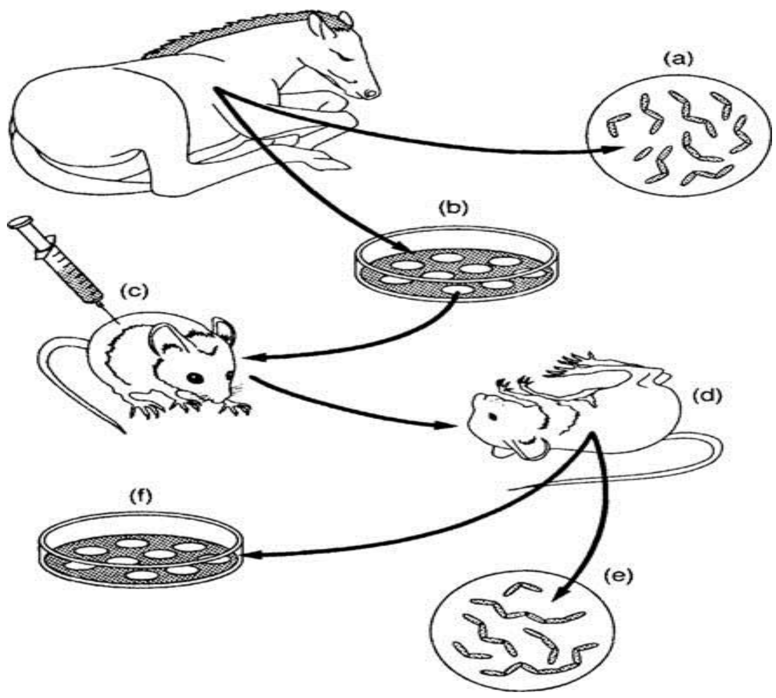

Figure 2 ***The steps of Koch's postulates used to relate a specific microorganism to a specific disease. (a) Microorganisms are observed in a sick animal and (b) cultivated in the lab. (c) The organisms are injected into a healthy animal, and (d) the animal develops the disease. (e) The organisms are observed in the sick animal and (f) re isolated in the lab.***

Epidemiology is the study of the various factors that influence the occurrence, distribution, prevention, and control of disease, injury, and other health-related events in a defined human population. By the application of various analytical techniques including mathematical analysis of the data, the probable cause of an infectious outbreak can be pinpointed. This connection between epidemiology and infection makes microorganisms an important facet of epidemiology.

Epidemiology and genetics are two distinct disciplines that converge into a new field of human science. Genetic epidemiology, a broad term used for the study of genetics and inheritance of disease, is a science that deals with origin, distribution, and control of disease in groups of related individuals, as well as inherited causes of diseases in populations. In particular, genetic epidemiology focuses on the role of genetic factors and their interaction with environmental factors in the occurrence of disease. This area of epidemiology is also known as molecular epidemiology. Molecular epidemiology has been used to trace the cause of bacterial, viral, and parasitic diseases. This knowledge is valuable in developing a strategy to prevent further outbreaks of the microbial illness, since the probable source of a disease can be identified.

4.3. REMOVAL OF PATHOGENS IN WATER

4.3.1 TREATMENT

i) Microstrainers

Microstrainers are fabric meshes woven of stainless steel or polyester wires, with apertures ranging from 15 to 45 µm (usually 30–35 µm). Such meshes are useful for removing algal cells and large protozoa (e.g. *Balantidium coli*), but have no significant impact on bacteria or viruses. Microstrainers generally remove about 40–70% of algae and, at the same time, about 5–20% of turbidity (Mouchet & Bonnelye, 1998).Although microstrainers can reduce the amount of coagulant needed, they do not remove smaller species or reproductive forms of algae.

ii) Off-stream storage

In this discussion, off-stream storage refers to a storage reservoir that directly or indirectly feeds a potable water intake. The effects of off-stream storage are difficult to generalize because important physical, biological and chemical processes are influenced by hydrological and limnological characteristics of the reservoir. The characteristics of reservoirs created by construction of a dam will differ from those of a natural or artificial lake. Oskam (1995) summarized the self-purification processes that improve water quality in off-stream reservoirs. The major factors that influence these processes are the degree of compartmentalization, the hydraulic residence time, the shape and flow through the reservoir, and the quality of the source water. Certain processes can also degrade water quality; for example, poorer quality of the impounded water can result from failure to:

• manage algal growth;

• control influx of nitrogen, phosphorus or other contaminants;

• limit faecal contamination from run-off of surrounding areas or roosting birds.

In a study by Bernhardt (1995), coliform bacteria in dammed reservoirs were reduced by 80–99% when residence times were greater than 40 days, and allochthonous bacteria were reduced by 90–99% when retention times exceeded about 100 days. Kors & Bosch (1995) reported reductions of enteroviruses (1.5 logs), Stewart et al. (1997) examined storm events that washed high levels of *Giardia* cysts (up to17 000 cysts/100 l) and *Cryptosporidium* oocysts (up to 42 000 oocysts/100 l) into receiving reservoirs.

iii) Conventional clarification

Conventional clarification typically refers to chemical addition, rapid mixing, flocculation and sedimentation (usually in a rectangular basin). Removal of particles depends mainly on the terminal settling velocity of the particles and the rate of basin surface loading or overflow. The efficiency of the sedimentation process may be improved by using inclined plates or tubes. For conventional treatment processes, chemical coagulation is critical for effective removal of microbial pathogens. In the absence of a chemical coagulant, removal of microbes is low because sedimentation velocities are low (Medema et al., 1998). A chemical coagulant destabilizes microbial particles (e.g. by neutralizing or reducing their surface electrical charge, enmeshing them in a floc particle or creating bridges between them) and allows particles to come into contact with one another. Flocculation of microbial particles creates aggregates with sufficient settling velocities to be removed in the sedimentation basin. When properly performed, coagulation, flocculation and sedimentation can result in 1–2 log removals of bacteria, viruses and protozoa. Factors that can result in poor clarification efficiency include variable plant flow rates, improper dose of coagulant, poor process control with little monitoring, shear of formed floc, inappropriate mixing of chemicals, poor mixing and flocculation, and inadequate sludge removal (USEPA, 1991).

iv) High-rate clarification

High-rate clarification was first used in the 1930s, and it grew in popularity during the 1970s and 1980s. It involves using smaller basins and higher surface loading rates than conventional clarifiers, and is therefore referred to as high rate clarification. Processes include floc-blanket sedimentation (also known as 'solids-contact clarification'), ballasted-floc sedimentation, and adsorption or contact clarification. In floc-blanket sedimentation, a fluidized blanket increases the particle concentration, thus increasing the rate of flocculation and sedimentation. Ballasted-floc systems combine coagulation with sand, clay, magnetite or carbon to increase the particle sedimentation rate. Adsorption or contact clarification involves passing coagulated water through a bed where particles attach to previously adsorbed material. High-rate clarifiers can be as effective as or even more effective than conventional basins for removal of microbes

v) Dissolved air flotation

In dissolved air flotation (DAF), bubbles are produced by reducing pressure in a water stream saturated with air. The rising bubbles attach to floc particles, causing the agglomerate to float to the surface, where the material is skimmed off (Gregory, Zabel & Edzwald, 1999). DAF can be particularly effective for removal of algal cells and *Cryptosporidium* cysts. It is most applicable to waters with heavy algal blooms or those with low turbidity, low alkalinity and high color, which are difficult to treat by sedimentation because the floc produced has a low settling velocity.

vi) Lime softening

Logsdon et al. (1994) evaluated the effects of lime softening on the removal and disinfection efficiency of *Giardia*, viruses and coliform bacteria. Coliform bacteria in river water (spiked with raw sewage) were inactivated by 0.1 log at pH 9.5, 1.0 log at pH 10.5 and 0.8–3.0 logs at pH 11.5 for 6 hours at 2–8°C. Bacteriophage MS2 was sensitive to lime softening conditions, demonstrating more than 4-log inactivation in the pH range of 11–11.5 within 2 hours. Hepatitis A virus was reduced by 99.8% when exposed to pH 10.5 for 6 hours. Poliovirus was the most resistant virus tested, requiring exposure to a pH level of 11 for 6 hours to achieve a 2.5-log inactivation.

4.3.2 FILTRATION

Various filtration processes are used in drinking-water treatment. Filtration can act as a consistent and effective barrier for microbial pathogen. These size spectra are useful for understanding removal mechanisms and efficiencies, and for developing strategies to remove microbes by different filtration processes.

i) Granular high rate Filtration

Granular media filtration is the most widely used filtration process in drinkingwater treatment. A comprehensive review of granular media filtration processes is provided by Cleasby and Logsdon (1999). Under optimal conditions, a combination of coagulation, flocculation, sedimentation and granular media filtration can result in 4 logs or better removal of protozoan pathogens with chlorine-resistant cysts. The chemical coagulation pretreatment is very important for removal of microbes by granular filtration and has been emphasized by numerous studies. Without any chemical addition, removal of *Giardia* cysts averaged 75% (0.60 logs) for conventional treatment and 64% (0.44 logs) for in-line filtration. With optimal chemical pretreatment, the removal increased to 98% (1.70 logs) for conventional treatment and 93.6% (1.19 logs) for in-line filtration.

ii) Slow and sand Filtration

The use of slow sand filtration to protect drinking-water consumers from microbial risk was well established more than 100 years ago. Two of the earliest successful cases were reductions in cholera in Altona (Germany) and typhoid fever in Lawrence, Massachusetts (USA) in the 1890s (Bellamy et al., 1985). Numerous disease outbreaks due to chlorine-resistant protozoan pathogens in the past two decades have increased interest in slow sand filtration because of its ability to remove parasites. Removal of particles by slow sand filtration occurs predominantly, if not entirely, in a thin layer on the top of the sand bed. This biologically active layer, composed of living and dead microorganisms and macroorganisms, is termed *schmutzdecke*. As operation progresses, deposited materials and biological growth on the sand medium increase the head loss across the filter. When the head loss reaches the operational limit (normally 1–2 m), the filter is removed from service.

iii) Pre coat Filtration

Precoat filtration was developed by the US Army during World War II as a portable unit for the removal of *Entamoeba histolytica* (a protozoan parasite prevalent in the Pacific war zone) from drinking-water. The process involves forcing water under pressure or by vacuum through a uniformly thin layer of filtering material precoated onto a permeable, rigid, supporting structure (referred to as a septum). Precoat materials include DE and perlite, with DE more commonly used in drinking-water treatment. As water passes through the filter media and septum, the precoat materials (filter cake) capture microbes and other particles, mainly by physical straining. Often, a "bodyfeed" solution containing the filter media slurry is added continuously to the system, to maintain the permeability of the filter cake. As the cake becomes thicker due to the captured particles, head loss increases until further filtration is impractical. The filter cake is removed from the support septum and disposed of. The filter is then cleaned and precoated with a new layer of coating materials, and a new filter cycle starts. Because the major removal mechanism is physical straining, efficiency of precoat filtration depends to a large extent on the grade (size) of the coating materials and on the size of the microbes. Other factors influencing the removal efficiency are chemical pretreatment of the filter media, filtration rate and body feed rate. Chemical pretreatment of the raw water is usually not necessary; however, the raw water must be of high quality (low turbidity) to maintain a reasonable filter run time.

iv) Membrane Filtration

In membrane filtration, a thin semi-permeable film (membrane) is used as a selective barrier to remove contaminants from water. There are very few contaminants that cannot be removed by membrane processes. For the past two decades, the use of membrane filtration in drinking-water treatment (including pathogen removal) has been growing, due to increasingly stringent drinking-water regulations and decreasing costs of purchasing and operating membrane filter The membrane processes most commonly used to remove microbes from drinking-water are microfiltration (MF), ultra filtration (UF), nanofiltration (NF) and reverse osmosis (RO). Detailed descriptions of the fundamentals, design and operation of these processes are available (AWWA, 1996; Taylor & Wiesner, 1999). Below the table summarizes these processes, including operating pressure, pore size, primary application and the type of microorganism that can be removed. Not all of these processes are used primarily for removal of pathogens. For example, RO is used mainly for desalination and NF for softening and for removal of precursors of disinfectant by-products. Nevertheless, the ability to remove pathogens broadens the application of these types of filter when used for these other treatment objectives.

Type	Operating Pressure (kPa)	Pore Size (μm)	Primary application	Microbes Removed
Microfiltration	30-50	≥0.1	Removal of particles and turbidity	Algae, protozoa and most bacteria
Ultrafiltration	30-50	≥0.01	Removal of dissolved nonionic solutes	Algae, protozoa and most bacteria and viruses.
Nanofiltration	500-1000	≥0.001	Removal of divalent ions (softening)and dissolved organic matter	Algae, protozoa and most bacteria and viruses
Reverse Osmosis	1000-5000	≥0.0001	Removal of monovalent ions(desalination)	Algae, protozoa and most bacteria and viruses

Source :Adapted from AWWARF (1996),Taylor & Weisner(1999).

Membrane filtration removes microbial pathogens mainly by size exclusion; that is, microbes larger than the membrane pores are removed. Chemical coagulation is not usually needed before membrane treatment for the removal of microbes. However, some degree of pretreatment is usually employed to reduce membrane fouling (caused by accumulation of chemicals, particles and biological growth on membrane surfaces) and to avoid membrane degradation from chemical attack (caused by hydrolysis and oxidation). Fouling reduces membrane productivity, and membranes must be chemically cleaned to restore productivity. Examples of pretreatment processes are microstraining, pH adjustment and addition of biocides (chlorine or copper sulfate). If the source water is of poor quality, advanced pretreatment systems (e.g. conventional coagulation– sedimentation–filtration or other membrane processes) may also be necessary.

v) Microfiltration

MF membranes have pores of 0.1 μm or more. Theoretically, MF can remove protozoa, algae and most bacteria very effectively, and this has been confirmed in a number of studies, some of which are discussed below. However, factors such as bacteria growing in the membrane systems can lead to poor removal of bacteria. Viruses, which are 0.01–0.1 μm in size, can generally pass through MF membranes, but may be removed by the membrane if they are associated with large particles. Numerous pilot studies have directly evaluated the removal of *Giardia*, *Cryptosporidium* and other specific microbial pathogens by MF.

vi) Ultrafiltration

UF membranes have pores of 0.01 μm or more, small enough to remove some viruses in addition to bacteria and protozoa. Removal of viruses by UF was significantly better than removal by MF, and depended essentially on the pore size of the membranes. The membranes with the lowest molecular weight cutoffs has the highest removal efficiency (6 log or higher) for MS2 bacteriophage. Many findings have suggested that, although physical sieving was the main mechanism for the removal of protozoan pathogens by UF and MF, cake layer formation and changes in the fouling of the membrane also contributed to the removal of viruses. The membrane used for ultra filtration effectively remove particles, turbidity, total coliforms and heterotrophic bacteria. Removal efficiencies for *Giardia muris*, coliforms, heterotrophic bacteria and MS2 bacteriophage were determined by various studies. Differences in water quality or changes in operating parameters did not affect the removal capabilities of the process, but maintenance of membrane integrity was critical to assuring process efficiency.

vii) Nanofiltration and reverse osmosis

The pore sizes of NF and RO membranes are smaller than those of UF membranes. However, NF and RO alone are seldom used to remove microbial pathogens because MF or UF are more cost-effective and can achieve a similar degree of microbial removal. Not surprisingly, there is far less literature on the removal of microbial pathogens by NF and RO than by MF and UF.

viii) Bags, cartridge and fibrous filters

A bag filter is one that has a non-rigid fabric medium for the filter. Water flow is usually pressure-driven from the inside of the filter bag to the outside. A cartridge filter is one that has a rigid fabric medium or membrane for the filter. In this type of filter, water flow is usually pressure-driven from the outside of the filter to the inside. Bag and cartridge filters are often developed for small systems and for point-of-use filtration applications. They are also sometimes applied as a pretreatment process for membrane filtration. Bag filters and cartridge filters remove microorganisms by physical straining. The removal efficiency thus depends primarily on the pore size of the filter medium and on the size of the microbes. A typical pore size range is from 0.2 μm to about 10 μm. The pore size of the filter medium is usually designed to be small enough to remove protozoa such as *Cryptosporidium* and *Giardia*. Straining of large compressible particles can blind the filters and reduce filter life. High turbidity and algae can also clog these filters. These processes are therefore only appropriate for high-quality waters. A pre-filtration process may be employed to remove large particles.

4.4. WATER SUPPLY AND WASTE WATER TREATMENT

Water supply is the provision of water by public utilities, commercial organisations, community endeavors. In 2010 about 84% of the global population (6.74 billion people) had access to piped water supply through house connections or to an improved through other means than house, including standpipes, "water kiosks", protected springs and protected wells. However, about 14% (884 million people) did not have access to an improved water source and had to use unprotected wells or springs, canals, lakes or rivers for their water needs. A clean water supply, especially so with regard to sewage, is the single most important determinant of public health. Destruction of water supply and/or sewage disposal infrastructure after major catastrophes (earthquakes, floods, war, etc.) poses the immediate threat of severe epidemics of waterborne diseases, several of which can be life-threatening. Water supply systems get water from a variety of locations, including groundwater (aquifers), surface water (lakes and rivers), conservation and the sea through desalination. The water is then, in most cases, purified, disinfected through chlorination and sometimes fluoridated. Treated water then either flows by gravity or is pumped to reservoirs, which can be elevated such as water towers or on the ground (for indicators related to the efficiency of drinking water distribution see non-revenue water). Once water is used, wastewater is typically discharged in a sewer system and treated in a wastewater treatment plant before being discharged into a river, lake or the sea or reused for landscaping, irrigation or industrial use. Thus it becomes very essential to check the drinking water quality on a regular basis. Drinking water quality has a micro-biological and a physico-chemical dimension. There are thousands of parameters of water quality. In public water supply systems water should, at a minimum, be disinfected most commonly through the use of chlorination or the use of ultra violet light or it may need to undergo treatment, especially in the case of surface water.

4.4.1 WASTE WATER TREATMENT: AN INTRODUCTION TO THE PROBLEM

The principal objective of wastewater treatment is generally to allow human and industrial effluents to be disposed of without danger to human health or unacceptable damage to the natural environment. Irrigation with wastewater is both disposal and utilization and indeed is an effective form of wastewater disposal (as in slow-rate land treatment). However, some degree of treatment must normally be provided to raw municipal wastewater before it can be used for agricultural or landscape irrigation or for aquaculture. The quality of treated effluent used in agriculture has a great influence on the operation and performance of the wastewater-soil-plant or aquaculture system. Through crop restriction and selection of irrigation systems which minimize health risk, the degree of pre-application wastewater treatment can be reduced. The most appropriate wastewater treatment to be applied before effluent use in agriculture is that which will produce an effluent meeting the recommended microbiological and chemical quality guidelines both at low cost and with minimal operational and maintenance requirements (Arar 1988). Adopting as low a level of treatment as possible is especially desirable in developing countries, not only from the point of view of cost but also in acknowledgement of the difficulty of operating complex systems reliably. In many locations it will be better to design the reuse system to accept a low-grade of effluent rather than to rely on advanced treatment processes producing a reclaimed effluent which continuously meets a stringent quality standard. The design of wastewater treatment plants is usually based on the need to reduce organic and suspended solids loads to limit pollution of the environment. Pathogen removal has very rarely been considered an objective but, for reuse of effluents in agriculture, this must now be of primary concern and processes should be selected and designed accordingly (Hillman 1988). Treatment to remove wastewater constituents that may be toxic or harmful to crops, aquatic plants (macrophytes) and fish is technically possible but is not normally economically feasible. Unfortunately, few performance data on wastewater treatment plants in developing countries are available and even then they do not normally include effluent quality parameters of importance in agricultural use.

4.4.2 CONVENTIONAL WASTE WATER TREATMENT PROCESSES

Conventional wastewater treatment consists of a combination of physical, chemical, and biological processes and operations to remove solids, organic matter and, sometimes, nutrients from wastewater. General terms used to describe different degrees of treatment, in order of increasing treatment level, are preliminary, primary, secondary, and tertiary and/or advanced wastewater treatment.

i) Preliminary treatment

The objective of preliminary treatment is the removal of coarse solids and other large materials often found in raw wastewater. Removal of these materials is necessary to enhance the operation and maintenance of subsequent treatment units. Preliminary treatment operations typically include coarse screening, grit removal and, in some cases, comminuting of large objects. In grit chambers, the velocity of the water through the chamber is maintained sufficiently high, or air is used, so as to prevent the settling of most organic solids. Grit removal is not included as a preliminary treatment step in most small wastewater treatment plants. Comminutors are sometimes adopted to supplement coarse screening and serve to reduce the size of large particles so that they will be removed in the form of a sludge in subsequent treatment processes. Flow measurement devices, often standing-wave flumes, are always included at the preliminary treatment stage.

ii) Primary treatment

The objective of primary treatment is the removal of settleable organic and inorganic solids by sedimentation, and the removal of materials that will float (scum) by skimming. Approximately 25 to 50% of the incoming biochemical oxygen demand (BOD_5), 50 to 70% of the total suspended solids (SS), and 65% of the oil and grease are removed during primary treatment. Some organic nitrogen, organic phosphorus, and heavy metals associated with solids are also removed during primary sedimentation but colloidal and dissolved constituents are not affected.

In large sewage treatment plants (> 7600 m^3/d in the US), primary sludge is most commonly processed biologically by anaerobic digestion. In the digestion process, anaerobic and facultative bacteria metabolize the organic material in sludge (see Example 3), thereby reducing the volume requiring ultimate disposal, making the sludge stable (nonputrescible) and improving its dewatering characteristics. Digestion is carried out in covered tanks (anaerobic digesters), typically 7 to 14 m deep. The residence time in a digester may vary from a minimum of about 10 days for high-rate digesters (well-mixed and heated) to 60 days or more in standard-rate digesters. Gas containing about 60 to 65% methane is produced during digestion and can be recovered as an energy source. In small sewage treatment plants, sludge is processed in a variety of ways including: aerobic digestion, storage in sludge lagoons, direct application to sludge drying beds, in-process storage.

The objective of secondary treatment is the further treatment of the effluent from primary treatment to remove the residual organics and suspended solids. In most cases, secondary treatment follows primary treatment and involves the removal of biodegradable dissolved and colloidal organic matter using aerobic biological treatment processes. Aerobic biological treatment (see Box) is performed in the presence of oxygen by aerobic microorganisms (principally bacteria) that metabolize the organic matter in the wastewater, thereby producing more microorganisms and inorganic end-products (principally CO_2, NH_3, and H_2O). Several aerobic biological processes are used for secondary treatment differing primarily in the manner in which oxygen is supplied to the microorganisms and in the rate at which organisms metabolize the organic matter. High-rate biological processes are characterized by relatively small reactor volumes and high concentrations of microorganisms compared with low rate processes. Consequently, the growth rate of new organisms is much greater in high-rate systems because of the well controlled environment. The microorganisms must be separated from the treated wastewater by sedimentation to produce clarified secondary effluent. The sedimentation tanks used in secondary treatment, often referred to as secondary clarifiers, operate in the same basic manner as the primary clarifiers described previously. The biological solids removed during secondary sedimentation, called secondary or biological sludge, are normally combined with primary sludge for sludge processing.

Common high-rate processes include the activated sludge processes, trickling filters or biofilters, oxidation ditches, and rotating biological contactors (RBC). A combination of two of these processes in series (e.g., biofilter followed by activated sludge) is sometimes used to treat municipal wastewater containing a high concentration of organic material from industrial sources.

❖ *Activated Sludge*

In the activated sludge process, the dispersed-growth reactor is an aeration tank or basin containing a suspension of the wastewater and microorganisms, the mixed liquor. The contents of the aeration tank are mixed vigorously by aeration devices which also supply oxygen to the biological suspension . Aeration devices commonly used include submerged diffusers that release compressed air and mechanical surface aerators that introduce air by agitating the liquid surface. Hydraulic retention time in the aeration tanks usually ranges from 3 to 8 hours but can be higher with high BOD_5 wastewaters. Following the aeration step, the microorganisms are separated from the liquid by sedimentation and the clarified liquid is secondary effluent. A portion of the biological sludge is recycled to the aeration basin to maintain a high mixed-liquor suspended solids (MLSS) level. The remainder is removed from the process and sent to sludge processing to maintain a relatively constant concentration of microorganisms in the system. Several variations of the basic activated sludge process, such as extended aeration and oxidation ditches, are in common use, but the principles are similar.

❖ *Trickling Filters*

A trickling filter or biofilter consists of a basin or tower filled with support media such as stones, plastic shapes, or wooden slats. Wastewater is applied intermittently, or sometimes continuously, over the media. Microorganisms become attached to the media and form a biological layer or fixed film. Organic matter in the wastewater diffuses into the film, where it is metabolized. Oxygen is normally supplied to the film by the natural flow of air either up or down through the media, depending on the relative temperatures of the wastewater and ambient air. Forced air can also be supplied by blowers but this is rarely necessary. The thickness of the biofilm increases as new organisms grow. Periodically, portions of the film 'slough off the media. The sloughed material is separated from the liquid in a secondary clarifier and discharged to sludge processing. Clarified liquid from the secondary clarifier is the secondary effluent and a portion is often recycled to the biofilter to improve hydraulic distribution of the wastewater over the filter.

❖ ***Rotating Biological Contactors***

Rotating biological contactors (RBCs) are fixed-film reactors similar to biofilters in that organisms are attached to support media. In the case of the RBC, the support media are slowly rotating discs that are partially submerged in flowing wastewater in the reactor. Oxygen is supplied to the attached biofilm from the air when the film is out of the water and from the liquid when submerged, since oxygen is transferred to the wastewater by surface turbulence created by the discs' rotation. Sloughed pieces of biofilm are removed in the same manner described for biofilters.High-rate biological treatment processes, in combination with primary sedimentation, typically remove 85 % of the BOD_5 and SS originally present in the raw wastewater and some of the heavy metals. Activated sludge generally produces an effluent of slightly higher quality, in terms of these constituents, than biofilters or RBCs. When coupled with a disinfection step, these processes can provide substantial but not complete removal of bacteria and virus. However, they remove very little phosphorus, nitrogen, non-biodegradable organics, or dissolved minerals stabilization ponds), and land application.

iii) Tertiary and/or advanced treatment

Tertiary and/or advanced wastewater treatment is employed when specific wastewater constituents which cannot be removed by secondary treatment must be removed. As shown in Figure 3, individual treatment processes are necessary to remove nitrogen, phosphorus, additional suspended solids, refractory organics, heavy metals and dissolved solids. Because advanced treatment usually follows high-rate secondary treatment, it is sometimes referred to as tertiary treatment. However, advanced treatment processes are sometimes combined with primary or secondary treatment (e.g., chemical addition to primary clarifiers or aeration basins to remove phosphorus) or used in place of secondary treatment (e.g., overland flow treatment of primary effluent).

An adaptation of the activated sludge process is often used to remove nitrogen and phosphorus and an example of this approach is the 23 Ml/d treatment plant commissioned in 1982 in British Columbia, Canada (World Water 1987).

In many situations, where the risk of public exposure to the reclaimed water or residual constituents is high, the intent of the treatment is to minimize the probability of human exposure to enteric viruses and other pathogens. Effective disinfection of viruses is believed to be inhibited by suspended and colloidal solids in the water, therefore these solids must be removed by advanced treatment before the disinfection step.

iv) Disinfection

Disinfection normally involves the injection of a chlorine solution at the head end of a chlorine contact basin. The chlorine dosage depends upon the strength of the wastewater and other factors, but dosages of 5 to 15 mg/l are common. Ozone and ultra violet (uv) irradiation can also be used for disinfection but these methods of disinfection are not in common use. Chlorine contact basins are usually rectangular channels, with baffles to prevent short-circuiting, designed to provide a contact time of about 30 minutes. However, to meet advanced wastewater treatment requirements, a chlorine contact time of as long as 120 minutes is sometimes required for specific irrigation uses of reclaimed wastewater. The bactericidal effects of chlorine and other disinfectants are dependent upon pH, contact time, organic content, and effluent temperature.

v) Effluent storage

Although not considered a step in the treatment process, a storage facility is, in most cases, a critical link between the wastewater treatment plant and the irrigation system. Storage is needed for the following reasons:

1. To equalize daily variations in flow from the treatment plant and to store excess when average wastewater flow exceeds irrigation demands; includes winter storage.

2. To meet peak irrigation demands in excess of the average wastewater flow.

3. To minimize the effects of disruptions in the operations of the treatment plant and irrigation system. Storage is used to provide insurance against the possibility of unsuitable reclaimed wastewater entering the irrigation system and to provide additional time to resolve temporary water quality problems.

4. To provide additional treatment. Oxygen demand, suspended solids, nitrogen, and microorganisms are further reduced during storage.

vi) **Reliability of conventional and advanced wastewater treatment**

Wastewater reclamation and reuse systems should contain both design and operational requirements necessary to ensure reliability of treatment. Reliability features such as alarm systems, standby power supplies, treatment process duplications, emergency storage or disposal of inadequately treated wastewater, monitoring devices, and automatic controllers are important. From a public health standpoint, provisions for adequate and reliable disinfection are the most essential features of the advanced wastewater treatment process. Where disinfection is required, several reliability features must be incorporated into the system to ensure uninterrupted chlorine feed.

4.4.3 NATURAL BIOLOGICAL TREATMENT SYSTEMS

Natural low-rate biological treatment systems are available for the treatment of organic wastewaters such as municipal sewage and tend to be lower in cost and less sophisticated in operation and maintenance. Although such processes tend to be land intensive by comparison with the conventional high-rate biological processes already described, they are often more effective in removing pathogens and do so reliably and continuously if properly designed and not overloaded. Among the natural biological treatment systems available, stabilization ponds and land treatment have been used widely around the world and a considerable record of experience and design practice has been documented. The nutrient film technique is a fairly recent development of the hydroponic plant growth system with application in the treatment and use of wastewater.

i) Wastewater stabilization ponds

Stabilization ponds are the preferred wastewater treatment process in developing countries, where land is often available at reasonable opportunity cost and skilled labour is in short supply. Wastewater stabilization pond systems are designed to achieve different forms of treatment in up to three stages in series, depending on the organic strength of the input waste and the effluent quality objectives. For ease of maintenance and flexibility of operation, at least two trains of ponds in parallel are incorporated in any design. Strong wastewaters, with BOD_5 concentration in excess of about 300 mg/l, will frequently be introduced into first-stage anaerobic ponds, which achieve a high volumetric rate of removal. Weaker wastes or, where anaerobic ponds are environmentally unacceptable, even stronger wastes (say up to

1000 mg/l BOD_5) may be discharged directly into primary facultative ponds. Effluent from first-stage anaerobic ponds will overflow into secondary facultative ponds which comprise the second-stage of biological treatment. Following primary or secondary facultative ponds, if further pathogen reduction is necessary maturation ponds are introduced to provide tertiary treatment.

ii) Overland treatment of wastewater

Apart from the use of effluent for irrigation of crops, termed 'slow rate' land treatment in the US Environmental Protection Agency's Process Design Manual for Land Treatment of Municipal Wastewaters (EPA 1977), and 'rapid infiltration' or 'infiltration percolation' of effluent discussed as soil-aquifer treatment in a later section of this document, the EPA manual deals with 'overland flow' as a wastewater treatment method. In overland flow treatment, effluent is distributed over gently sloping grassland on fairly impermeable soils. Ideally, the wastewater moves evenly down the slope to collecting ditches at the bottom edge of the area and water-tolerant grasses are an essential component of the system. This form of land treatment requires alternating applications of effluent (usually treated) and resting of the land, to allow soil reaction and grass cutting. The total area utilized is normally broken up into small plots to allow this form of intermittent operation and yet achieve continuous treatment of the flow of wastewater. Although this type of land treatment has been widely adopted in Australia, New Zealand and the UK for tertiary upgrading of secondary effluents, it has been used for the treatment of primary effluent in Werribee, Australia and is being considered for the treatment of raw sewage in Karachi, Pakistan.The application rate for wastewaters will depend principally on the type of soil, the quality of wastewater effluent and the physical and biochemical activity in the near-surface environment. Rational design procedures, based on the kinetics of BOD removal, have been developed for overland flow systems by Middlebrooks *et al.*(1982). Slope lengths from 30 - 60 m are common in the US for overland flow systems.The cover crop is an important component of the overland flow system since it prevents soil erosion, provides nutrient uptake and serves as a fixed-film medium for biological treatment. Suspended and colloidal organic materials in the wastewater are removed by sedimentation and filtration through surface grass and organic layers. Removal of total nitrogen and ammonia is inversely related to application rate, slope length and soil temperature. Phosphorus and trace elements removal is by sorption on soil clay colloids and precipitation as insoluble complexes of calcium, iron and aluminium. Overland flow systems also remove pathogens from sewage effluent at levels comparable with conventional secondary treatment systems, without chlorination. A monitoring programme should always be incorporated into the design of overland flow projects both for wastewater and effluent quality and for application rates.

iii) Macrophyte treatment

Maturation ponds which incorporate floating, submerged or emergent aquatic plant species are termed *macrophyte ponds* and these have been used in recent years for upgrading effluents from stabilization ponds. Macrophytes take up large amounts of inorganic nutrients (especially N and P) and heavy metals (such as Cd, Cu, Hg and Zn) as a consequnce of the growth requirements and decrease the concentration of algal cells through light shading by the leaf canopy and, possibly, adherence to gelatinous biomass which grows on the roots.Floating macrophyte systems utilizing water hyacinth and receiving primary sewage effluent in Florida have achieved secondary treatment effluent quality with a 6 day hydraulic retention time, water depth of 60 cm and hydraulic loading 1860 m^3/ha d (Reddy and Debusk 1987). The same authors suggested that similar results had also been observed for artificial wetlands using emergent macrophytes. In Europe, the land area considered to be necessary for treatment of preliminary-treated sewage is estimated at 2-5 m^2 per population equivalent to achieve a secondary effluent quality (Cooper et al. 1988).

❖ ***Floating Aquatic Macrophyte Systems***

Floating macrophyte species, with their large root systems, are very efficient at nutrient stripping. Although several genera have been used in pilot schemes, including*Salvinia, Spirodella*, *Lemna* and *Eichornia* (O'Brien 1981), *Eichornia crassipes* (water hyacinth) has been studied in much greater detail. In tropical regions, water hyacinth doubles in mass about every 6 days and a macrophyte pond can produce more than 250 kg/ha d (dry weight). Nitrogen and phosphorus reductions up to 80% and 50% have been achieved. In Tamil Nadu, India, studies have indicated that the coontail, *Ceratophyllum demersum,* a submerged macrophyte, is very efficient at removing ammonia (97%) and phosphorus (96%) from raw sewage and also removes 95% of the BOD_5. It has a lower growth rate than *Eichornia crassipes*, which allows less frequent harvesting.

❖ ***Emergent Macrophyte Treatment Systems***

In recent years, natural and artificial wetlands and marshes have been used to treat raw sewage and partially-treated effluents. Natural wetlands are usually unmanaged, whereas artificial systems are specially designed to maximize performance by providing the optimum conditions for emergent macrophyte growth. The key features of such reed bed treatment systems are:

- Rhizomes of the reeds grow vertically and horizontally in the soil or gravel bed, opening up 'hydraulic pathways'.
- Wastewater BOD and nitrogen are removed by bacterial activity; aerobic treatment takes place in the rhizosphere, with anoxic and anaerobic treatment taking place in the surrounding soil.
- Oxygen passes from the atmosphere to the rhizosphere via the leaves and stems of the reeds through the hollow rhizomes and out through the roots.
- Suspended solids in the sewage are aerobically composted in the above-ground layer of vegetation formed from dead leaves and stems.
- Nutrients and heavy metals are removed by plant uptake.
- The growth rate and pollutant assimilative capacity of emergent macrophytes such as *Phragmites communis and Scirpus lacstris* are limited by the culture system, wastewater loading rate, plant density, climate and management factors.

❖ **Nutrient film technique**

The nutrient film technique (NFT) is a modification of the hydroponic plant growth system in which plants are grown directly on an impermeable surface to which a thin film of wastewater is continuously applied. Root production on the impermeable surface is high and the large surface area traps and accumulates matter. Plant top-growth provides nutrient uptake, shade for protection against algal growth and water removal in the form of transpiration, while the large mass of self-generating root systems and accumulated material serve as living filters. Jewell **et al.** (1983) have hypothesized the following mechanisms, taking place in three plant sections:

- Roughing or preliminary treatment by plant species with large root systems capable of surviving and growing in a grossly polluted condition. Large sludge accumulations, anaerobic conditions and trace metal precipitation and entrapment characterize this mechanism and a large portion of wastewater BOD and suspended solids would thereby be removed.
- Nutrient conversion and recovery due to high biomass production.
- Wastewater polishing during nutrient-limited plant production, depending on the required effluent quality.

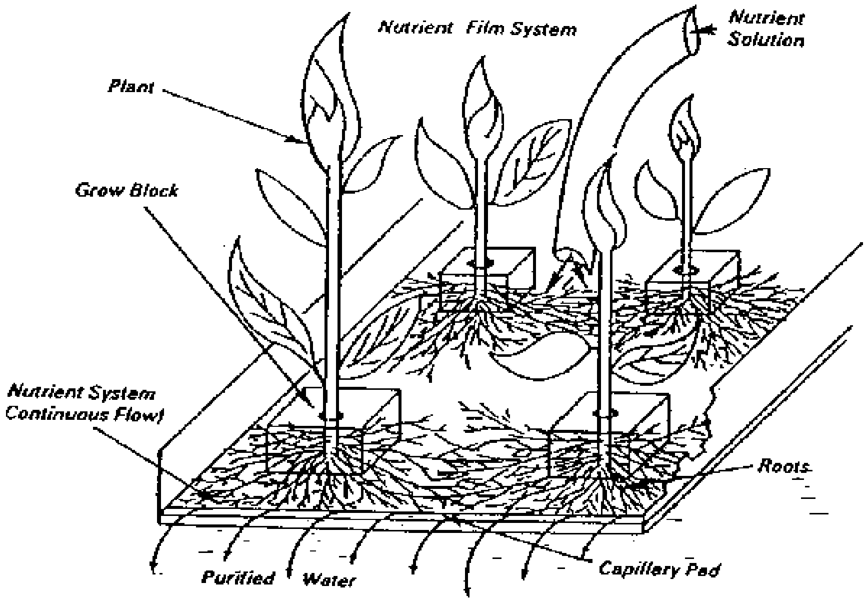

Fig 3: ***Nutrient film technique variation of hydroponic plant production systems (Jewell et al. 1983)***

4.5. RISK MANAGEMENT

About half the world's reported cases of polio, a crippling disease virtually wiped out in Western countries, occur in India. Each year, diarrhea kills 500,000 Indian children. A jaundice epidemic strikes a small district of India's Rajasthan state as regularly as the annual monsoon.Those deadly diseases and others that afflict India and rest of the world can be traced to the same source: drinking water contaminated by human waste. Infected water causes an estimated 80 percent of disease in all over the world, according to the World Health Organization (WHO), making poor sanitation and inadequate sewage disposal the nation's biggest public health problems.

To protect drinking water from disease-causing organisms, or pathogens, water suppliers often add a disinfectant, such as chlorine, to drinking water. However, disinfection practices can be complicated because certain microbial pathogens, such as *Cryptosporidium*, are highly resistant to traditional disinfection practices. Also, disinfectants themselves can react with naturally-occurring materials in the water to form byproducts, such as trihalomethanes and haloacetic acids, which may pose health risks. A major challenge for water suppliers is how to control and limit the risks from pathogens and disinfection byproducts. It is important to provide protection from pathogens while simultaneously minimizing health risks to the population from disinfection byproducts. In 1974, Congress passed the Safe Drinking Water Act. This law requires EPA to determine the level of contaminants in drinking water at which no adverse health effects are likely to occur. These non-enforceable health goals, based solely on possible health risks and exposure over a lifetime, with an adequate margin of safety, are called maximum contaminant level goals (MCLG). Contaminants are any physical, chemical, biological or radiological substances or matter in water. EPA sets MCLGs based on the best available science to prevent potential health problems.For most contaminants, EPA sets an enforceable regulation called a maximum contaminant level (MCL) based on the MCLG. MCLs are set as close to the MCLGs as possible, considering cost, benefits and the ability of public water systems to detect and remove contaminants using suitable treatment technologies. When there is no reliable method that is economically and technically feasible to measure a contaminant at particularly low concentrations, a treatment technique is set rather than an MCL. A treatment technique is an enforceable procedure or level of technological performance which public water systems must follow to ensure control of a contaminant. States may set a more stringent MCL or treatment technique level for pathogens and indicators in drinking water than EPA.

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DEM 103 URBAN WATER MANAGEMENT CR 4

UNIT-5: SUSTAINABLE WATER MANAGEMENT IN BUILDINGS

UNIT STRUCTURE

5.0 OBJECTIVES
5.1 INTRODUCTION.
    5.1.1 THE IMPORTANCE OF WATER EFFICIENCY
5.2 WATER USES AND EQUIPMENTS IN HOUSES
    5.2.1 EQUIPMENT INSTALLATION, INTEGRATION, AND MAINTENANCE
        5.2.1.1 EQUIPMENT INSTALLATION
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5.6 SUMMARY

5.0 OBJECTIVES

After going through this unit, you will be able to:

- discuss the importance of water efficiency and water uses
- install water equipments in houses
- list water saving technologies
- recycle water

5.1INTRODUCTION

A sustainable water management system is one of the most important components concerning water conservation around the world. Liberal economic development and globalization affects the urban markets, industries and manufacturing companies eventually consuming more water, generating more wastes and polluting environment. This leads to the need of water conservation, efficiency and re-use of water at different levels. Climate change reduced ground water level, drought, flood etc makes us to think in a new way so that proper utilization of water can be done.

Use of water and electricity is the basic need of a building. The daily consumptive use of water in public buildings such as hospitals, hotels, shopping mall is maximum. It is very difficult and costly to supply water to such type of buildings. Proper utilization and sustainable water management will definitely help to overcome this problem.

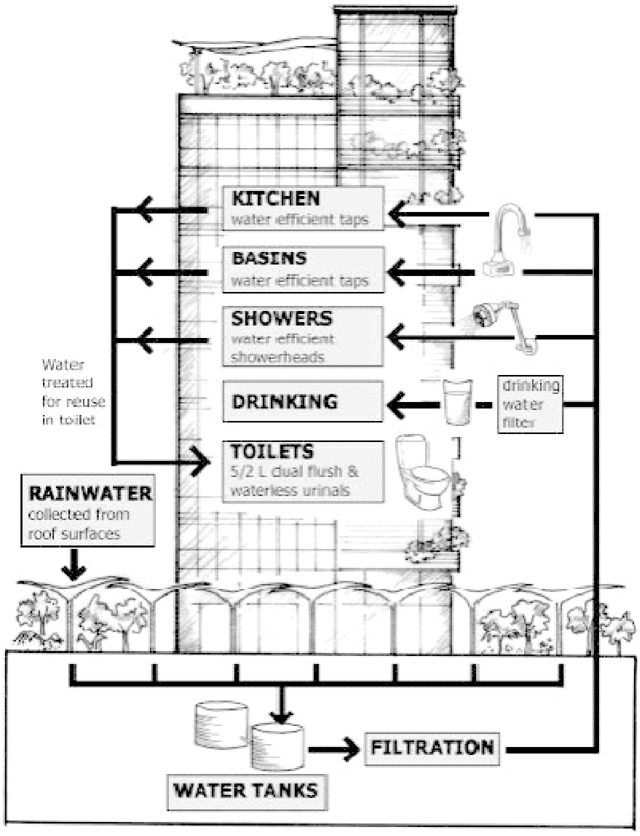

Figure 1: Water Management in a commercial building(Source : website)

5.1.1 THE IMPORTANCE OF WATER EFFICIENCY

a) Climate change and water security : Climate change is an important issue for India's water supplies. Although there is some debate in the media as to the exact severity of climate change, the chemistry and physics behind global warming have been known for over 30 years. What we are now seeing is evidence that climate change is already occurring.

b) Importance for owners : Owners play an important role in implementing water efficiency in buildings, particularly when it comes to base building applications such as cooling towers. Owners can initiate larger projects, such as substituting potable water with alternative water sources, along with technologies that use less water and hence provide a substantial reduction in potable water use in a building.

c) Importance for builders and contractors: During construction of buildings, builders and contractors can implement changes in how they use water. This can include substituting potable water with water of a lower quality for activities such as wetting down roads for dust control. Alternative procedures for the testing of services with water, or the capture and re-use of water used in the testing of services, can also be considered.

d) Importance for designers: The National Building Code offers guidelines for construction. Plumbing has to be attuned to the general design of the building. Many technical aspects such as water pressure, venting and concepts of wet and dry areas in toilets have to be looked into in any structure. Recently, the International Association of Plumbing and Mechanical Officials (IAPMO) developed a Plumbing Code for India. The Indian Plumbing Association (IPA), country's apex body of plumbing professionals, has launched 'Uniform Plumbing Code' (UPC)**.**The World Plumbing Council's uniform plumbing code was mended as per Indian needs and created the code for India. These code provide guidance to the designer, and foster innovation to achieve water efficiency goals.

e) Importance for occupiers : It is important for occupiers to participate in water efficiency initiatives, as there are many initiatives that rely on behavioural change (such as ensuring taps are turned off properly, only turning a dishwasher on when full, and reporting leaks to building maintenance technicians). Such initiatives can result in significant savings in a building.

f) Importance for managers : Managers play an important role in leading and/or supporting water-saving initiatives by influencing behavioural change across an organisation, and are also responsible for the implementation and accountability of such initiatives. In addition, managers can set water efficiency targets for a building in regards to fit-outs, upgrades, or when looking for a new premises.

5.2 WATER USES AND EQUIPMENTS IN HOUSES

Sustainable water management systems are based on the principle of the water quality cascade. This means that water sources should be matched with end uses in terms of the required water quality as shown in Table 1. Generally two types of waste water come out from a building. One is greywater and the other part is blackwater. Greywater is wastewater generated from domestic activities such as laundry, dishwashing, and bathing, which can be recycled on-site for uses such as landscape irrigation and constructed wetlands. Greywater gets its name from its cloudy appearance and from its status as being between fresh, potable water (known as "white water"). In 1970s Blackwater is a term which describe wastewater containing fecal matter and urine. It is also known as brown water, foul water, or sewage. It is distinct from greywater or sullage, the residues of washing processes.

Table: 1

Source	End use	Increasing water quality requirement ↑
Treated and disinfected rainwater water	Drinking Kitchen Showers Basins	
Treated and disinfected	Cleaning	

greywater	Toilet flushing	
Treated and disinfected blackwater	Gardening and irrigation	

The commercial sector typically comprises 10-20% of total water demand in an urban water supply system. This provides a good prospect for sustainable water management and potential savings in water supply scheme. This sector, unlike the industrial sector, is easy to target for water conservation measures, as a significant proportion of its indoor water use is similar to residential water use. Hence, commercial office buildings can make use of the technological advances made in the improved water efficiency of fixtures like toilets, urinals, taps and showerheads and other systems such as cooling towers, reuse systems and rainwater capture and treatment systems. In table 2 an idea about the breakdown of end use of water in commercial building is given.

Table 2 Breakdown of end use in a typical commercial building

Indoor (domestic/restrooms)	31%
Cooling and heating	48%
Landscaping	18%
Other	3%

As can be seen from Table 1 and Table 2 over 50% of the total water demand in a commercial office building can be met by substituting potable water with rainwater or treated greywater and blackwater.

5.2.1 EQUIPMENT INSTALLATION, INTEGRATION, AND MAINTENANCE

Water used in kitchen, toilet etc needs some fixtures and proper equipments to be installed and integrated properly for the efficient use of water in buildings. An appropriate pipe networking system and modern plumbing configuration will definitely provide a satisfactory use of water in every end. Increasing the efficiency of fixtures leads to significant reductions in water demand from the end uses and also translates into considerable cost savings. Below describes the various water efficient fixtures that can be used effectively with proper installation in a building.

5.2.1.1 EQUIPMENT INSTALLATION

It is important to know the water pressure of a building or other facility before installing flow-reducing retrofits. There are some special considerations to keep in mind when installing low-flush toilets or toilet retrofit devices.

Showerheads : one should check the required water pressure to facilitate before installing showerheads. The water pressure generally in the range of 40 - 60 psi (276 – 414 kPa). In buildings with extremely low water pressure, flow rates might become so low with these fixtures that users might try to bypass or modify a fixture to achieve a more satisfactory flow. In buildings with extremely high water pressure, the resulting high flow rate can accelerate the deterioration of a fixture as well as reduce savings.

Toilets: one should ask building managers, plumbers, or other professionals for recommendations. One can also see the manufacturer's performance testing data and guarantees. Look for toilets with a 2 in. (50.8 mm) glazed trapway, which makes the fixture less likely to plug up. It is to be ensured that the water pressure on each floor is adequate for the type of toilet that has been selected. A low-consumption toilets can make some problems in waste line or venting pipes. Solving current problems now may increase project costs, but it will also help to avoid expensive repairs later. It is required for regular checking of shutoff valves, drain line slopes, waste lines, and venting pipes before installation.

Toilet retrofits: Sometimes a retrofit can make an older toilet more efficient. With gravity-flush models, placing displacement devices in the tank, such as plastic bottles filled with water or pebbles, could save as much as 1 gallon (3.8 liters) per flush. Toilet dams can keep a certain amount of water from entering the flush cycle. And some toilets can be retrofit with early closure devices or dual-flush adapters that save from 0.5 - 2 gpf (about 1.9 - 7.6 lpf). Retrofit devices are more likely to work on toilets that consume a large amount of water per flush. One can ask local plumbers and water utility conservation staff about retrofit devices or can do a test a device on a few sample toilets.

5.2.1.2 INTEGRATION

One can install most of the products and appliances described earlier almost anywhere a fixture or appliance is already being used. Utilities, plumbing contractors, local water boards, zoning authorities, and others may have to be involved, as well, depending on the complexity and size of a particular installation. It is important to ensure that even simple water-management technologies are integrated correctly into the plumbing and HVAC (heating, ventilation and conditioning) systems. The water temperature, pressure, piping, installation height, and other factors must be correct for new fixtures and appliances. It is to be ensured that controls are adjusted properly. In older facilities, sewer and drain lines can become fouled or constricted from many years of use. Older technologies usually keep enough water flowing through a drain line to move waste material. However, the quantity of water used with low-flow technologies can be substantially less and in older facilities, this could increase clogs and backups. To prevent them, one should clean out older sewer and drain lines before installing low-flush toilets to make sure there is sufficient line capacity for waste removal. Most of the technologies can be integrated successfully with various kinds of piping.

5.2.1.3 MAINTENANCE

Even the simplest water-efficient technologies need some maintenance. One has to check that equipment parts are readily available for all new water-using equipment and also has to make sure that maintenance staff receive training in the care of new technologies. Some of the maintenance parts are discussed as follows

Faucets - Faucet filters need to be unclogged, cleaned, and replaced periodically and fixtures and pipes need to be checked regularly for leaks or damage. Many leaky faucets can be fixed simply by replacing the washer at the spout. This low-cost, high savings measure should be part of a maintenance program.

Toilets - Large amounts of water can be lost when toilet flappers or diaphragms leak. Some leaks can be detected by simply listening, but some are not noticeable.

Waterless urinals - Urinals that don’t require flush water need much less maintenance than other kinds, primarily because they lack moving parts. Maintenance for one model involves replacing a very small amount of liquid on a regular basis

5.3 COMPREHENSIVE ASSESSMENT SYSTEM FOR BUILDING ENVIRONMENT EFFICIENCY

Comprehensive Assessment System for Building Environmental Efficiency (CASBEE) is a building rating system to assess the environmental efficiency of buildings that was developed by the Japan Sustainable Building Consortium. CASBEE is used to assess buildings based on interior comfort; scenery consideration and environmental awareness (utilize energy saving materials and equipment, or those that cause smaller environmental loads). Comprehensive assessments are ranked in five grades: - Poor (C); Fairly Poor (B-); Good (B+); Very Good (A); Excellent (S).

In India keeping in view the agro-climatic conditions and, in particular, the preponderance of non-air-conditioned buildings, the National Rating System – GRIHA (Green Rating for Integrated Habitat Assessment) has been developed as a suitable system for all kinds of buildings in different climatic zones of the country. GRIHA- the National Rating System will evaluate the environmental performance of a building holistically over its entire life cycle, thereby providing a definitive standard for what constitutes a ‘green building’. The rating system is based on accepted energy and environmental principles, will seek to strike a balance between established practices and emerging concepts, both national and international.

Buildings are major consumers of water during construction and operation. It was found that per capita water consumption in 1990 was 2464 m^3 per capita per annum, but by 2025 with an expected population of 1.4 billion, it will almost certainly be in the stress category with less than 1700 m3 per capita per annum.

Buildings have major environmental impacts during their life. Resources such as ground cover, forests, water, and energy are dwindling to give way to buildings. Resource-intensive materials provide structure to a building and landscaping adds beauty to it, in turn using up water and pesticides to maintain it. Energy-consuming systems for lighting, air conditioning, and water heating provide comfort to its occupants. Water as a most essential resource for the occupants, gets consumed continuously during building construction and operation. Several building processes and occupant functions generate large amounts of waste, which can be recycled for use or can be reused directly. Buildings are thus one of the major pollutants that affect urban air quality and contribute to climate change.

Figure 2: Schematic diagram highlighting select green building features (source: GRIHA manual, Vol 1 Ministry of New and Renewable Energy, Government of India and The Energy and Resources Institute New Delhi)

A green building depletes the natural resources to a minimum during its construction and operation. The aim of a green building design is to minimize the demand on non-renewable resources, maximize the utilization efficiency of these resources when in use, and maximize the reuse, recycling, and utilization of renewable resources.

As stated in GRIHA manual the following aspects of a green building design are looked into in an integrated way.

1. Site planning
2. Building envelope design
3. Building system design (HVAC [heating ventilation and air conditioning], lighting, electrical, and water heating)
4. Integration of renewable energy sources to generate energy on-site
5. Water and waste management
6. Selection of ecologically sustainable materials (with high recycled content, rapidly renewable resources with low emission potential, and so on)
7. Indoor environmental quality (maintain indoor thermal and visual comfort and air quality)

5.4 WATER SAVING TECHNOLOGIES

Water-saving technologies provide important benefits to provide facilities in severely dry areas, but they are worth considering for national facilities everywhere because of their environmental and economic benefits. Even in areas where water resources are not scarce, we are likely to see increases in the use of these and other practical, water-saving technologies in our homes, places of business, and government facilities, because they are cost-effective, they help us to save natural resources. There are some methods through which we can use water efficiently in residential and commercial buildings. Following are the some fixtures which can be effectively used in buildings.

The benefits of implementing water efficiency initiatives in buildings may include:

1. cost savings in annual water bills, particularly when the price of water is likely to increase, based on the current drought conditions
2. adding to the corporate image of a business/organization
3. reduced energy costs and greenhouse emissions
4. helping to ensure water is available for future generations.

Toilets

Toilets usually account for a significant portion of total water demand in a building. Based on typical usage patterns, 6/3 dual flush toilets have an average water demand of 4 L/flush. With higher drainage grades, flush toilets can operate at 5/2 L or lower, reducing average demand per flush to less than 3 L/flush. There are different types of water efficient toilets on the market and in production, ranging from low and ultra low flush toilets to composting toilets that use no water at all. Air used vacuum toilets have had a wide application in aircraft and marine transportation, their use in commercial buildings and public restrooms is increasing. In these systems, the waste is evacuated from the toilet bowl through a vacuum that is generated by a vacuum pump. The waste is then macerated and can be directly discharged to sewer or transported to a holding tank or treatment system. The average amount of water used is between 1 and 1.5 L per flush.

Composting toilets can be used both in multi-storey commercial buildings as well as in office buildings. The main advantages of composting toilets are that they require little or no water for flushing, thus reducing water demand. They reduce the quantity and strength of the wastewater to be treated or disposed and return nutrients to the environment.

Urinals

Standard urinals use an average of 6 L of water per flush; water efficient urinals use 2.8 L per flush. The toilet is the single biggest water user in your home. Flushing accounts for about 38%, more than a third, of the water used within your home each day.

Replacing an old model toilet with a new low-consumption toilet could automatically and permanently cut your home water consumption by 25% or more.

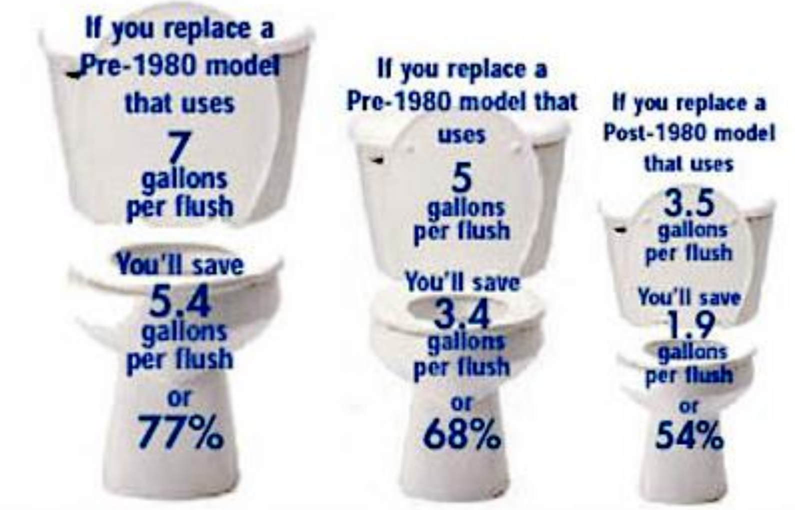

Figure 3 : Different types of flush model (Source: website)

Taps

Adjusting the flow rate of taps while maintaining spray pattern through the installation of flow regulating tap aerators can significantly reduce tap water use in hand basins and kitchen sinks. Typical flow rates for non-efficient taps are usually 10-12 L/minute, which can be reduced to 2.5 L/minute with the installation of appropriate flow regulators. Infrared tap controllers reduce the duration of the flow of water, by only operating when the sensor is activated. These taps require energy to operate, and are more expensive. A combination of flow regulated and infrared taps can achieve significant savings in water demand. Taps can be made efficient through design or through addition of flow restrictors or regulators (flow limiters). Manufacturers take a variety of approaches to incorporating efficient taps in their ranges. Some have taps that are efficient by design and others address efficiency solely through addition of flow limiters. For standard taps, the Water Calculator allows the maximum flow rate to be set by these flow limiters. Flow limiters can be either incorporated within the tap or fitted on to the pipe network supplying the tap. If the external option is chosen it must be remembered that flow limiters will be required on both hot and cold supplies.

Figure 4: Aerators and flow restrictors
Taps can be replaced with water-efficient taps that have inbuilt aerators and/or flow restrictors. Alternatively, aerators and flow restrictors can be installed in existing tapware to improve efficiency.

Showerheads

While showering may be the largest source of residential water demand, shower demand is not as high in commercial buildings. Typical non-efficient showerheads have a flow rate of approximately 11 L/minute in use. AAA-rated showerheads have flow rates between 7 and 9 L/minute and highly efficient showerheads can have flow rates of 5 L/minute or less. Showers can also be fitted with digital readout meters that show the user the amount of water being consumed and the duration of the shower. This can encourage the user in an office building situation to reduce water demand for showers.

Figure 5: Water-efficient showerheads

Cooling Towers

Cooling towers use make-up water to replace water lost in evaporation as well as for blow down. The water use efficiency in the cooling tower can be maximized by ensuring that blow down is controlled to a set maximum total dissolved solids (TDS) concentration with the help of a TDS monitoring device. Evaporation losses are reduced by operating the cooling system more efficiently and reducing the heat load on the building through improved energy efficiency.

Waterless urinals

Waterless urinals are being used in commercial buildings, hotels and government institutions. They are currently installed in a number of buildings in many developed country mostly in Europe, New Zealand and US. Most of these urinals operate through the use of an oil barrier between the urine and the atmosphere, preventing odours from escaping. The potential water savings from a waterless urinal compared to a 2.8 litre per flush urinal in a commercial building is approximately 1.5 ML/annum, based on typical usage of four flushes per day (DEH, 2006a).

Figure 8 : waterless urinals

Roof gardens

Roof gardens or green roofs in commercial buildings can play a part not only in water and wastewater management but also in improving the energy performance of the building. There are two types of green roofs - extensive and intensive. Extensive green roofs have a thin growing medium, have lower plant diversity and are relatively inexpensive. Intensive green roofs have a deeper soil substrate, have a greater diversity of plants and habitats, and potentially have greater energy efficiency and storm water retention capabilities and a longer membrane life. Roof gardens can reduce the ‘urban heat island effect’, the overheating of urban areas due to an increase in paved and concreted areas in relation to ‘green’ areas. This reduction may lead to substantial energy savings. Other important benefits include prolonging roof life, filtering of airborne particles, sound insulation, creation of aesthetically pleasing landscapes and storm water retention (Peck & Kuhn, 2001).

In a commercial building, roof gardens can be used either for storm water retention or to evapotranspirate the effluent generated from wastewater treatment plants. In the latter case it is important to ensure that the roof gardens are protected from rain, in order to maximize their evaporation capacity. The type of plants to be used and the location of the roof garden need to be carefully chosen to maximize evapo-transpiration of effluent.

The role of building users

All users of a building have an important role to play in sustainable water practices. Some of the key actions that can be taken include:

- reporting leakages immediately to building maintenance or facility management staff
- ensuring taps are turned off properly
- reducing the time taken when using water, such as in showers, basins, wash-down facilities, and cleaning
- Operating water-using appliances responsibly (e.g. only turning on washing machines and dishwashers when they are full).

5.5 WATER RECYCLING TECHNOLOGY IN THE SUPPLY SYSTEM

For many years, the world enjoyed an abundance of high-quality of fresh water that was inexpensive to obtain, treat and transport. Now, many communities face water shortages, deteriorating water quality from seawater intrusion and greater demands due to population growth, tourism, recreational use, drought and industrial expansion.

Some systems collecting rainwater or greywater for supply to non-potable uses such as WC flushing, clothes washing and various outdoor uses, are becoming increasingly common. Recycling systems are well established in non-domestic settings, particularly in the commercial sector. They are increasingly viable in domestic settings and in terms of cost and maintenance communal systems may be more viable than single dwelling systems.

Advantages of water recycling systems:

i. Inclusion of a recycling system can facilitate relaxation of some of the flow rate or volumetric restrictions required to meet the consumption targets.
ii. It has the added benefit to the end-user of lower water charges for metered customers.
iii. Rainwater harvesting can contribute to sustainable urban drainage systems (SUDS) .

Disadvantages of recycling systems are:

i. It has been estimated that a standard recycling system would add more to the cost of a new home.
ii. It needs some maintenance. Although maintenance needs are usually not very demanding, companies that supply recycling systems should stipulate their maintenance requirements.
iii. Recycling system are of wider environmental concerns. There are two main issues here. Firstly the high embodied energy associated with recycling systems, which in

some instances may result in the recycled water having a higher carbon footprint than mains water. Secondly water recycling systems reduce cold water demand rather than hot water (which has higher associated carbon emissions) so there are concerns that water recycling will take focus away from reducing carbon emissions associated with hot water.

5.5.1 GREY WATER RECYCLING SYSTEM:

Greywater harvesting is differentiated from other harvested water sources like rainwater or condensate in that is, it has already been "gently used" usually as water from showers and sinks, but it could also be sourced from the rinse water in a commercial washing machine or dishwasher. It is most often harvested to flush toilets in a building, but the cleaned water can also be used for irrigation and other applications. Toilet waste water is termed as "black water" and is not normally considered for harvested water systems. The greywater supply can usually meet 100% of toilet flushing requirements. Harvesting greywater is a relatively new practice in commercial and institutional buildings, and carries many system and regulatory implications not associated with rainwater or condensate harvesting. Unlike other renewable water sources, greywater normally contains biological and chemical contaminants that can quickly turn to "black water", resulting in unpleasant odours, colors and health hazards if not treated correctly. Consequently, a number of leading-edge filtration, sterilization and monitoring steps are required to bring the water to near-potable quality and elimination of any health and aesthetic concerns.

5.5.1.1 COMPONENTS OF GREYWATER RECYCLING SYSTEM:

Following are the components given in sequent for recycle of greywater in a building

1. Filtration: Greywater is routed from showers, baths, and sinks through a plumbing system that is separated from toilets and urinals. The first filtration step is designed to remove the larger particulates and a settling tank will separate the heavier and floating material where it can be sent to the sewer system.
2. Sterilization/Disinfection: It is necessary to sterilize the water to keep algae, viruses, bacteria and other organic contaminants from forming in the storage tanks. Several technologies available for this purpose are using sterilizer agents such as chlorination, ozone, or chlorine dioxide and ultraviolet sterilizers.
3. Storage: Storage of the treated greywater is determined by the demand and uses for the water, available greywater volume and turnover frequency. Storage systems have a connection to a municipal source so that toilet flushing can occur even if there is not an adequate supply source of greywater.
4. Distribution System: Pumps and Pipes.

5. Programmable Control System: Controlling the entire process and interfacing with other building automatic alarm systems as well as tracking the amount of water in each tank and the monthly water usage for educational purposes. Below figure shows a schematic diagram of greywater recycling system.

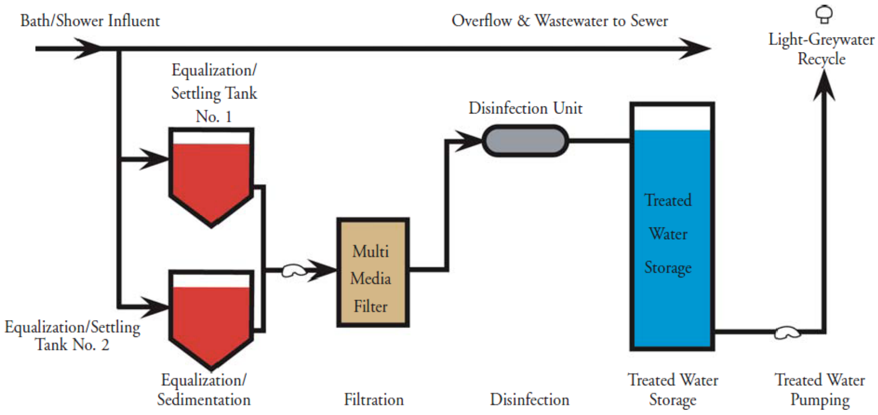

Figure 4 : Layout of greywater recycling system for a building

Green roofs have some certain concerns, which would limit their use, and so do composting toilets. Extensive green roofs are extremely heavy; therefore require extra structural support incurring much higher costs. They also require constant maintenance, gardening and trimming for example, a cost that will always be needed. Composting toilets are limited in that they require a shaft directly beneath them. Unlike that of a conventional toilet where plumbing can be hidden behind walls, these shafts would restrict placement. Also, the toilets ability to compost waste is limited and depending on anticipated usage may not be able to supports the demands in high traffic areas.

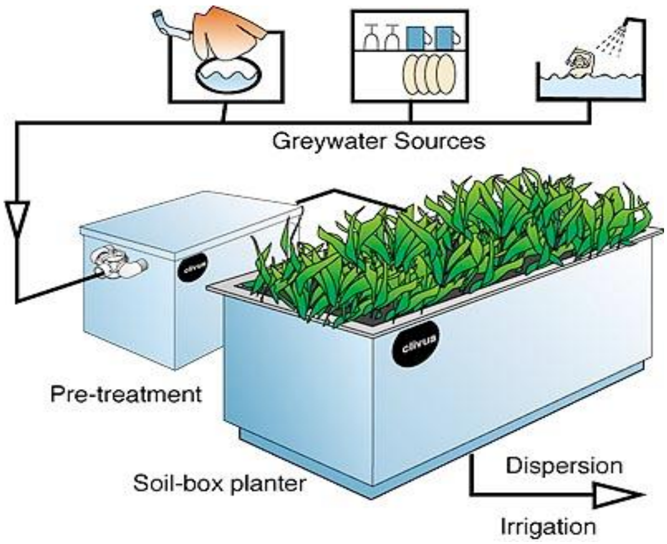

Figure 5: Simple Greywater Filtration Diagram(Source: Clivus Mutrum Website)

5.6 SUMMARY

A sustainable water management system for a building is a fully advantageous choice. The only disadvantage would be the extra cost for the system to be implemented and even that would be mostly covered by the savings on the water consumption. The only uncertainty associated is the amount of extra costs for the required material such as piping, storage tanks, and the rain catchment which need to be determined based on detailed price on each part.

For commercial buildings there are four main types of water that need to be considered, these are potable water, greywater, blackwater and stormwater. Potable water is generally defined as water which is suitable for human consumption and is commonly referred to as drinking water. Greywater is the domestic wastewater from bathroom fixtures such as basins, showers and baths, laundry fixtures such as clothes washing machines and laundry troughs and kitchen facilities such as sinks and dishwashing machines. Depending on the level of wastewater treatment, greywater can be recovered and used for applications such as toilet flushing and irrigation. Blackwater refers to waste discharges from the human body which are collected through fixtures such as toilets and urinals. It is possible to use this wastewater for non-drinking purposes once treated and disinfected. Stormwater refers to run-off due to rainfall collected from roofs, impervious surfaces and drainage systems. Stormwater or rainwater collected from roofs can be used untreated for applications such as wash-down, irrigation and toilet flushing.

Use of water in a building depends on the type of building. The majority of water used in a restaurant is for kitchen applications, whereas for other buildings, such as office buildings, school and large shopping centres, the majority of water is used in cooling towers. Reducing water consumption in buildings and improving water efficiency is a major aspect of creating sustainable management of water in buildings.

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Questions:

1. Why sustainable water management is required in a building?
2. What are the importance of water efficiency?
3. What is greywater and blackwater?
4. How greywater is recycled in a building

DEM 103 URBAN WATER MANAGEMENT CR 4

UNIT-6: URBAN SURFACE WATER ANAGEMENT

UNIT STRUCTURE

6.0 OBJECTIVES
6.1. INTRODUCTION
    6.1.1 THE PROBLEM OF DIFFUSE POLLUTION
    6.1.2 COMPONENT OF URBAN SURFACE WATER SYSTEM
    6.1.3 OBJECTIVES OF URBAN SURFACE WATER MANAGEMENT
6.2. REVETMENT STRUCTURE AND THEIR PROBLEMS
    6.2.1 EFFECTS OF CHANNELIZATION AND CHANNEL MODIFICATION ACTIVITIES
    6.2.2 MAJOR CATEGORIES OF CHANNELIZATION AND CHANNEL MODIFICATION EFFECTS AND EXAMPLES OF ASSOCIATED PROBLEMS AND BENEFITS.
6.3. HUMAN IMPACTED FLOW REGIME IN THE URBAN AREA
6.4. URBAN FLOOD AND COUNTER MEASURES
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    6.4.2 MEASURES TO MITIGATE FLOOD HAZARD.
6.5. RIVER ECOSYSTEM CONSERVATION:
    6.5.1 ISSUES RELATED TO WATER MANAGEMENT
    6.5.2 SOME PRACTICES OF WATER MANAGEMENT HELP IN CONSERVING ECOSYSTEM
6.6. COASTAL ZONE MANAGEMENT
    6.6.1 CLASSIFICATION CRITERIA AND REGULATORY NORMS
    6.6.2 PLANNING APPROACHES
    6.6.3 CONSTRUCTION TECHNIQUES
6.7. SUMMARY

6.0 OBJECTIVES

After going through this unit, you will be able to:

- discuss the problem of diffuse pollution
- list the major categories of channelisation and channel modification effects
- discuss the problems of urban flood and its counter measures
- conserve river ecosystem
- learn about coastal zone management

6.1 INTRODUCTION

Surface water is precipitation that does not infiltrate into the ground or return to the atmosphere by transpiration or evaporation. Water that stands or flows on the surface of the Earth is commonly referred to as runoff. The management of surface water is a complex issue, mainly centred on historical precedent and practices. Since the spread of urbanization associated with the change from an agrarian to industrial society, in developed countries we have drained our landscapes using essentially the same approach. Standing water is perceived as a hazard and therefore we have tried to move the runoff, or storm water, quickly, safely and economically into sewers, and then with the same emphasis into the nearest watercourse. However, urbanization changes the local natural hydrological cycle as the impermeable surfaces associated with development reduce infiltration and transpiration, and instead divert the precipitation into the drainage system (Fig. 1).

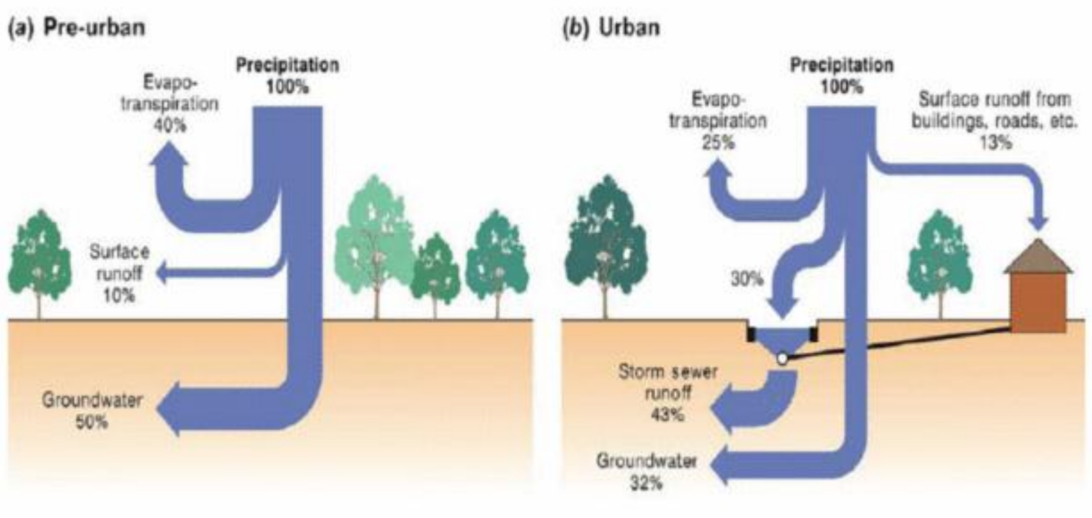

Fig:1 The volume of surface runoff changes between natural and urbanized environments

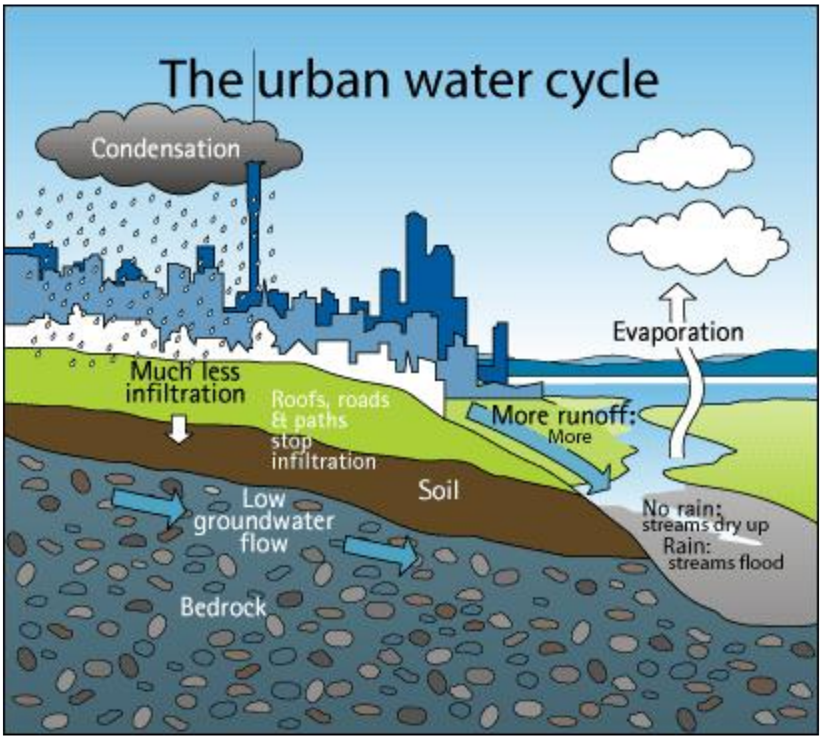

Fig:2 Urban Water Cycle

When people roof and pave the land, water can't soak into the soil. It runs off these hard surfaces very rapidly, so pipes are needed to rapidly carry the resulting large volumes of storm water to the nearest stream or beach. The result is that streams dry up when it isn't raining and flood when it does. Pollutants on roads and yards are also swept into our streams and onto our beaches (Fig. 2).

6.1.1 THE PROBLEM OF DIFFUSE POLLUTION

There are two main sources of pollution, point-source, such as the type that occurs from sewage and industrial effluent, and diffuse, which is the term given to pollution resulting from the combined problems of less quantifiable practices. Point source pollution is becoming more effectively regulated using the national and trans-national environmental protection legislation. Conversely however, as point source pollution has become more effectively controlled, the pollution arising from diffuse sources, such as surface water runoff, now has a proportionally greater effect on domestic watercourse quality and has been widely identified as the single biggest challenge to improving water quality. The effective management of diffuse pollution presents a significantly more complicated problem to solve than the traditional view of pollution. The principal challenge arises due to diffuse pollution effectively operating outside of many of our existing environmental protection mechanisms, making its recognition, reduction and subsequent monitoring a complex issue. On the whole, developed societies manage surface water by a storm water sewer system, a drainage method that separates runoff from sanitary treatment. This division however, helps to create problems of diffuse pollution, as it transports surface runoff into sewers and then into watercourses without any treatment. Consequently, effective management of diffuse pollution is unachievable using conventional drainage techniques

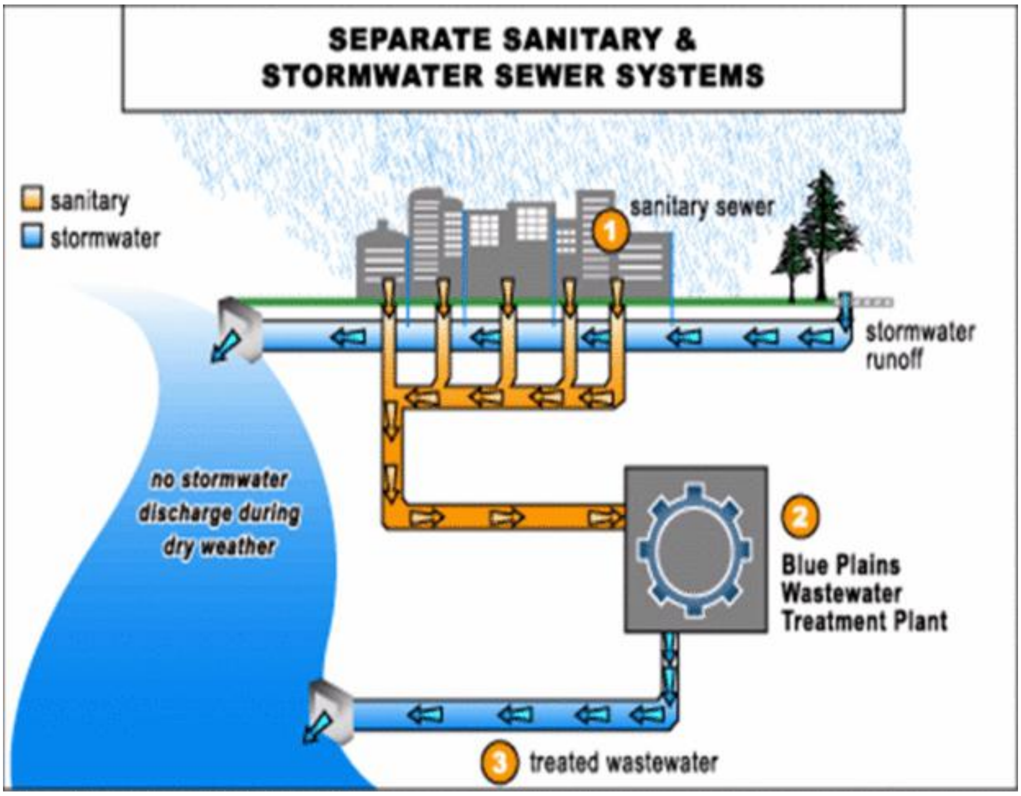

Fig:3 A separate sewer system. (Source: DC Water and Sewer Authority)

The separate sewer system does not attempt to manage problems of diffuse pollution as the 'wash' off roads and other surfaced areas conveys polluted debris into the storm water system and therefore untreated into the watercourse. In an urban area common pollutants include oils, metals, dog faeces, etc., and outfalls that should discharge surface water have been found with average concentrations of suspended solids at a level equivalent to raw sewage. The problem is exacerbated as the build up of debris and pollutants on surfaces occurs at a steady rate and a storm provides the first 'flush' of an urban area, conveying diffuse pollution into the watercourse. This is even more concentrated after periods of dry weather. An additional concern is that there is no management of accidental spills using the separate system. For example, if oil is spilled by a car or industrial area the contaminant is simply washed with the rest of the untreated storm water into the watercourse. The mis-connection of foul sewage into surface water drains, such as by washing machines or dishwashers is also a surprisingly common problem.

Instead of a separate sewer system, in many older developments a combined sewer system may be in operation. This system, which was the forerunner to the separate system, also encounters many environmental problems, as all household wastewater and storm water is diverted into one combined sewer system where it is then transported to the treatment plant. This method may seem to be more environmentally friendly than the modern system, but during periods of significant rainfall the capacity of a combined sewer may be exceeded. When this occurs, regulators are designed to let the excess flow, which is a mixture of storm water and sanitary wastes, to be discharged untreated to the watercourse, causing pollution. This excess flow is called ***combined sewer overflow*** and is necessary to prevent flooding in property, businesses, and streets. Its magnitude may depend on factors such as rainfall intensity, or the volume of current and recent rainfall levels (Fig. 4).

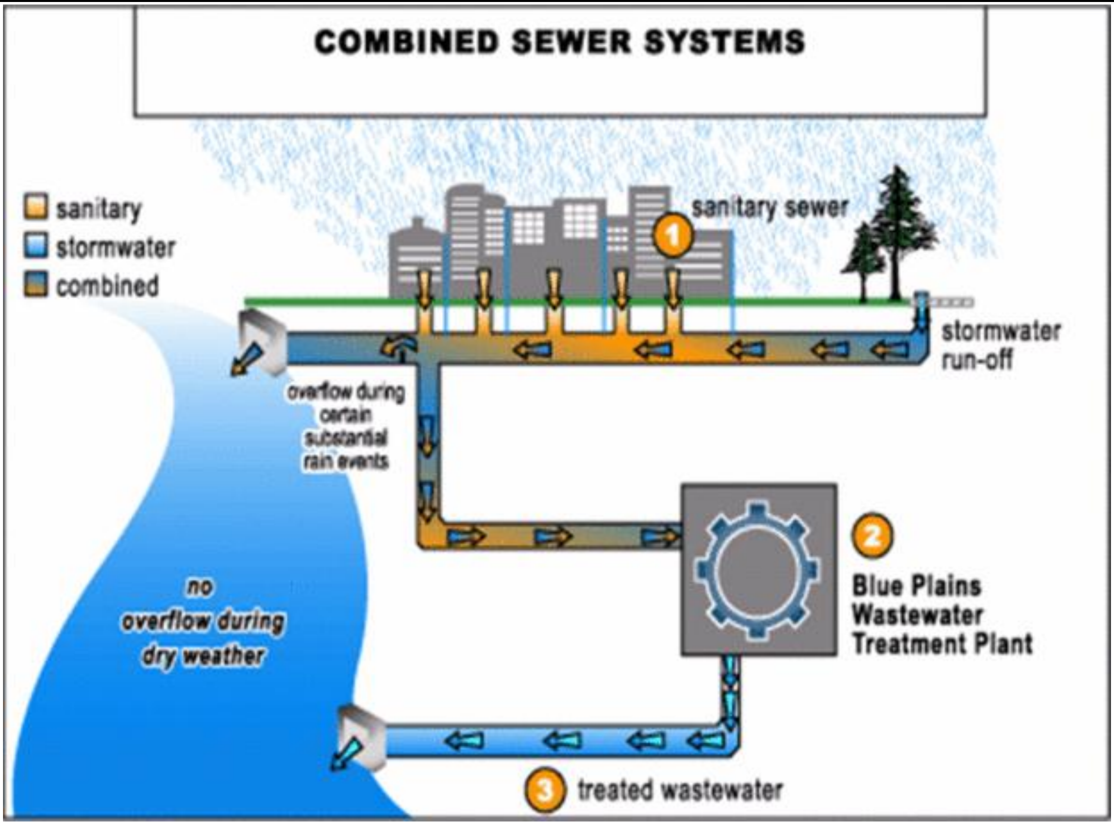

Fig 4: ***A combined sewer system. (Source: DC Water and Sewer Authority)***

In addition to problems of diffuse pollution, the way we manage water resources as a society can cause other forms of environmental damage. For example, traditional drainage techniques ensure that the flow levels of watercourses are tied quite closely to the rainfall levels in the immediate area, they may run either low or high in direct response to precipitation, and high, fast flows may wash away or damage riverside habitats, erode banks and deposit sediment. The process of flooding itself also brings direct environmental damage as sewer overflows and other forms of contaminant enter the watercourse, while the nearby flora and fauna are also detrimentally affected by the severe flows.

6.1.2 COMPONENT OF URBAN SURFACE WATER

Components	Surface water Control Function
Permeable land surface and associated vegetal cover	Permit interception and infiltration and provide for surface runoff
Swale and Open Channel	Receive, concentrate and transmit surface runoff from the land surface to other surface components of the storm water system
Culvert	Provide for the passage of stormwater flow beneath highways, street, private drives and driveways
Roadways with roadside ditches or curb and gutter	Provide during minor and major runofff
Parking lots, roof tops and other impervious surfaces	Provide during minor runoff for collection of storm water
Inlet	Primarily Provide during minor runoff for transition between surface and sub-surface components of a storm water control

	system
Catch basin	Provide by means of sump for retention of sediment and other heavy debris
Storm sewer	For collection and conveying of storm water to minimize disruptive surface ponding in streets, parking lots and other low areas.
Manhole	Provide for the intersection of storm water having different grade, elevation, direction or size.
Detention facility	Provide normally in dry area or enclosures for temporary storage of storm water.
Retention facility	Provide normally in reservoir contains a substantial volume of water at a predetermined conservation pool level
Sedimentary basin	Trap suspended solids, suspended and buoyant debris.

6.1.3 OBJECTIVES OF URBAN SURFACE WATER MANAGEMENT

1. Protecting life and lessening public health and safety risks: A review of recent flooding events and the resulting loss of life emphasize the need to attend this first and most important objective of urban SWM.
2. Reducing risks of monetary damage to private and public property. Flood damage to private and public property ranges from minor occurrences of strictly local interest to large, catastrophic events that attract national or international attention.
3. Minimizing disruption of community affairs: Urban SWM seeks to minimize the usually annoying and sometimes costly disruption caused by flooding in urban areas. Manufacturing and business activities are interrupted not only during the flood period but also after the flood during the clean up and repair period.
4. Protecting quality of surface and groundwater: Storm runoff from urban areas contains significant quantities of potential pollutants. These substances have adverse impact on surface and groundwater resources.
5. Enhancement of the quality of life in urban areas. As urbanisation proceeds, consideration should be given to retaining natural drainage features, such as swales, channels, floodplains, ponds and wetlands, and incorporating them into the surface water system. Preservation, conservation, restoration of these features and of their recreational, aesthetic, ecological and cultural values can greatly enhance the quality of life in urban areas.

6.2. REVETMENT STRUCTURE AND THEIR PROBLEMS

Revetments are sloping structures placed on banks or cliffs to absorb the energy of incoming water. In the bank of river, lake they are used to prevent damage during periods of flood or heavy seasonal rains. It is built along an embankment, shoreline or steep facing slope in order to protect it against erosion generated by wave or current action

- ***Channelization and Channel Modification Management***:- The terms *channelization* and *channel modification* refers to excavation of borrow pits, canals, underwater mining, or other practices that change the depth, width, or location of waterways or embayment in coastal areas for the purpose of flood control, navigation, drainage improvement, and reduction of channel migration potential.
- ***Flow alteration***:-*Flow alterations* include diversions, withdrawals, and impoundment. Result in either an increase or a decrease in the usual supply of fresh water to a stream, river, or estuary
- ***Levees***:- A *levee* is an embankment or shaped mound for flood control or hurricane protection.

6.2.1 EFFECTS OF CHANNELIZATION AND CHANNEL MODIFICATION ACTIVITIES:

- Channel modification activities have deprived wetlands and estuarine shorelines of enriching sediments, changed the ability of natural systems to both absorb hydraulic energy and filter pollutants from surface waters, and caused interruptions in the different life stages of aquatic organisms (Sherwood et al., 1990). Channel modification activities can also alter in -stream water temperature and sediment characteristics, as well as the rates and paths of sediment erosion, transport, and deposition. A frequent result of channelization and channel modification activities is a diminished suitability of in-stream and riparian habitat for fish and wildlife. Hardening of banks along waterways has eliminated in-stream and riparian habitat, decreased the quantity of organic matter entering aquatic systems, and increased the movement of non-point source pollutants from the upper reaches of watersheds into coastal waters. Excavation projects can result in reduced flushing, lowered dissolved oxygen levels, saltwater intrusion, loss of streamside vegetation, accelerated discharge of pollutants, and changed physical and chemical characteristics of bottom sediments in surface waters surrounding channelization or channel modification projects. Reduced flushing, in particular, can increase the deposition of finer-grained sediments and associated organic materials or other pollutants.
- Levees may reduce overbank flooding and the subsequent deposition of sediment needed to nourish riverine and estuarine wetlands and riparian areas.

Levees can cause increased transport of suspended sediment to coastal and near-coastal waters during high-flow events. Levees located close to stream banks can also prevent the lateral movement of sediment-laden waters into adjacent wetlands and riparian areas that would otherwise serve as depositories for sediment, nutrients, and other NPS pollutants. This has been a major factor, for example, in the rapid loss of coastal wetlands in Louisiana (Hynson et al., 1985). Levees also interrupt natural drainage from upland slopes and can cause concentrated, erosive flows of surface waters.

➢ The resulting changes to the distribution, amount, and timing of flows caused by flow alterations can affect a wide variety of living resources. Where tidal flow restrictors cause impoundments, there may be a loss of streamside vegetation, disruption of riparian habitat, changes in the historic plant and animal communities, and decline in sediment quality. Restricted flows can impede the movement of fish or crustaceans. Flow alteration can reduce the level of tidal flushing and the exchange rate for surface waters within coastal embayments, with resulting impacts on the quality of surface waters and on the rates and paths of sediment transport and deposition.

6.2.2 MAJOR CATEGORIES OF CHANNELIZATION AND CHANNEL MODIFICATION EFFECTS AND EXAMPLES OF ASSOCIATED PROBLEMS AND BENEFITS

❖ **Changed Sediment Supply**. One of the more significant changes in instream habitat associated with channelization and channel modification projects is in sediment supply and delivery. Streamside levees have been linked to accelerated rates of erosion and decreased sediment supplies to coastal areas (Hynson et al., 1985). Sherwood and others (1990) evaluated the long-term impacts of channelization projects on the Columbia River estuary and found that changes to the river system resulted in a net increase of 68 million cubic meters of sediment in the estuary. These changes in sediment supply can include problems such as increased sedimentation to some areas (an estuary, for example) or decreased sediment to other areas (such as streamside wetlands or estuarine marshes). Other changes may be beneficial; for example, a diversion that delivers sediment to eroding marshes (Hynson et al., 1985). Another example of a beneficial channel stabilization project might be one that results in increased flushing and the elimination of unwanted sediment in the spawning area of a stream.

- **Reduced Freshwater Availability**. Salinity above threshold levels is considered to be a form of NPS pollution in freshwater supplies. Reduced freshwater availability for municipal, industrial, or agricultural purposes can result from some channelization and channel modification practices. Similarly, alteration of the salinity regime in portions of a channel can result in ecological changes in vegetation in the streamside area. Diversion of fresh water by flood- and hurricane-protection levees has reduced freshwater inputs to adjacent marshes. This has resulted in increased marsh salinities and degradation of the marsh ecosystem (Hynson et al., 1985). A benefit of other diversion projects was a reduction of freshwater inputs to estuarine areas that were becoming too fresh because of overall increases in fresh water from changes in land use within a watershed. Increases in oyster harvests have been attributed to a freshwater diversion in Plaquemines Parish, Louisiana. Over the 6-year period from 1970 to 1976, oyster harvests increased by over 3.5 million pounds (Hynson et al., 1985). Potential problems with diversions include erosion, settlement, seepage, and liquefaction failure (Hynson et al., 1985).
- **Accelerated Delivery of Pollutants**. Channelization and channel modification projects can lead to an increased quantity of pollutants and accelerated rate of delivery of pollutants to downstream sites. Alterations that increase the velocity of surface water or that increase flushing of the streambed can lead to more pollutants being transported to downstream areas at possibly faster rates. Urbanization has been linked to downstream channelization problems in Hawaii (Anderson, 1992). It is believed that the deterioration of Kaneohe Bay may be caused by development within the watershed, which has increased runoff flows to streams entering the Bay. Streams that once meandered and contained natural vegetation to filter out nutrient and sediment are now channelized and contain surface water that is rich in nutrients and other pollutants associated with urban areas (Anderson, 1992). Some excavation projects have resulted in poor surface water circulation along with increased sedimentation and other surface water quality problems within the excavated basin. In some of these cases, additional, carefully designed channel modifications can increase flushing rates, which deliver accumulated pollutants from the basin to points downstream that are able to assimilate or otherwise beneficially use the accumulated materials.
- **Loss of Contact with Overbank Areas**. Instream hydraulic changes can decrease or interfere with surface water contact to overbank areas during floods or other high-water events. Channelization and channel modification activities that lead to a loss of surface water contact in overbank areas also may result in reduced filtering of NPS pollutants by streamside area vegetation and soils. Areas of the overbank that are dependent on surface

water contact (i.e., riparian areas and wetlands) may change in character and function as the frequency and duration of flooding change. Erickson and others (1979) reported a major influence on wetland drainage in the Wild Rice Creek Watershed in North and South Dakota. Drainage rates from streamside areas were 2.6 times higher in the channelized area than in undisturbed areas during preliminary project activities and 5.3 times higher following construction. Schoof (1980) reported several other impacts of channelization, including drainage of wetlands, reduction of oxbows and stream meander, clearing of floodplain hardwood, lowering of ground-water levels, and increased erosion. Channel modification projects such as setback levees or compound channel design can provide the overbank flooding to areas needing it while also providing a desired level of flood protection to adjoining lands.

❖ **Changes to Ecosystems.** Channelization and channel modification activities can lead to loss of instream and riparian habitat and ecosystem benefits such as pathways for wildlife migration and conditions suitable for reproduction and growth. Problematic flow modifications, for example, have resulted in reversal of flow regimes of some California rivers or streams, which has led to the disorientation of anadromous fish that rely on flow to direct them to spawning areas (James and Stokes Associates, Inc., 1976). Eroded sediment may deposit in new areas, covering benthic communities or altering instream habitat (Sherwood et al., 1990). Orlova and Popova (1976) researched the effects on fish population resulting from altering the hydrologic regime with hydraulic structures such as channels.

6.3. HUMAN IMPACTED FLOW REGIME IN THE URBAN AREA

Changes to the low flow regime may have significant negative impacts on downstream users, whether they abstract water (irrigation schemes, drinking supplies) or use the river for transportation or hydropower. Minimum demands from both existing and potential future users need to be clearly identified and assessed in relation to current and future low flows. The quality of low flows is also important. Return flows are likely to have significant quantities of pollutants. Low flows need to be high enough to ensure sufficient dilution of pollutants discharged from irrigation schemes and other sources such as industry and urban areas. A reduction in the natural river flow together with a discharge of lower quality drainage water can have severe negative impacts on downstream users, including irrigation schemes. Habitats both within and alongside rivers are particularly rich, often supporting a high diversity of species. Large changes to low flows will alter micro-habitats of which wetlands are a special case. It is particularly important to identify any endangered species and determine the impact of any changes on their survival. Such species are often endangered because of their restrictive ecological requirements. An example is the Senegal River downstream of the Manantali Dam where the extent of wetlands has been considerably reduced, fisheries have declined and recession irrigation has all but disappeared. The ecology of estuaries is sensitive to the salinity of the water which may be determined by the low flows. Saline intrusion into the estuary will also affect drinking water supplies and fish catches. Construction of dams has a significant impact on the river downstream. Dams result in reduced sediment load downstream. Because the rate of deposition of sediment is greatly reduced since there is less to deposit but the rate of erosion remains nearly constant, the water flow eats away at the river shores and riverbed, threatening shoreline ecosystems, deepening the riverbed, and narrowing the river over time. This leads to a compromised water table, reduced water levels, homogenization of the river flow and thus reduced ecosystem variability, reduced support for wildlife, and reduced amount of sediment reaching coastal plains and deltas

6. 4. URBAN FLOOD AND COUNTER MEASURES

Flooding in urban areas can be caused by flash floods, or coastal floods, or river floods. Urban flooding is due to a lack of drainage in an urban area. As there is little open soil that can be used for water storage nearly all the precipitation needs to be transport to surface water or the sewage system. High intensity rainfall can cause flooding when the city sewage system and draining canals do not have the necessary capacity to drain away the amounts of rain that are falling. In extreme cases urban flood can results in disasters that set back urban development by years or even decades. It is seen that continuing urbanization process results economic damages cause by floods at the same time floods are increasing in terms of frequency and magnitude. Under these circumstances the sustainable management of urban flood risks is becoming an increasingly challenging task for urban communities and responsible authorities to address.

6.4.1 THE PROBLEM OF FLOODING

The conventional drainage orthodoxy increases the potential for flooding, especially localized flash floods, due to the speed at which the runoff is conveyed. Although it should be noted that a small minority of drainage does incorporate devices to slow down drainage in urban areas, overall the strong emphasis is on moving the runoff from the urban area to the watercourse at high velocity, which causes a number of problems. Firstly, a watercourse of limited capacity is required to manage a potentially high volume of water from across the catchment within a relatively short period of time. If the precipitation is of a very intense nature this may result in the watercourse following its natural processes and utilizing its flood plain. These events are called flash floods and all things being equal are increasingly likely to occur as development and land use patterns distort the natural local hydrological cycle.

Following major flooding episodes we have been warned that the threat of inland flooding will become increasingly common, as both the proposed development needs and the impact of climate change increase the possibility of future problems from rainfall. Furthermore, attention has also been drawn to the possibility that the built environment professions have exacerbated the social and economic impacts by allowing development to take place on flood plains and failing to exert an effective control over surface water. *Fig 4. demonstrates the impact of urbanization on stream flow levels after a precipitation event, detailing how development can increase the risk of flooding by increasing both the volume and speed of runoff directed towards the watercourse.*

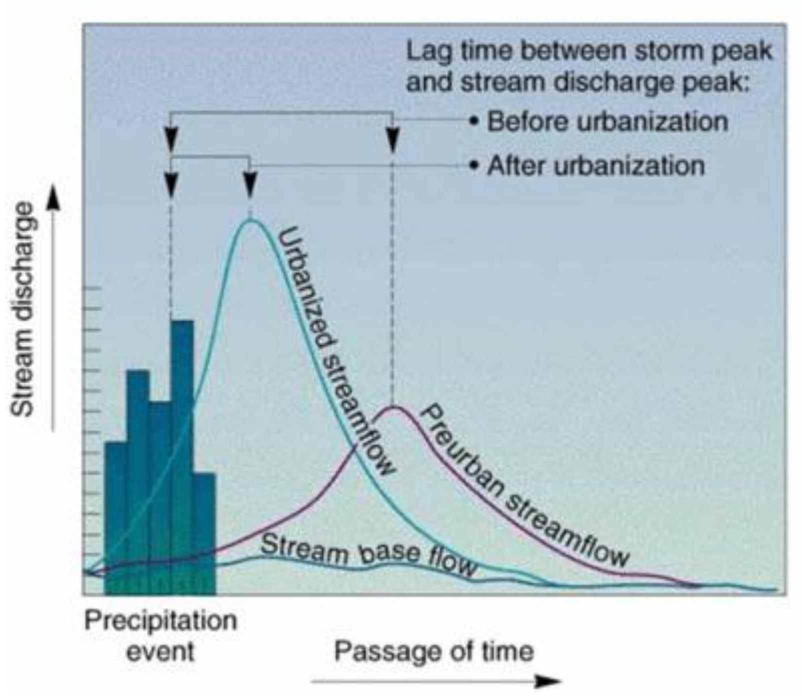

Fig 4: Before and after urbanisation hydrograph. (Source: Christopherson, R. W. (1997). Geosystems:An introduction to physical geography. Saddle River, NJ: Prentice Hall.)

In addition to problems of flash flooding, inundation of a more conventional nature may become more likely due to the current techniques of surface water management. Although time factors may place extra demands on a watercourse, issues of overall capacity become more prevalent as the additional runoff from new development is diverted into the watercourse. Furthermore, from a flooding perspective traditional land use controls focus heavily on spatial factors, such as the restriction of property within a flood plain and have only recently attempted to manage land use, runoff and flooding from a catchments wide viewpoint. However, both the delayed recognition of the catchment-wide linkages and a lack of will and institutional capacity to implement many preventative measures have meant that these recent efforts have as yet only had a peripheral impact. It should be noted however, that the rural sector has recognized that the management of land via watershed control or management is an option to increase the management of runoff, yet the problem of flooding is still exacerbated in some areas by certain intensive agricultural practices and land use management.

The emphasis on transporting the storm water at speed not only increases the potential for localized flash flooding, but also reduces the time available to issue effective flood warnings, and the time available for householders to take preventative measures. Flooding episodes can also have a serious lasting impact on the health of the householders affected, especially if sewage is involved. Health problems can include premature death, various clinical problems, drug and alcohol increase and treatment for depression.

6.4.2 MEASURES TO MITIGATE FLOOD HAZARD

a) **Local Floods**:-Urban drainage systems made up of channels, culverts, sewers etc. should be implement to prevent local floods by conveying stormwater away from vulnerable sites.

b) **Source control measures:** To retain or reduce storm water runoff in order to prevent the exceedance of the drainage system and to mitigate the generation of flood hazards downstream.

c) **Reduction of surface runoff**: The reduction of surface runoff in absolute terms can be achieved by preserve unsealed and greened spaces that increase infiltration, evaporation and transpiration from the catchment areas that contribute to local flooding. Other measures such as retain water through interception, filter the percolating water, recharge groundwater resources, reduce air pollution and improve the urban microclimate

6.5. RIVER ECOSYSTEM CONSERVATION:

Two-thirds of the earth is covered by water. The world's lakes and rivers are the most important freshwater resources. But the amount of fresh water constitutes only 2.53% of the earth's water. On the earth's surface, fresh water is the habitat of a large number of species. These aquatic organisms and the ecosystem in which they live represent a substantial sector of the earth's biological diversity. Aquatic ecosystems contribute to a large proportion of the planet's biotic productivity as about 30% of the world's primary productivity comes from plants living in the, ocean.

River management aims at promoting development of social economy and improving ecosystem through rationally utilizing water and energy resources and preventing natural disasters. Its mainly involves watershed management with focus on soil and water conservation, river regulation through revetment and management of water resources in rivers.

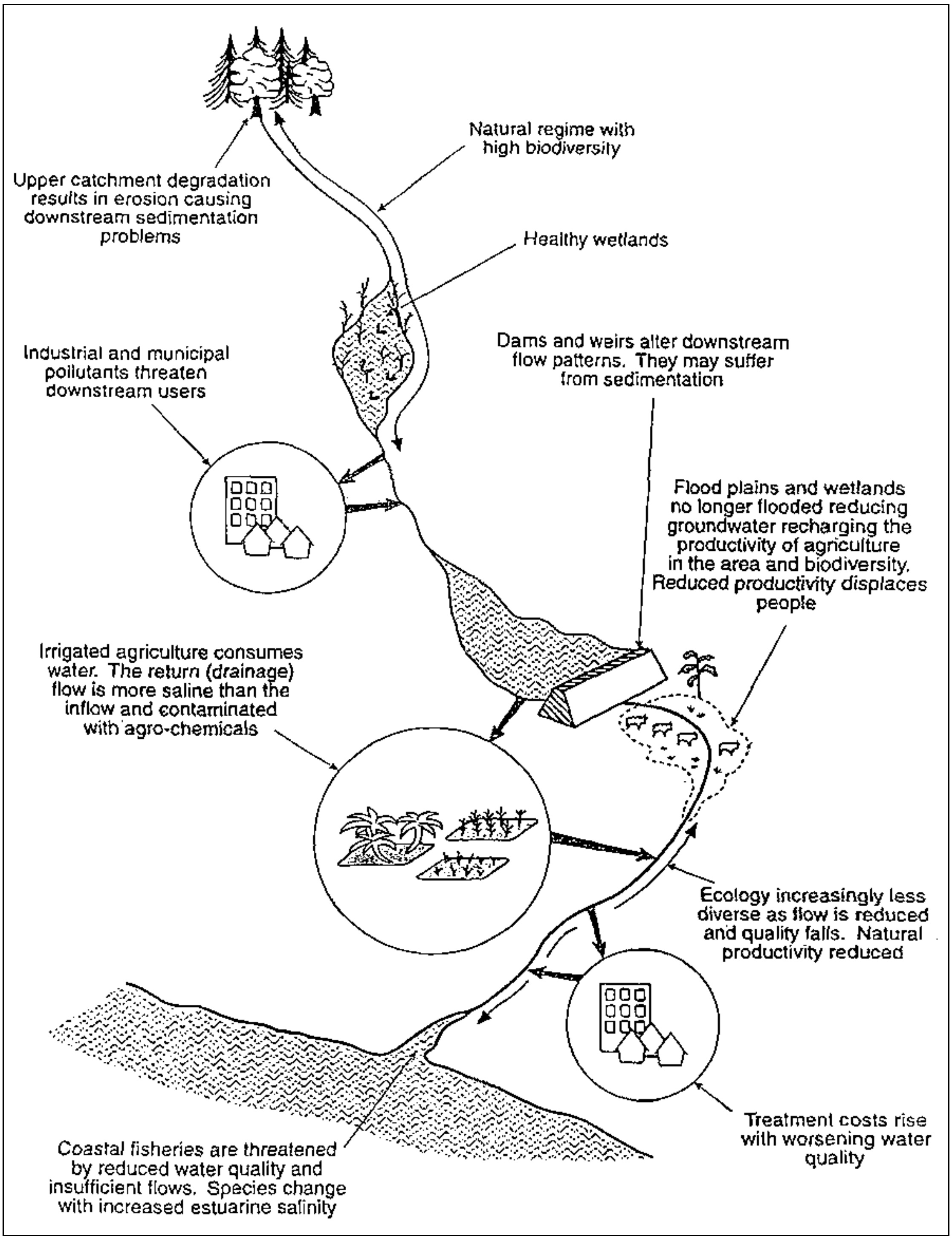

Fig 6: Causes and impacts of reduced water quality in a river system

6.5.1 ISSUES RELATED TO WATER MANAGEMENT:

a) Low standard of flood control

b) Losses of storage capacity in reservoirs and lakes

c) Shrinking of river channels

d) Severe soil erosion in the basins

e) Water pollution in rivers

6.5.2 SOME PRACTICES OF WATER MANAGEMENT HELP IN CONSERVING ECOSYSTEM

a) Flood Control: - Flood is the most devastating, widespread and frequent natural hazard of the world. It is evident that the problem of river folding is getting more and more acute due to human intervention in the flood plain at an increasing scale. Some methods of flood control have been practiced since ancient times. These methods include planting vegetation to retain extra water, terracing hillsides to slow flow downhill, and the construction of floodways. Other techniques include the construction of levees, dikes, dams, reservoirs or retention ponds to hold extra water during times of flooding.

The strategy for flood control must be changed from mainly constructing flood control works to establishing comprehensive flood –control and disaster-reducing system including structural and non-structural measures, technical and socio-economic approaches in order to conserve ecosystem and achieve harmony between mankind and flood.

b) Allocation of water in rivers:- In the allocation of water resources the water demand of the ecosystem should be ensured. It includes water demand for forest, grass and other natural vegetation, water consumption for soil conservation, base flows in rivers to maintain the balance between water and sediment and to preserve biodiversity.

c) Soil and water conservation:- Soil and water conservation should be strengthened, especially for the soil-eroded areas. It helps to conserve ecosystem, agricultural production, reduced sediment entering rivers and increase stream flows in dry seasons.

d) Resettlement for reservoirs:- Selection of the sites for high dams and large reservoirs should take into account the pressure of farmland inundation and population relocation.

e) Control of water pollution in rivers:-The planning, design, construction and operation of water works should be innovated according to eco-friendly principle to reduce their unfavourable impacts on ecosystem.

6. 6 .COASTAL ZONE MANAGEMENT

Central Government have declared the coastal stretches of seas, bays, estuaries, creeks, rivers and back waters which are influenced by tidal action (in the landward side) up to 500 mts. from the High Tide Line (HTL) and the land between the Low Tide Line (LTL) and the HTL as "Coastal Regulation Zone" (CRZ), on 19.2.1991.

6.6.1 CLASSIFICATION CRITERIA AND REGULATORY NORMS

The coastal regulation zone has been classified as CRZ-I, CRZ-II and CRZ-II in the State for the purpose of regulation of the permitted activities.

CRZ-I : Ecological sensitive area and the area between High Tide Line (HTL) and Low Tide Line (LTL). No new construction is permitted except for a few specified most essential activities like support activities for Atomic Energy Plants and Defense requirements, facilities required for disposal of treated effluents and other port related water front activities.

CRZ-II : The area that have been developed up to or close to the shore line which includes the designated urban areas that are substantially built up. Buildings permitted only on the landward side of the existing road (or roads approved in the coastal zone Management Plan of the area) or on the landward side of the existing authorized structures as defined in the notification. Reconstruction of the authorized buildings permitted subject to existing FSI/FAR norms without change in the use.

CRZ-III : The areas that are relatively undisturbed and those which do not belong to either CRZ-I or CRZ-II which includes mainly the rural area and those not substantially built up within designated urban areas. The area up to 200 mts. from HTL is earmarked as "No Development Zone". No construction is permitted within this zone except for repairs to the existing authorized structures without exceeding existing FSI, plinth area and density. Development of vacant plots between 200 and 500 mts. of HTL is permitted in CRZ III for the purpose of construction of dwelling units and hotels/beach resorts subject to certain conditions.

6.6.2 PLANNING APPROACHES

There are five generic strategies for coastal defense:

1. Inaction leading to eventual abandonment
2. Managed retreat or realignment, which plans for retreat and adopts engineering solutions that recognise natural processes of adjustment, and identifies a new line of defence where to construct new defences
3. Hold the line, shoreline protection, whereby seawalls are constructed around the coastlines
4. Move seawards, this happens by constructing new defenses seaward the original ones

5. Limited intervention, accommodation, by which adjustments are made to be able to cope with inundation, raising coastal land and buildings vertically

6.6.3 CONSTRUCTION TECHNIQUES

❖ ***Hard Engineering methods***

- **Groynes:-** Groynes are wooden often made of greenhart, concrete and/or rock barriers or walls perpendicular to the sea. Beach material builds up on the downdrift side, where lflittoral drift is predominantly in one direction, creating a wider and a more plentiful beach, therefore enhancing the protection for the coast because the sand material filters and absorbs the wave energy. Groynes are extremely cost-effective coastal defence measures, requiring little maintenance, and are one of the most common coastal defence structures.
- **Sea Walls:-** Walls of concrete or rock, built at the base of a cliff or at the back of a beach, or used to protect a settlement against erosion or flooding. They are usually about 3-5 metres high. Older style vertical seawalls reflected all the energy of the waves back out to sea, and for this purpose were often given recurved crest walls which also increase the local turbulence, and thus increasing entrainment of sand and sediment. During storms, sea walls help longshore drift.
- **Revetments**:- Wooden slanted or upright blockades, built parallel to the sea on the coast, usually towards the back of the beach to protect the cliff or settlement beyond. The most basic revetments consist of timber slants with a possible rock infill. Waves break against the revetments, which dissipate and absorb the energy. The cliff base is protected by the beach material held behind the barriers, as the revetments trap some of the material.
- **Rock armour:-** Rock armour is large rocks piled or placed at the foot of dunes or cliffs with native stones of the beach. This is generally used in areas prone to erosion to absorb the wave energy and hold beach material.

❖ ***Soft Engineering methods.***

- **Beach Replenishment:-** Beach replenishment or nourishment is one of the most popular soft engineering techniques of coastal defence management schemes. This involves importing sand off the beach and piling it on top of the existing sand. The imported sand must be of a similar quality to the existing beach material so it can integrate with the natural processes occurring there, without causing any adverse effects.

- **Sand dune stabilization:-** Vegetation can be used to encourage dune growth by trapping and stabilising blown sand.
- **Beach Drainage**:- Beach drainage or beach face dewatering lowers the water table locally beneath the beach face. This causes accretion of sand above the drainage system

6.7. SUMMARY

Urban Surface Water Management is a development and implementation of a combination of structural and non-structural measures intended to reconcile the water conveyance and storage function of the depressions, lakes, channels and floodplains with the space and related needs of an expanding urban population. Urban Surface Water Management consists of planning, design, construction and operation functions. It is necessary to remedy existing surface water problems and to prevent the occurrence of new problems Urban Surface Water Management is valuable as a reference for residential, commercial and industrial land developers. This sector of our economy is increasingly expected to understand and meet the ever increasing expectations and requirement of government and society in all aspects of land development including management of the quantity and quality of surface water. The management of rainwater is a complicated issue as differing bodies may be responsible for surface water drainage dependent upon what is being drained and where to. In many areas, due to the nature of sewers rainwater has been managed as an incidental by water companies when managing sewage, rather than as an explicit task, and yet the nature of the impacts would suggest that the consideration of surface water issues should receive a higher recognition. Despite the perceived parallels between land use control and water quality control, the two areas have significant differences as they have been developed independently of each other. Yet, the unsustainable impacts experienced from rainfall appear to present a persuasive case for the re-examination of both the current management techniques and the regulations which sustain them. Moreover, the continuation of these problems indicates that to a large extent surface water management operates outside of conventional environmental control, thus making any reduction or mitigation of the impacts a considerable challenge. High quality technical work coupled with effective public education and interaction programs are needed to raise the

profile of surface water management. Much more emphasis must be placed on preventive rather than remedial efforts, on planning instead of fixing.

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QUESTIONS & ANSWERS

Q.1 What is Urban Surface water Management? How does urbanisation affect surface water?

Ans: Urban Surface Water Management is a development and implementation of a combination of structural and non-structural measures intended to reconcile the water conveyance and storage function of the depressions, lakes, channels and floodplains with the space and related needs of an expanding urban population. Urban Surface Water Management consist of planning, design, construction and operation functions.

Urbanization changes the local natural hydrological cycle as the impermeable surfaces associated with development reduce infiltration and transpiration, and instead divert the precipitation into the drainage system.

Q.2 What is a urban flood? How does urbanisation cause river flooding?

Ans:- Flood caused in urban areas due to lack of drainage facilities & other defects in engineering's work such as defects in the canals built is known as urban floods.

In urban areas, vast areas are covered in impermeable surfaces such as concrete and tarmac, therefore the water that falls on it, can't infiltrate into the soil below, and so runs over the surface. If a sufficient amount of water falls in a certain space of time, the drains will fill and the water will have nowhere to go.

In urban areas, the deforestation activity leads to decline in the amount of water that the trees can absorb through interception and there would lead to more water on the ground surface, aiding possible flooding. As more and more farmlands and wooded areas are converted to urban and suburban areas, the amount of surface area available for water infiltration into the soils decreases. The covering of the ground by roads and buildings does not allow the water to follow its natural path of seeping into the ground so flooding occurs.

Q.3.What is revetment structure?

Ans: Revetment are sloping structures placed on banks or cliffs to absorb the energy of incoming water . In the bank of river, lake they are used to prevent damage during periods of flood or heavy seasonal rains. It is built along an embankment, shoreline or steep facing slope in order to protect it against erosion generated by wave or current action.

PROBABLE QUESTIONS

Q.1. What are the components of Urban Surface Water System?

Q.2 How does urban flooding occur and what are its impact?

Q.3 How does the river ecosystem help in conserving biodiversity?

Q.4. What are Coastal Regulation Zones? Give classification.

Q.5. Enumerate the impact of human activity in river flow system.

UNIT-7: MUNICIPAL SOLID WASTE MANAGEMENT AND ITS IMPACT ON WATER RESOUR

UNIT STRUCTURE

7.0 OBJECTIVES
7.1 INTRODUCTION
7.2 SOUND MATERIAL CYCLE AND 3R
7.2.1 CONCEPT
7.2.2 INCENTIVES FOR 3R
7.3. TRANSBOUNDARY MOVEMENT OF CIRCULATIVE RESOURCE
7.3.1APPROACHES TO FACILITATE IMPORTS AND EXPORTS OF RECYCLABLE RESOURCES
7.3.2 ISSUES RELATED WITH TRANSBOUNDARY MOVEMENT
7.4 IMPACT ON WATER RESOURCES
7.4.1 IMPACT ON GROUNDWATER AND WATER RESOURCES
7.4.2 IMPACT ON MARINE ENVIRONMENT
7.5 COUNTERMEASURES TO MINIMIZE THE IMPACT OF SOLID MANAGEMENT ON WATER RESOURCES
7.5.1. STORM WATER MANAGEMENT
7.5.2. MEASURES
7.6 MODERNIZATION OF MUNICIPAL SOLID WASTE MANAGEMENT
7.6.1. TECHNOLOGIES AVAILABLE FOR PROCESSING, TREATMENT, AND DISPOSAL OF SOLID WASTE
7.6.2. JUDICIAL INTERVENTION TO IMPROVE THE SYSTEM
7.6.3. MUNICIPAL SOLID WASTE (MANAGEMENT AND HANDLING) RULES 2000
7.7 SUMMARY

7.0 OBJECTIVES

After going through this unit, you will be able to:

- Discuss sound material system and 3R
- Discuss transboundary movement of circulative resource
- List the measures to minimise the impact of solid management on water resources
- Describe the modernisation of municipal solid waste management

7.1. INTRODUCTION

❖ ***Municipal Solid Waste***

Garbage is generally referred to "Waste" and is also termed as rubbish, trash, junk, unwanted or undesired material. As per the Municipal Solid Waste (Management &Handling) Rule, 2000 garbage is define as Municipal Solid Waste which includes commercial and residential wastes generated in a municipal or notified areas in either solid or semi-solid form excluding industrial hazardous wastes but including treated bio-medical wastes Municipal solid waste consists of household waste, construction and demolition debris, sanitation residue, and waste from streets. This garbage is generated mainly from residential and commercial complexes.

❖ **Main Sources of Municipal Waste**

❖ **Principal of Municipal Solid Waste Management**

- Development of an insight of impact of solid waste generation, collection, transformation and disposal methods adopted by society on the environment.

- Adoption of new technology which reduces the impact of solid waste on environment.

7.2 SOUND MATERIAL CYCLE AND 3R

7.2.1 CONCEPT

Sound Material-Cycle Society" means a society in which the consumption of natural resources will be conserved and the environmental load will be reduced to the greatest extent possible, by preventing or reducing the generation of wastes, etc. from products, etc., by promoting proper cyclical use of products, etc. when these products, etc. have become circulative resources, and by ensuring proper disposal of circulative resources not put into cyclical use. Whatever the level of waste minimization is, waste will still be produced. Therefore, the proper disposal of solid waste remains essential in promoting the "Sound Material-Cycle Society." (i.e., disposal as wastes, with "wastes" defined as set forth in Article 2, paragraph (1) of the Waste Disposal and Public Cleansing Act (Act No. 137 of 1970).

This definition is closely related to the concept of recyclable resources, which regards usable wastes as resources. In order to establish this Sound Material-Cycle Society (SMS), the government has been setting numerical targets for domestic economic activities regarding resource productivity, cyclical use rate, and final disposal amounts through a governmental plan (the Fundamental SMS Plan). The Plan is annually reviewed at a council consisting of academics, representatives from industrial sectors, local governments, consumers, and labour unions. As economic activities become global and the transboundary movement of recyclable resources increases, however, it is becoming increasingly important to establish an SMS beyond national boundaries. Considering that recyclable resources have a wide range of characteristics in terms of their economic value and toxicity, establishing an international SMS necessitates strategy based on proper treatment of various recyclable resources through understanding the current situation surrounding recyclable resources and international collaboration based on the concept of SMS shared among countries.

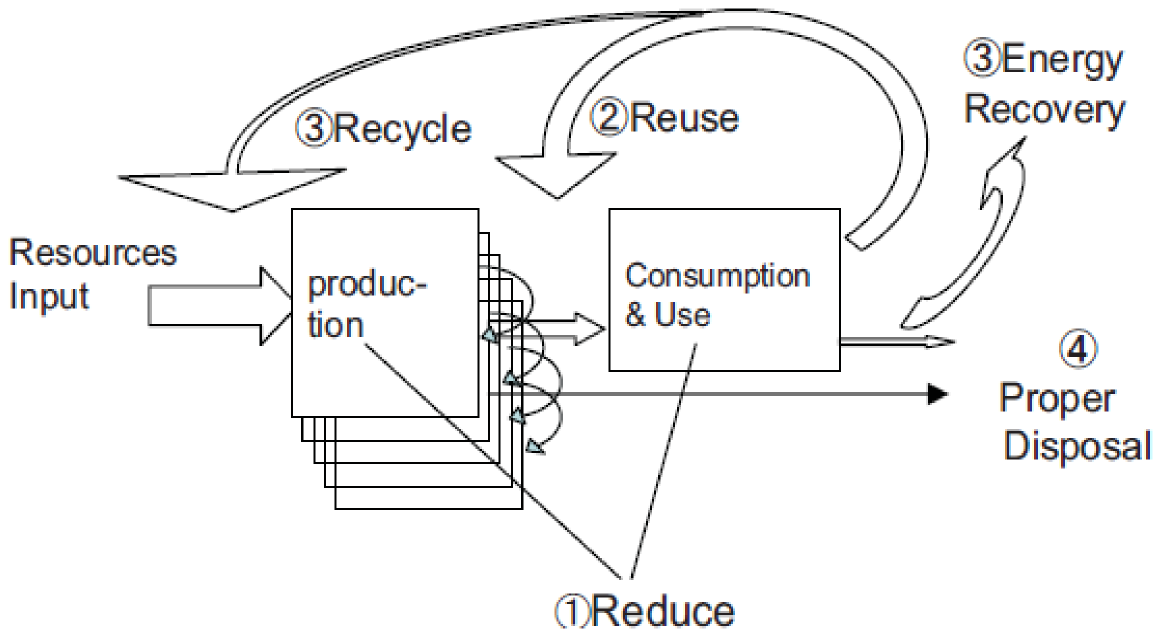

Fig 1: Promoting the 3Rs for a Sound Material-Cycle Society

Fig 2: Fundamental Plan For Establishing a Sound Material-Cycle Society

Image of a Sound Material-Cycle Society

Manufacturing : Dfe (Design for Environment), long life products, lease & rental
Waste management: cyclical use, appropriate disposal system

Quantative targets FY2000-

Efforts Required of Entities

1. Targets on Indicators Based on Material Flow Accounts

a) Resource productivity
b) Cyclical Use Rate
c) Final Disposal Amount

2. Targets for Indices Related to Efforts

a) Reducing the quantity of municipal solid waste
20% reduction of garbage discharged from households per person per day compared with FY2000

b) Promoting sound material-cycle related businesses
Doubling the size of the related market and the number of related jobs compared with FY1997

- **National Government**
  Fostering partnerships among stakeholders
- **Citizens**
  Changing their lifestyle
- **NPOs and NGOs**
  Promotion of their activities
- **Business Organizations**
  Promoting the "3Rs" based on EPR (Extended Producer Responsibility)
- **Local Governments**
  Enforcing laws and regulations; acting as coordinators

3R- The **waste hierarchy** refers to the **3 R** of ***reduce, reuse, recycle***, which classify **waste management** strategies according to their desirability. The Rs are meant to be a hierarchy, in order of importance. The aim of the waste hierarchy is to extract the maximum practical benefits from products and to generate the minimum amount of waste.

The Rs are categories at the top of our disposal options. They include a variety of initiatives for disposing of discards.

- ❖ **Reduce** - to buy less and use less. Incorporates common sense ideas like turning off the lights, rain barrels, and taking shorter showers, but also plays a part in composting/grass cycling (transportation energy is reduced), low-flow toilets, and programmable thermostats. Includes the terms Re-think, Recycle, Carpool, Efficient, and Environmental Footprint.

- ❖ **Reuse** - elements of the discarded item are used again. Initiatives include hand-me-downs, garage sales, quilting, travel mugs, and composting (nutrients). Includes the terms laundry, repair, regift, and up cycle.
- ❖ **Recycle** - discards are separated into materials that may be incorporated into new products. This is different from Reuse in that energy is used to change the physical properties of the material. Initiatives include Composting, Beverage Container Deposits and buying products with a high content of post-consumer material. Within recycling there is distinction between two types.

7.2.2 INCENTIVES FOR 3R

The 3R's of reduce, reuse and recycle have been considered to be a base of environmental awareness and a way of promoting ecological balance through conscious behaviour and choices. It is generally accepted that these patterns of behaviour and consumer choices will lead to savings in materials and energy which will benefit the environment.

In this context it may be enquired whether certain economic instruments may be considered to further strengthen these behaviours and choices. An example may be to reduce the sales tax or value added tax on goods that are made by recycling used materials, such as paper, plastics, glass, metals. Another example may be to reduce sales tax or value added tax on second-hand goods, which may include books, clothes, house-hold gadgets, bicycles, cars and automobiles, office equipment, medical and scientific equipment, telecommunication equipment, agricultural equipment, industrial and manufacturing equipment, boats, ships, trains and trams, aeroplanes, oil rigs, and so forth.

An additional approach may be to reduce the interest rates on the financial loans, which companies avail of, for their commercial activities in the recycling, re-use and resale of used material and equipments. It is plausible that this may have a significant impact on consumer behaviour, and may strengthen those sections of the economy and trade that are associated with such goods and services. Additionally, this would be consistent with supporting consumer behaviour and choices that are beneficial for the environment and for the economy

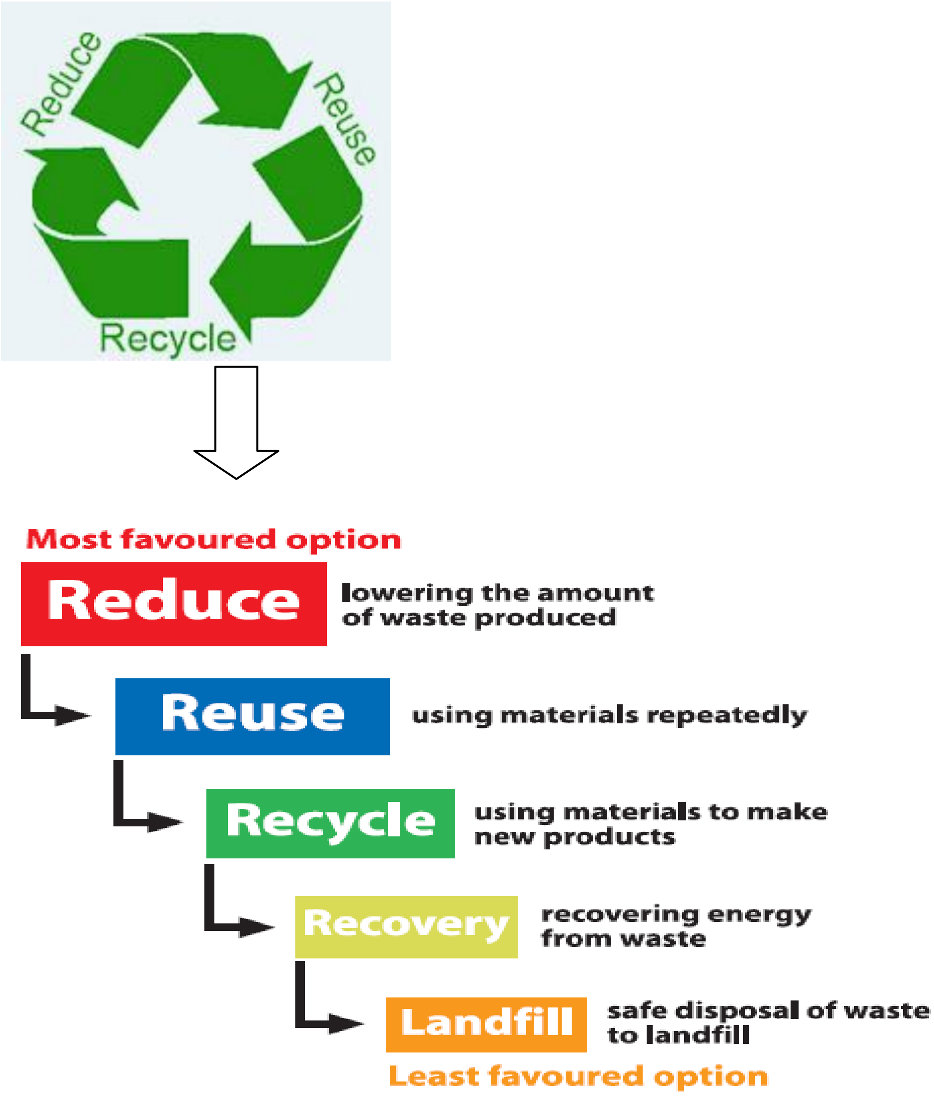

Fig 3: ***Waste Hierarchy***

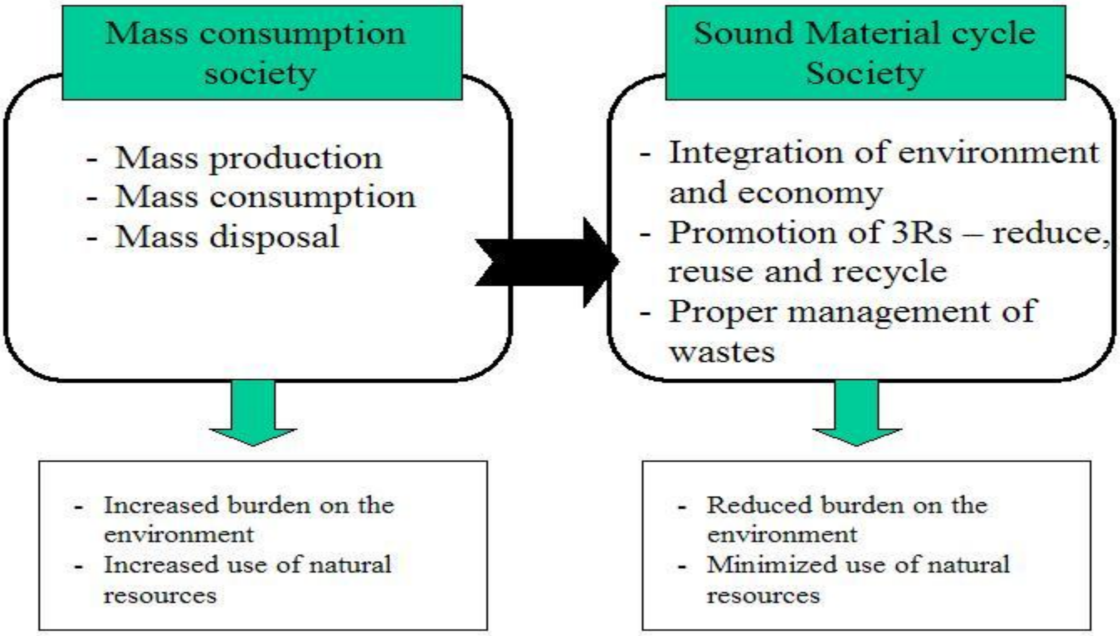

Fig: 1 ***The basic idea of a 3R approach is a shift away from a mass consumption society to one that is based on a life-cycle, sound material flow society***

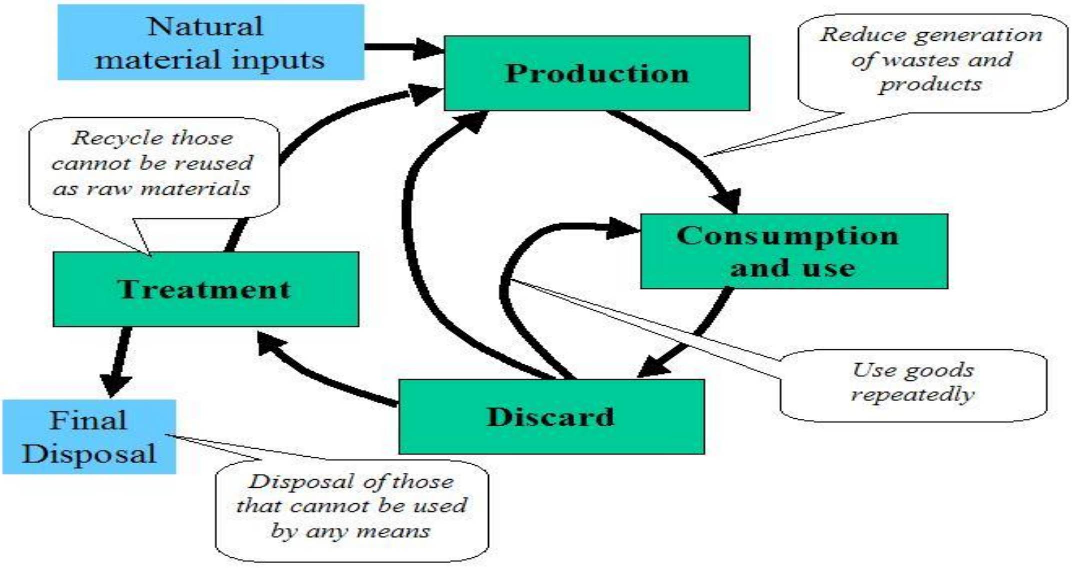

Fig 4 : ***3R concept within the production cycle***

7.3. TRANSBOUNDARY MOVEMENT OF CIRCULATIVE RESOURCE

Global, or transboundary, resource circulation involves the movement of recyclable resources from developed to developing countries.

7.3.1 APPROACHES TO FACILITATE IMPORTS AND EXPORTS OF RECYCLABLE RESOURCES

Two approaches should be included toward facilitating the import and export of recyclable resources:

1) The first approach is the construction of an international database of hazardous waste to be shared throughout Asia.
2) The second is a study on reducing trade barriers against remanufactured goods with a view to positive impacts on preservation of the environment.

Transboundary movement of circulative resource should facilitate in a way that protects the environment. It is important to advance the policy measures that can promote the effective utilization of circulative resource through their transboundary movement, focusing on the economic values of circulative resource on the condition that environmental pollution will be prevented and its environmental impact be minimized.

At the Ministerial Conference on the 3R Initiative, the importance of sharing experiences between developed and developing countries and of establishing common criteria was recognized for distinguishing regulated items from wastes that will become recyclable resources for recycling.

Furthermore, using its highly developed 3R technologies, developing countries will need to study policy measures for trade facilitation that contribute to environmental preservation, including measures regarding the acceptance of hazardous recyclable resources that cannot be appropriately treated . Such approaches should be based on the standpoints of promoting the 3Rs internationally, reducing the environmental load in the entire Asian region, and the preservation of Japan's scarce valuable resources. It should be mentioned that the promotion of the abovementioned approaches will require full understanding of the needs in developing countries, consideration of impacts on domestic waste treatment and recycling systems, and consistency with the global trade system under the World Trade Organization (WTO) and the Economic Partnership Agreement (EPA), among others. Furthermore, it is thought that approaches toward establishment of both domestic and international SMSs can be further enhanced through synergetic effects from policy measures in other areas of environmental policy, such as measures to mitigate climate change.

7.3.2 ISSUES RELATED WITH TRANSBOUNDARY MOVEMENT

- The first issue involves the fact that, in terms of finance and institutions, systems for the appropriate treatment of waste cannot be put in place quickly enough to keep up with the growth in waste generation, the diversification of waste characteristics, and the increase of imports of recyclable resources, particularly in developing countries. There are concerns that this situation is leading to environmental pollution. A related problem here is regulation of what is often called the "informal sector," in which businesses that are not officially recognized handle waste.

❖ The second issue involves resource outflow due to the exporting of recyclable resources and its impact on domestic waste management and recycling systems. Japan does not have any particular trade regulations pertaining to the transboundary movement of nonhazardous wastes such as plastics. Consequently, the amount of such waste exported to China and other East Asian countries has been increasing in recent years. Such transboundary movements of recyclable resources based on market principles leads to stagnation and hollowing-out of the domestic recycling industry..

❖ The third issue involves trade in used or recycled products. Used products – such as home appliances and vehicles can be used cheaply in importing countries. While this practice on the one hand represents effective use of resources, some people claim that it should be classified as the transboundary movement of waste. One of the reasons is that such items become waste after a relatively short period of time. The other reason is that this may interfere with industrial development in developing countries. However, while it cannot be denied that such issues are important, the transboundary movement of recyclable resources may make reuse and recycling efforts cheaper and more efficient.

7.4. IMPACT ON WATER RESOURCES

The migration of solid waste from disposal sites can also contaminate water resources such as rivers, streams, ponds and wetlands. This occurs directly if the water resource is near a dumpsite or indirectly if contaminated ground water moves through the water cycle. This contaminated water cannot be used for drinking or any other domestic application, therefore affecting water availability and the cost of providing safe drinking water to residents and visitors Solid waste impacts water quality through the release of leachate from landfills into water sources. As water comes in contact with decomposing solid waste, it will dissolve together with soluble inorganic and organic wastes producing polluted liquid known as leachate or waste juice. The concentration of leachate increases as it seeps into deeper layers of the landfill; this contributes to the light brown/black colour of leachate and it's horrible stench). It has a high polluting potential impact due to its high concentrations of organic contaminants and high ammoniac nitrogen. Once leachate is discharged into water bodies or/and aquatic environment, it will have an acute and chronic impact. If toxic metals are present, this can lead to chronic toxin accumulation in organisms that depend on it and may consequently affect humans if we feed on these organisms (e.g. fish, prawns, crabs etc.)

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7.4.1 IMPACT ON GROUNDWATER AND WATER RESOURCES

Improper disposal of wastewater can directly impact the quality of an area's groundwater and water resources and since their movements are dynamic, contaminants can spread far beyond the immediate pollution area. In developing countries, the presence of faecal matter in surface waters is common because of improper/incomplete treatment facilities. Faecal contamination of surface and groundwater sources has serious health implications for residents and tourists since faecal bacteria can cause diarrhoea and dysentery.

7.4.2 IMPACT ON MARINE ENVIRONMENT

Poorly treated wastewater significantly impacts marine environments:

- Suspended solids may cause excessive turbidity and shading of sea grasses, produce sedimentation, damaging benthic (bottom layer) habitats and affect anaerobic conditions at the sea bottom.
- High BOD (Biochemical Oxygen Demand) levels may cause severe oxygen depletion, especially in shallow and enclosed aquatic systems such as estuaries that are ideal breeding grounds for various marine species. BOD results in fish deaths and anaerobic conditions which release bad odours
- Adverse nutrient levels cause algal blooms, resulting in the death of coral and sea grasses and eutrophication leading to severe oxygen depletion which kills living resources.
- Many toxic materials and suspected carcinogens and mutagens can concentrate in shellfish and fish tissue, putting humans at risk when they eat them.
- Metals in specific forms can be toxic to humans and various marine organisms, especially shellfish which is vulnerable, in areas with highly contaminated sediment layers.
- Fats, oil and grease that float on the water surface interfere with natural aeration. They are possibly toxic to aquatic life, destroy coastal vegetation and reduce recreational use of waters and beaches.

7.5. COUNTERMEASURES TO MINIMIZE THE IMPACT OF SOLID MANAGEMENT ON WATER RESOURCES

7.5.1 STORM WATER MANAGEMENT

Best practices for storm water management limit the disruption of natural water hydrology by reducing impervious cover, increasing onsite infiltration, and reducing or eliminating pollution from storm water runoff. Green goals used in industry-based programs such as LEED can be applied to cleanup construction; sample targets include:

- Implementing a management plan that results in a 25% decrease in runoff at sites with impervious cover exceeding 50%,
- Capturing 90% of the site's average annual rainfall, and

- Removing 80% of the average annual total load of suspended solids based on pre-construction monitoring reports.

7.5.2 MEASURES

- Conservation designs for minimizing runoff generation through open-space preservation methods such as cluster development, reduced pavement widths, shared transportation access, reduced property setbacks, and site fingerprinting during construction,
- Engineered structures or landscape features helping to capture and infiltrate runoff, such as basins or trenches, porous pavement, disconnected downspouts, and rain gardens or other vegetated treatment systems,
- Storage of captured runoff in rain barrels or cisterns, green (vegetated) roofs, and natural depressions such as landscape islands,
- Conveyance systems to route excess runoff through and off the site, such as grassed swales or channels, terraces or check dams, and elimination of curbs and gutters.
- Reclaim treated water for beneficial use or re-inject it into an aquifer for storage, rather than discharging to surface water. Where treatment processes result in wastewater discharge to surface water or municipal sewage treatment plants (publicly owned treatment works), green remediation strategies build on criteria of EPA's effluent guidelines. The guidelines rely on industry-proven performance of treatment and control technologies. Best practices for wastewater treatment, including any resulting in pollutant discharge significantly below regulatory thresholds, can be recorded in associated permits for national pollutant discharge elimination systems.
- One goal might be to replace 50% of the potable water used at a site with non-potable water. Targets can be met by using high efficiency water fixtures, valves, and piping, and by reusing storm water and grey water for applications such as mechanical systems and custodial operations.

7.6. MODERNIZATION OF MUNICIPAL SOLID WASTE MANAGEMENT

7.6.1 TECHNOLOGIES AVAILABLE FOR PROCESSING, TREATMENT, AND DISPOSAL OF SOLID WASTE

The main technological options available for processing/ treatment and disposal of MSW are composting, vermicomposting, anaerobic digestion/biomethanation, incineration, gasification and pyrolysis, plasma pyrolysis, production of Refuse Derived Fuel (RDF), also known as pelletization and sanitary landfilling/landfill gas recovery

- ***Composting***

Composting is a technology known in India since times immemorial. Composting is the decomposition of organic ***Solid Waste Management*** matter by microorganism in warm, moist, aerobic and anaerobic environment. Farmers have been using compost made out of cow dung and other agro-waste. The compost made out of urban heterogeneous waste is found to be of higher nutrient value as compared to the compost made out of cow dung and agro-waste. Composting of MSW is, therefore, the most simple and cost effective technology for treating the organic fraction of MSW. Composting is suitable for organic biodegradable fraction of MSW, yard (or garden) waste/waste containing high proportion of lignocelluloses materials, which do not readily degrade under anaerobic conditions, waste from slaughterhouse and dairy waste. This method, however, is not very suitable for wastes that may be too wet and during heavy rains open compost plants have to be stopped. Land required for open compost plants is relatively large. Also, issues of methane emission, odour, and flies from badly managed open compost plants remain. At the operational level, if waste segregation at source is not properly carried out there is possibility of toxic material entering the stream of MSW. It is essential that compost produced be safe for application. Standardization of compost quality is, therefore, necessary. The MSW (Management and Handling) Rules 2000 (MSW Rules 2000) have specified certain limits to acceptable percentage of heavy metals in compost produced from MSW and a mechanism is put in place to ensure that the same are strictly implemented.

❖ ***Vermi Composting***

Vermi-compost is the natural organic manure produced from the excreta of earthworms fed on scientifically semi-decomposed organic waste. A few vermi composting plants generally of small size have been set up in some cities and towns in India, the largest plant being in Bangalore of about 100 MT/da capacity. Normally, vermi-composting is preferred to microbial composting in small towns as it requires less mechanization and it is easy to operate. It is, however, to be ensured that toxic material does not enter the chain which if present could kill the earthworms.

❖ ***Waste to Energy***

Waste to energy (WTE) projects has been proven worldwide, its viability and sustainability is yet to be to be demonstrated and established in the country. WTE projects generally involve higher capital investment and are more complex when compared to other options of waste disposal, but as pointed by Ministry of Non-Conventional Energy Sources (MNES), gains in terms of waste reduction, energy, etc. are also higher. Such plants are financially viable in developed countries mainly because of the tipping fees/gate fees charged by the facility for the service of waste disposal, in addition to its revenue income from power sales. It is thereafter the sole responsibility of the facility operator to treat and dispose of the accepted waste as per statutory requirements.

❖ ***Anaerobic Digestion and Biomethanation***

Biomethanation is a comparatively well-established technology for disinfections, deodorization and stabilization of sewage sludge, farmyard manures, animal slurries, and industrial sludge. Its application to the organic fraction of MSW is more recent and less extensive. It leads to bio-gas/power generation in addition to production of compost (residual sludge). This method provides a value addition to the aerobic (composting) process and also offers certain other clear advantages over composting in terms of energy production/consumption, compost quality and net environmental gains.

❖ ***Incineration***

This method, commonly used in developed countries is most suitable for high calorific value waste with a large component of paper, plastic, packaging material, pathological wastes, etc.

It can reduce waste volumes by over 90 per cent and convert waste to innocuous material, with energy recovery. The method is relatively hygienic, noiseless, and odourless, and land requirements are minimal. The plant can be located within city limits, reducing the cost of waste transportation.

❖ ***Pyrolysis/Gasification, Plasma Pyrolysis Vitrification (PPV)/Plasma Arc Process***

Pyrolysis gasification processes are established for homogenous organic matter like wood, pulp, etc., while plasma pyrolysis vitrification is a relatively new technology for disposal of particularly hazardous wastes, radioactive wastes, etc. Toxic materials get encapsulated in vitreous mass, which is relatively much safer to handle than incinerator/gasifier ash. These are now being offered as an attractive option for disposal of MSW also. In all these processes, besides net energy recovery, proper destruction of the waste is also ensured. These processes, therefore, have an edge over incineration.

❖ ***Production of Refuse Derived Fuel (RDF) or Pelletization***

It is basically a processing method for mixed MSW, which can be very effective in preparing an enriched fuel feed for thermal processes like incineration or industrial furnaces. The RDF pellets can be conveniently stored and transported long distances and can be used as a coal substitute at a lower price. As pelletization involves significant MSW sorting operations, it provides a greater opportunity to remove environmentally harmful materials from the incoming waste prior to combustion.

❖ ***Sanitary Landfills and Landfill Gas Recovery***

Sanitary landfills are the ultimate means of disposal of all types of residual, residential, commercial and institutional waste as well as unutilized municipal solid waste from waste processing facilities and other types of inorganic waste and inerts that cannot be reused or recycled in the foreseeable future. Its main advantage is that it is the least cost option for waste disposal and has the potential for the recovery of landfill gas as a source of energy, with net environmental gains if organic wastes are landfilled. The gas after necessary cleaning, can be utilized for power generation or as domestic fuel for direct thermal applications1. Highly skilled personnel are not required to operate a sanitary landfill.

7.6.2. JUDICIAL INTERVENTION TO IMPROVE THE SYSTEM

A public interest litigation was filed by Almitra H. Patel and another in The Supreme Court of India in the year 1996 (Special Civil Application No. 888 of 1996) against the Government of India, all state governments and several municipal authorities in the country alleging that they have failed to discharge their obligatory duty to manage municipal solid waste appropriately. The Supreme Court set up an Expert Committee, which deliberated on the issue after consulting 300 municipal authorities in class I cities and other stakeholders by holding regional workshops in Mumbai, Delhi, Chennai, and Kolkata. It submitted its report to the Supreme Court in March, 1999 making detailed recommendations, which were circulated to all the class I cities and various stakeholders through the Government of India with interim directions for implementation. To ensure compliance, the principal recommendations of the Supreme Court appointed Committee have been incorporated in the Municipal Solid Waste (Management andHandling) Rules 2000 notified by the Ministry of Environment and Forest in September 2000.

7.6.3. MUNICIPAL SOLID WASTE (MANAGEMENT AND HANDLING) RULES 2000

The Ministry of Environment and Forest notified Municipal Solid Waste (Management and Handling) Rules 2000 after widely circulating the draft rules in 1999 inviting objections and suggestions if any and made it mandatory for all municipal authorities in the country, irrespective of their size and population, to implement the rules. To improve the systems the following seven directives are given.

- Prohibit littering on the streets by ensuring storage of waste at source in two bins; one for biodegradable waste and another for recyclable material.
- Primary collection of biodegradable and non-biodegradable waste from the doorstep, (including slums and squatter areas) at pre-informed timings on a day-to-day basis using containerized tricycle/handcarts/pick up vans.
- Street sweeping covering all the residential and commercial areas on all the days of the year irrespective of Sundays and public holidays.

- Abolition of open waste storage depots and provision of covered containers or closed body waste storage depots.
- Transportation of waste in covered vehicles on a day to day basis.
- Treatment of biodegradable waste using composting or waste to energy technologies meeting the standards laid down.
- Minimize the waste going to the land fill and dispose of only rejects from the treatment plants and inert material at the landfills as per the standards laid down in the rules.

7.7. SUMMARY

A solid waste management (SWM) system includes the generation of waste, storage, collection, transportation, processing and final disposal. This study will focus on disposal options for MSW in India. Agricultural and manufactured products of no more value are discarded as wastes. Once items are discarded as waste, they need to be collected. Waste collection in most parts of the world is centralized and all kinds of waste generated by a household or institution are collected together as mixed wastes.

Solid waste management (SWM) is a basic public necessity and this service is provided by respective urban local bodies (ULBs) in India. SWM starts with the collection of solid wastes and ends with their disposal and/or beneficial use. Proper SWM requires separate collection of different wastes, called source separated waste collection. Source separated collection is common in high income regions of the world like Europe, North America and Japan where the infrastructure to transport separate waste streams exists. Most centralized municipal systems in low income countries like India collect solid wastes in a mixed form because source separate collection systems are non-existent. Source separated collection of waste is limited by infrastructure, personnel and public awareness. A significant amount of paper is collected in a source separated form, but informally. In this report, unmixed waste will be specially referred to as source separated waste, in all other cases municipal solid waste (MSW) or solid waste would refer to mixed wastes.

UNIT-8: CLIMATE CHANGE AND URBAN WATER USE

UNIT STRUCTURE

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8.0 OBJECTIVES

After going through this unit, you will be able to:

- discuss the impact of climate change on urban water resources
- see the direct and induced change in water use due to urbanization and global warming
- list the consequences of urban heat island

8.1 INTRODUCTION

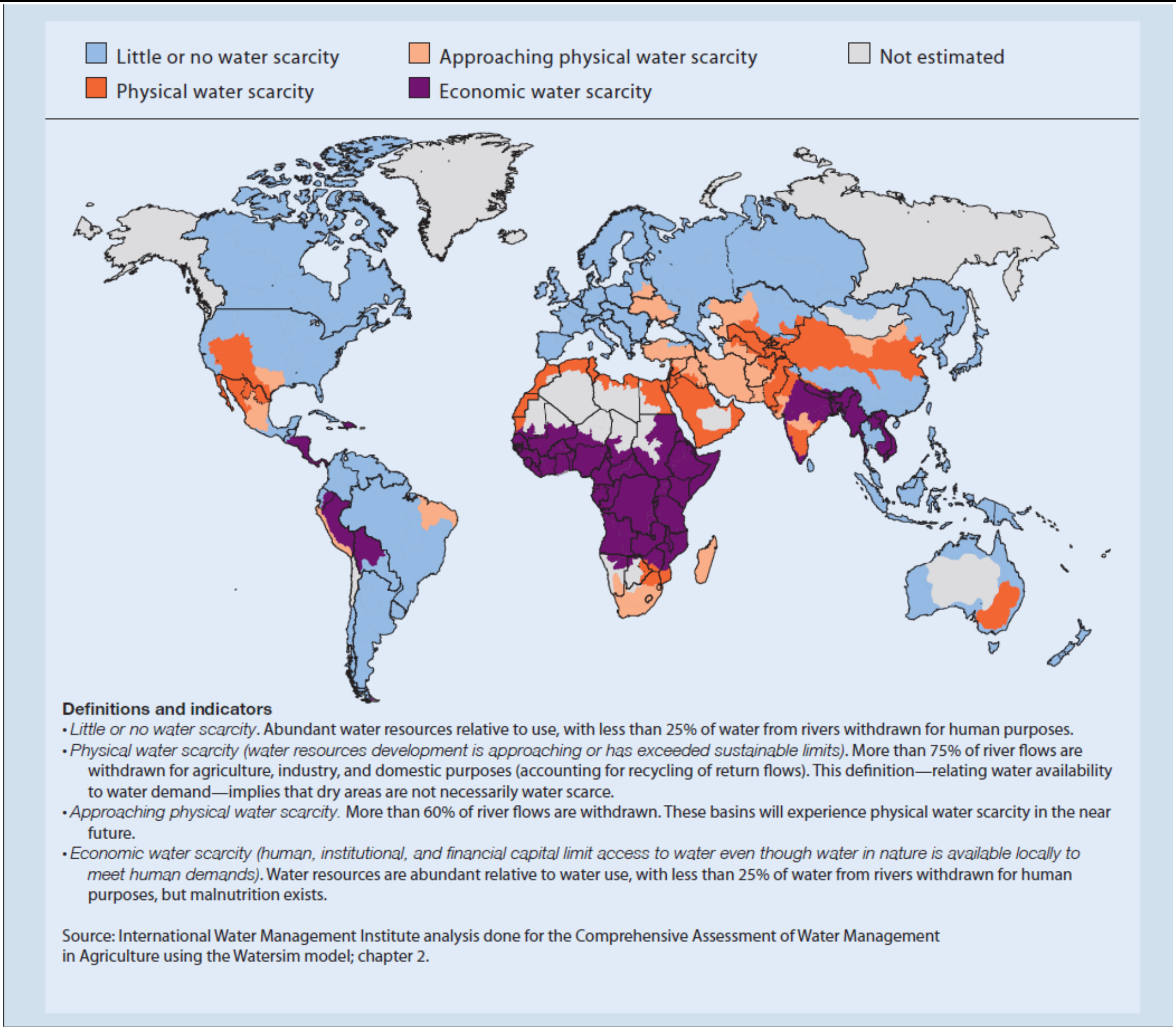
Climate change will affect the water resource base for many water utilities. Higher temperatures and reduced precipitation levels will cause shortages in available supply due to slower replenishment rates of groundwater resources and/or reduced availability of surface water. Rising seawater levels and inland flooding will cause land inundation and blockages in natural drainage structures. These effects will be even more difficult to manage for those water utilities that are unprepared and/or financially weak.

General agreement among various climate change models suggests that surface water runoff will decrease by 10 percent to 30 percent in the Mediterranean, southern Africa, the western USA, and northern Mexico. The impact of climate change will lead to variations in the seasonality of river flows especially where winter precipitation comes as snow; rapid melting of glaciers and snow will lead to an *increase* in winter flow and thus a *decrease* in summer flow. The European Alps, Himalayas, North America, Andes in Latin America, Russia, Scandinavia and Baltic regions will face this phenomenon [IPCC, 2007]. Due to melting glaciers in the Himalaya-Hindu-Kush region nearly one billion people in India, Bangladesh, Pakistan and China will be affected. Glaciers in the Andes have shrunk by 20 percent since 1970, which creates serious implications for water resources *and* hydro-power generation in countries like Colombia, Ecuador, Peru, Bolivia, Chile and Argentina [Vergara, 2007].

An important milestone was passed this year when the fraction of the world's population living in cities exceeded 50%. This shift from the countryside to urban areas is certain to continue and, for many, the destination will be large cities. Already there are over 400 cities with populations greater than one million inhabitants and twenty cities with populations greater than ten million inhabitants.

At the time of independence more than 75% of population was village based and the country was an agriculture-oriented nation. With the industrialization and development, more and more people migrated towards the big cities. New cities which were small also developed and became large towns based on industries. Such growth caused large-scale changes in demographic patterns; for example a city like Pune has grown from small town of 1.5 lakh population in 1901 to population of 42 lakh in 2001.

A demographic shift is taking place at a remarkable pace across the developing world that will likely see another two billion residents added to urban area in the next twenty years, with the urban populations of South Asia and Africa doubling during that time. As a city's population grows there is a need to expand the capacity of existing water sources to meet the increasing demand. In many cases cities have to access supplemental sources of water supply (ground water, desalination, conveyance from distant areas) in order to sustain residential, industrial and agricultural water consumption levels. Increased urban water demand generates pressure on existing infrastructure and demands substantial investments for expansion. The problem is even more severe in developing countries where limited financial resources, often stemming from low efficiency and subsidized tariffs, reduce the ability of water utilities to address priorities to improve service delivery.



(Source: UNEP/GRID, 2008)

An example of this is Rawalpindi, Pakistan where at present 70 percent of the current population is served either through the piped network or tanker delivery. However only 35 percent of the service area is covered by a sewerage system and none of the collected sewage is treated. The city is witnessing a population growth of 4.29 percent per annum. Connecting 100 percent of the population with water supply and sewage would need significant investments, which is currently beyond the financial capacity of the water utility as well as additional technical expertise [Pintz and Johnson, 2006].

A similar problem can be seen in case of Dhaka, Bangladesh .The Dhaka Metropolitan Area (DMA) is one of the fastest growing megacities in the world with a total population estimated at over 12 million. Of this, about 8.6 million people live in the formal city and about 4 million in slums. The elevation in Dhaka ranges between 2 and 13 meters above sea level implying that even a slight rise in sea level would likely engulf large parts of the city. High urban growth rates and urban population densities make Dhaka susceptible to human-induced and environmental disasters. Inland flooding due to extreme rainfall events and coastal flooding caused by sea level rise are expected to be more frequent as a result of climate change. The problems associated with recurrent flooding are compounded by poor quality housing and overcrowding as nearly 60 percent of the city's slums have poor or no drainage. Water supplies also become contaminated during floods, as pipes in slum areas are likely to be damaged or to leak. The situation worsens when floodwater in slums mixes with raw sewage and breeds water-borne diseases(UN-Habitat, 2008).

8.2 IMPACTS OF CLIMATE CHANGE ON URBAN WATER RESOURCES

According to IPCC (2007a) runoff and water availability are projected to have a regionally differentiated behaviour by 2050: increases by 10-20% at higher latitudes and in some areas in the wet tropics (e.g. populous areas in tropical E and SE Asia); decreases by 10-30% over areas in the mid-latitudes and dry tropics, some of which are presently water-stressed. Increases in the frequency and severity of floods and droughts as well as declines in water quantities stored in glaciers and snow cover are also expected.

All these changes will have profound consequences for cities in terms of both water resources and water systems. With profound implications for the availability of water resources, during the last century, mean precipitation in all four seasons of the year has tended to decrease in all the world's main arid and semi-arid regions: northern Chile, the Brazilian northeast and northern Mexico, west Africa and Ethiopia, the drier parts of southern Africa, and western China (Folland et al. quoted in Wilbanks and Romero Lankao et al. 2007). If these trends continue, water resource limitations will become more severe in precisely those parts of the world where they are already most likely to be critical (Rhode, (1999) quoted in Wilbanks and Romero Lankao et al. 2007). Yet it is also likely that together with reduced annual average rainfall, greater extremes in individual rainfall events will mean that overall flood hazard may not be reduced, even in these regions.

Many water basins will get less precipitation constraining the availability of freshwater sources for urban centers. These will be especially hard for growing cities and large cities that already face serious problems to obtain sufficient freshwater supplies - e.g., urban centers along the U.S. Mexican border and Mexico City; in central, south, east and southeast Asia; and in Africa (Parry, Canziani and Palutikof *et al.* 2007, Muller 2007 quoted in Satterthwaite et al. 2007), already suffering water scarcity or water stress –especially affecting poorer groups. The cities of these countries already face governance failures to manage water resources and services, independent of climate change. For example, around half of Africa's and Asia's urban populations lack provision for water and sanitation to a standard that is healthy and convenient. For Latin America and the Caribbean, more than a quarter lack such provision (UN-Habitat 2003). Therefore, any action to increase the adaptive capacity of urban water supplies in those cities has to be done keeping in mind the massive deficiencies in provision and the very large backlog in basic infrastructure that needs to be addressed.

Climate variability and change affect urban water supply and sewage systems in different ways (Wilbanks and Romero-Lankao et al. 2007). Increased temperatures can affect water demand for drinking, for cooling systems and for garden watering. Regional water supplies can be reduced through changes in precipitation patterns, reductions in river flows, falling ground water tables and, in coastal areas, saline intrusion in rivers and ground water. For example, detected declines in glacier volumes in parts of Asia and Latin America will reduce river flows at key times of the year. For cities located in the Andean valleys and the Himalaya-Hindu-Kush region this will mean substantial impacts on water flows (and also reductions in hydro-electric generation, Magrin and Gay et al. 2007, Vergara 2005).

Water supplies are designed to have a life of many years, so as to respond to future growth in demand and to variations in seasonal and day-long demand. Thus, if appropriately designed and if working effectively, most water supply systems are quite able to cope with the relatively small changes in mean temperature and precipitation that are expected for many decades (Wilbanks and Romero Lankao et al. 2007). However, different phenomena might coalesce to negatively affect the coping capacity of urban water systems.

These phenomena include:

a) The increased competition for freshwater resources between urban enterprises and consumers on the one hand and agriculture on the other, with agriculture still the largest water user within virtually all national economies.

b) The fact that many major urban centers (e.g. Los Angeles and Mexico City) have imported freshwater from increasingly distant watersheds, as local surface and groundwater sources no longer meet the demand for water, or as they become depleted or polluted. Many coastal cities have depleted their local groundwater supplies to the point where saline intrusion limits freshwater supplies (UN-Habitat 2006).

c) The dramatic impacts on water supplies likely to occur, under extremes of weather (e.g. heavier rainfall or rainfall that is more prolonged than in the past) that could result from climate change, particularly *drought* and *flooding*.

Droughts have diverse implications for urban water systems and especially for the urban poor: they constrain water availability; they might result, through complex causal chains, in infectious diseases, respiratory diseases and other health problems. For instance, the drought affecting the western and central part of the Amazon region, especially Bolivia, Peru, and Brazil in 2005 resulted in waterborne infections due to low water levels leading to pathogen concentration in surface water. There were also respiratory problems due to heavy smoke from forest fires (Confalonieri and Menne et al. 2007).

Floods are already one of the most frequent natural disasters often overwhelming the physical infrastructure, human resilience and social organization of Dhaka, Mumbai, Jakarta, Caracas, and many other cities around the world. Some of these disasters are reported in the news and form part of the official statistics generated by national governments and international organizations. Yet for every flood large enough to get noticed internationally, there are hundreds that do not get reported, but kill and seriously injure many people and destroy or damage many people's homes and assets (Satterthwaite et al. 2007).

Cities always present some risk of flooding when precipitation occurs, because buildings, roads, and infrastructure prevent rainfall from infiltrating into the soil – and so produce more run-off. Heavy and/or prolonged rainfall generates very large volumes of surface water which can easily overwhelm drainage systems in many cities. This does not pose a problem to well governed cities, because they generally have good drainage systems together with parks and other complementary measures to protect from flooding. However in poorly governed cities (e.g. Mombasa, Alam and Golam Rabbani 2007) or cities where drainage does not cover all neighborhoods (e.g. Mexico City, Rio de Janeiro and Mumbai (Romero Lankao 2006, de Sherbinin et al. 2007), the affects of excess runoff can be devastating. The ineffectiveness and/insufficiency of their drainage systems is further compounded by inadequate solid waste management; with inappropriately disposed of solid waste often clogging any drainage they do have; or by the fact that their buildings and infrastructure are constructed in such a way that they actually obstruct natural drainage channels.

Higher than average and more extreme rainfall events associated with climate change are, and will be, related not only to flood hazards, but also to increased landslides and mudflows, and in alpine areas, to avalanches. Although landslides and mudflows are a primary trigger for local disasters, they are usually localized. This results in an underestimation of the impact of these events. Both floods and landslides are influenced by such factors as land use practices in surrounding watersheds, as well as by solid-waste management, land-use and drain maintenance within the city. Urban areas are faced with two options. The first is to reduce the future occurrence of these risks in the face of climate change by appropriate management and governance. The second option is to do nothing, in which case climate change will add additional flood hazard onto drainage systems that are unable to cope with current rainfall.

Water supply, drainage and treatment infrastructures are frequently the first to be affected by floods. Electrical switchgear and pump motors are particularly at risk. In severe riverine floods with high flow velocities, pipelines may also be damaged (Wilbanks and Romero-Lankao et al. 2007). Note that, for the most part, the urban centers in sub-Saharan Africa, Asia and Latin America have no sewers; if they do exist they serve only a very small proportion of the population (UN-Habitat 2003), Therefore as pointed out by IPCC, the main significance of floods for sanitation is that sanitation infrastructures such as pit latrines or septic tanks (or the lack of them) can become sources of the contamination of urban flood water with faecal material, presenting a substantial threat of enteric disease (Ahern et al. 2005 quoted in Wilbanks and Romero Lankao 2007).

The vulnerability of urban water supply, wastewater and storm water systems to climate change is outlined in this section. These systems will be strongly affected by the various manifestations of climate change, with impacts primarily relating to their physical infrastructure but also to their functionality.

8.2.1 IMPACT ON WATER SUPPLY

Water supply will suffer from most of the anticipated manifestations of climate change, whether in terms of water quantity or quality. Flows into rivers, lakes and reservoirs as well as groundwater will be affected:

❖ Sea level rise can reduce the availability of potable water through saltwater intrusion into aquifers and estuaries.

❖ Water supply will be reduced by altered precipitation patterns and increased temperatures (which increase evapo-transpiration).

❖ Security of supply is negatively affected by droughts both directly, since these reduce stream flow and inflows into reservoirs, lakes and groundwater, and indirectly, for instance through the increased occurrence of wildfires. In Australia for example, wildfires followed by vegetation regrowth significantly reduce catchment yields. (Howe,Jones, Maheepala & Rhodes, 2005).

❖ The seasonality of water supply levels may change, particularly in regions where spring snowmelt is the main source of water. Reduced winter rainfall will affect the recharge period of groundwater, lakes and reservoirs. Many Latin American countries dependent on snow and glacier melt have already seen reductions in available water. In Peru for example, freshwater availability at the coast, where over half of the population is concentrated, has seen a reduction of 12% over a period of 35 years (Bates, Kundzewicz, Wu & Palutikof, 2008).

Water quality is an important component of water supply, since it determines to what extent water needs to be treated prior to its use for drinking or other purposes such as irrigation. Changes in water quality therefore affect water users but also increase the cost of services. Water quality will be affected by flooding, through erosion and consequent turbidity increases, increases in non-point pollution, but also through damage to wastewater treatment plants and consequent bacterial contamination of water. It will also be affected by increased temperatures, which have an effect on the chemical and biological characteristics of water bodies, and by decreased precipitation which concentrates pollution. Consequences for certain water sources will have knock-on effects on others: precipitation decrease and its impact on surface water will result in increased water abstraction from groundwater and from sources with lower water quality (Bates, Kundzewicz, Wu & Palutikof, 2008).

The physical infrastructure of water supply will be negatively affected by flooding, through direct damage to pipelines and facilities, sedimentation of reservoirs as well as overloading of capacity. For example, infrastructural damage resulting in power cuts affects the ability to pump water. Climate change can also reduce the functionality of drinking water treatment, by for example lessening the effectiveness of treatment processes such as chlorination or causing overly high disinfection by-product levels in distribution systems (Zwolsman et al., 2009).

Functionality is affected by increased temperatures, which favour the proliferation of equipment-clogging algae and lead to greater expense for treatment to remove the taste and smell linked to bacterial and fungal growth. Unanticipated colder temperatures also affect functionality by freezing water in pipes which then leads to cracks and leaks, as happened in Ireland during the winter of 2010/2011. Pipes can also crack because of the drying of soils during drought conditions. Moreover, certain management decisions made as a response to climate change events can have consequences for water supply: for example, setting aside reservoir capacity as a flood absorption buffer can decrease drinking water availability.

Water supplies will also be affected by climate change driven alterations in water demand. Increased temperatures will increase water demand for all consumptive uses – barring efficiency improvements – and might therefore lead to stronger competition for water resources or require the sourcing of alternative water supplies. Water use in New York City for example increases by 11 litres per degree centigrade once temperatures go above 25°C (Protopapas et al., as cited in Kundzewicz et al., 2007). A related point is that in the context of reduced water availability, meeting any existing minimum ecological flow requirements will become more challenging, and could put into question drinking water production licence renewals (Zwolsman et al., 2009).

The increased occurrence and intensity of rainfall events can cause erosion within lake or river catchment areas and raise the turbidity levels of water. This turbidity can affect water quality even if the eroded soil is not particularly polluted. Turbidity affects drinking water production by interfering with disinfection processes, by requiring greater expenditure for coagulants and handling of solids and by overloading process functionality. It is a particular concern for cities such as New York City that do not filter their drinking water supply, as it can require the very costly installation of filtration systems if alternative means to control erosion are not put in place (Zwolsman et al., 2009).

8.2.2 IMPACT ON WASTEWATER SYSTEM

Much like water supply, the integrity and functionality of wastewater treatment infrastructure will be affected by climate change. The infrastructure of collection lines and wastewater treatment, including outfalls, pipelines and tanks, can be physically damaged by coastal flooding linked to sea level rise and also by flooding caused by increased precipitation. The functionality of wastewater treatment can also be reduced by flooding: in the case of cities with combined sewer systems, heavy rainfall events can overwhelm wastewater treatment capacity, which usually results in increased overflows. Coastal flooding can increase the salinity of influent and thereby disrupt biological processes and potentially affect the reuse of treated wastewater. Extreme events can challenge wastewater treatment plants by diluting or concentrating inflows, in the case of floods or droughts respectively.

Functionality is also impaired by increased temperatures: these can have both positive and negative consequences for wastewater treatment (Bates, Kundzewicz, Wu and Palutikof, 2008). Higher temperatures coupled with reduced rainfall can lead to increased pipe breakage due to drying of soils as well as increased deterioration of pipes due to corrosion from hydrogen sulphide build-up (Zwolsman et al., 2009; Howe, Jones, Maheepala and Rhodes, 2005). Wastewater management can also be indirectly influenced, for example if increased temperatures affect the oxygen levels of receiving water bodies and therefore lead to more stringent wastewater treatment requirements in order to stabilise these levels so as not to endanger ecosystems.

8.2.3 IMPACT ON STORM WATER AND DRAINAGE SYSTEM

Drainage or storm water systems will be most affected by the increased occurrence and intensity of precipitation. As rainfall becomes more intense, surface runoff levels can exceed the capacity of storm water entry points or cause sewer overflows in combined sewer systems. This can cause street flooding, with associated health dangers due to contamination, but can also increase the cost of meeting related regulatory requirements. Combined sewer overflows are a problem linked both to storm water and to wastewater: excess storm water causes overflows, but the conveyance of wastewater by means of combined pipes is also at the root of the problem. In London, for example, discharges from combined sewer overflow outlets into the Thames River can occur between 50 and 60 times per year, and heavy rainfall can lead to over a million tonnes of a combination of untreated sewage and rainwater entering the city’s rivers (Greater London Authority,2009).

In addition, drying and shrinking soils caused by droughts can generate cracks in storm water drains and sewers. This can lead to problems of contamination but also increases maintenance costs. Changes in vegetation and soil characteristics due to increased temperatures and higher rates of evapotranspiration can also change attenuation and infiltration rates, affecting soil retention capacity.

Increased heavy precipitation and more frequent and severe cyclones can cause riverine and coastal flooding and overwhelm city defences. Although the link between these two events and climate change has not been proven, the 2011 flooding in Queensland, Australia, and the hurricane-driven storm surge in 2005 in New Orleans, U.S.A., serve as reminders of the catastrophic impact of extreme weather events on urban areas and society in general. Hurricane Katrina cost New Orleans $30 billion in damage, destroying over 160,000 homes (Waggonner & Sternad, 2010). The costs and consequences of flooding are increased by growing population density and economic activity in at-risk areas, as well as by the existence and spread of informal settlements in developing countries. The dominance of impermeable surfaces in cities exacerbates the problems caused by heavy rainfall.

8.2.4 SENSITIVITY WITHIN WATER-RELIANT SYSTEMS

Apart from water-related infrastructure, cities are also supported by a number of other systems which are at least partly reliant upon water. These include transportation, energy supply, health, food production and green spaces. Some impacts will be caused by the systems' direct reliance upon water: one example within the energy supply system is hydropower, whose ability to produce energy is governed by the availability of water. Another example is the food production system which is dependent upon the timely availability of sufficient quantities of water. Both of these systems will be altered by projected changes in the quantity, seasonality and geographical distribution of precipitation.

8.2.5 OTHER PRESSURE ON WATER SYSTEMS

Although the public and decision makers have become more aware of climate change,
it is vital not to lose sight of the dominant role of the impacts of other human activities on freshwater and related systems. In many cases, the effects of other anthropogenic interventions are hard to separate from the effects of variations in climate. For example, river flows are substantially affected not only by climate-related precipitation and temperature patterns, but also by human activities such as dam building, land use changes and pollutant loads. Similarly, observed decreases in groundwater levels should first and foremost be attributed to overabstraction rather than climate-driven changes in recharge rates (Bates, Kundzewicz, Wu & Palutikof, 2008). Human activities can exacerbate the negative impacts of climate change by increasing the vulnerability of systems to a changing climate (Bates, Kundzewicz, Wu & Palutikof, 2008). While this handbook only focuses on adaptation to the impacts of climate change on the water cycle, it takes as a central assumption that sound

planning should take all driving forces into consideration. In some cases, placing the focus exclusively on climate change may lead a city to miss more obvious leverage points, which might be more cost-effectively addressed and lead to better results and greater co-benefits. Attribution of impacts to driving forces should therefore be a key exercise within a city's assessment of its baseline situation.

Other impacts will be caused by indirect effects, where climatic events damage the infrastructure – production, distribution or other – related to urban systems. Flooding for example can harm health infrastructure components such as hospitals, creating indirect health effects by preventing provision of and access to health services, and can also affect food distribution by damaging the transport network. The links between the water sector and other sectors also work in the reverse direction, for instance, effective wastewater treatment is strongly reliant upon the regular and affordable provision of electricity, which may be affected by climate change.

8.3 DIRECT AND INDUCED CHANGE IN WATER USE DUE TO URBANIZATION AND GLOBAL WARMING

The trend to urbanization further aggravates the problem by increasing per capita demand. Between 1990 and 2025, the percentage of the world population living in urban areas could rise by 50%, accounting for nearly two thirds of the total world population in 2025. Whereas most rural populations consume no more than 100-200 L per capita per day, and within the last decade nearly two thirds of the world population survived on less than 50 L, cities typically consume 300-600 L. Centralized sewage systems, industrial processing and the accoutrements of modern urban living are largely to blame. Perhaps fortunately for water demand, but sadly not for human health, much of the new urbanization in the developing world is unplanned and often unsupported by central supply systems and sewerage. Nevertheless, it is estimated that by 2025, 79% of the world urban community could be in the least developed countries (LDCs), compounding the stress on the least resilient economies. A very crude but conservative estimate of the "multiplier effect" of urbanization suggests that by 2025 the world will have over two billion more city dwellers than in the early 1990s, almost double the 1990 urban community, each consuming over twice the current rural average. To this must be added the demand for irrigation, which is rising in direct response to the need to feed the growing population. The peak wave of expansion may have passed, but irrigation remains the largest consumer of water worldwide, consumption has increased by nearly 20% in the last two decades, and a further 20% expansion in the area of irrigated agriculture is still regarded as environmentally feasible (Jones,1997, p. 14).

To the effects of expanding urbanization and irrigation must be added the problems of inefficiency and wastage in all spheres of consumption. Here the problems are very much a question of water quality as well as quantity. Lvovich's (1979) doomsday scenario of pollution essentially destroying global water resources by 2000 may have been averted, but the legacy of the decades of neglect that influenced Lvovich's viewpoint was clearly apparent in much of former communist eastern Europe in the early 1990s. Current fears focus on urban wastewater pollution in Southeast Asia, where rapid urbanization is likely to triple the amount of urban wastewater during the 1990s, and where increasing amounts receive little or no treatment. The current financial crises in the "tiger economies" will only exacerbate urban squalor and delay the provision of treatment plants.

As tragically illustrated during 1998 in Bangladesh, China and Central America, floods combined with poor urban sanitation can be the source of major threats to human health from water-borne diseases. Similar health problems followed the River Oder floods in Poland in 1997, although petroleum products and industrial chemicals were possibly more important ingredients than human sewage in those floodwaters. There is a potentially important interaction here with climate change, if flood frequencies increase.

The high resolution coupled atmosphere-ocean GCM model developed by the UK

Hadley Centre showed a significant improvement in the hindcasting experiment over its predecessor (Johns *et al*, 1997) and has formed the basis for a wide-ranging study 546 *J. A. A. Jones* of global impacts (Meteorological Office, 1997). Amell & King's (1997) estimation of the impact of greenhouse gas warming (the HadCM2GHG scenario) on global runoff by 2080 suggests increases in equatorial regions, peaking at over 50% in parts of East Africa and eastern Brazil, much of Southeast Asia, the USA (except the Great Plains) and the south-central Asian republics of the CIS (Commonwealth of Independent States), as well as generally north of 60°N. The main areas with reduced surface water resources occur in the sub-tropical and Mediterranean climates, especially between the North Atlantic and India and from Argentina, across southern Africa to Australia. In general, the reductions are under 25%, but in India and the Southern Hemisphere there are large areas with deductions over 25% and even over 50%. The critical feature of these calculations is that most of the increase will occur in regions that are not currently stressed and most of the decreases will occur in those that are already stressed under the present climate. The main beneficiaries, countries currently using more than 20% of their potential resources and therefore considered "under stress", that will experience fewer problems by the 2020s, include the USA, the broad belt from the Caspian to China and Mongolia, the Sudan, Somalia and Peru. The main losers include Mexico, the belt from Mauritania through Egypt, Turkey and the Middle East to India and Bangladesh, South Africa and western continental Europe from Spain to Poland and Italy. Table 1 shows the combined effects of population increase and climate change over the coming century, assuming that per capita demand remains static. Although population growth is seen to be the overwhelming source of stress, climate change alone could bring at least 100 million extra people within the realm of "extreme water stress", without allowing for any increase in demand due to climate change. Estimates for the 2050s vary from 117 million (graphs in Arnell & King, 1997) to 170 million (Arnell, 1998), but perhaps with a slight reduction by 2080.

Table1: Predicted trends in global precipitation, runoff and per capita water resources based on the output from HadCM2GHG, with some additions from HadCM2SUL.

	Present	2020s	2050s	2080s
Precipitation*(HadCM2GHG)		+3.0%	+4.5%	+6.25%
Precipitation* (HadCM2SUL)		+2.0%	+2.5%	+4.2%
Runoff (HadCM2)†		+2.9%	+4.0%	+6.5%
Additional runoff (km^3) (HadCM2GHG)		1126	1553	2524
Population increase				
Population in millions‡	5266	8121	9759	10 672
% increase	–	+54%	+85%	+103%
Per capita resources				
Due to population increase only		–35%	–46%	–51%
Due to population increase + climate change		–34%	–44%	–48%
Population in stress†				
Billions using >20% of available water resources (AWR)	1.9	5.1	5.9	6.5
% increase		+168%	+211%	+242%
extra millions due to climate change§		–	66	–
Billions using >40% of available water resources (AWR)	0.454	2.4	3.1	3.6
% increase		+429%	+583%	+693%
extra millions due to climate change†		26	117(†)170(§)	98

* Data from Hadley Centre and Climatic Research Unit, University of East Anglia, LINK Programme.
† Data from graphs and text in Arnell & King (1997).
‡ UN (1991) "most likely" estimates.
§ Arnell (1998).

8.4 THE URBAN HEAT ISLAND

The Urban Heat Island Effect (UHI) is a phenomenon whereby the concentration of structures and waste heat from human activity (most notably air conditioners and internal combustion engines) results in a slightly warmer envelope of air over urbanised areas when compared to surrounding rural areas. It has been suggested that UHI has significantly influenced temperature records over the 20^{th} century with rapid growth of urban environments.

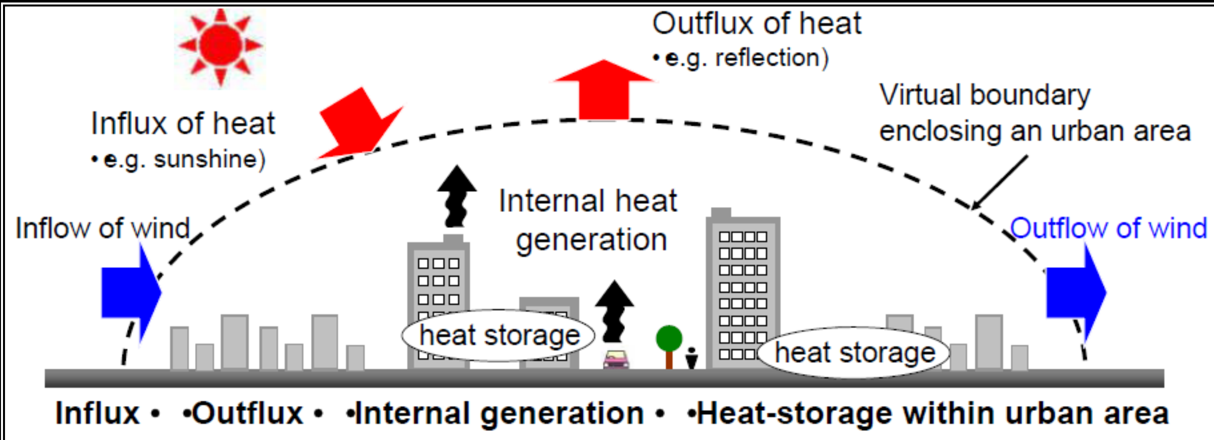


Fig 1: Heat balance in urban area (Source: Murakami, S 2006).

The urban heat island phenomenon was first observed over one hundred years ago in northern latitude cities, where the city centres were slightly warmer than the suburbs. (Instantaneous communications probably played a role in its identification, much as it did for other weather-related events.) For these cities, a heat island was generally a positive effect because it resulted in reduced heating requirements during the winters. It was only in the 1960s, as air conditioning and heavy reliance on automobiles grew, that the negative impacts of heat islands became apparent. The heat islands made summer conditions much less comfortable and increased air conditioning energy use. Since then the summer heat island has become the dominant environmental concern.

Urban Heat Island (UHI) is considered as one of the major problems in the 21st century posed to human beings as a result of urbanization and industrialization of human civilization. The large amount of heat generated from urban structures, as they consume and re-radiate solar radiations, and from the anthropogenic heat sources are the main causes of UHI. The two heat sources increase the temperatures of an urban area as compared to its surroundings, which is known as Urban Heat Island Intensity (UHII). The problem is even worse in cities or metropolises with large population and extensive economic activities. The estimated three billion people living in the urban areas in the world are directly exposed to the problem, which will be increased significantly in the near future. Due to the severity of the problem, vast research effort has been dedicated and a wide range of literature is available for the subject. The literature available in this area includes the latest research approaches, concepts, methodologies, latest investigation tools and mitigation measures. This study was carried out to review and summarize this research area through an investigation of the most important feature of UHI. It was concluded that the heat re-radiated by the urban structures plays the most important role which should be investigated in details to study urban heating especially the UHI. It was also concluded that the future research should be focused on design and planning parameters for reducing the effects of urban heat island and ultimately living in a better environment.

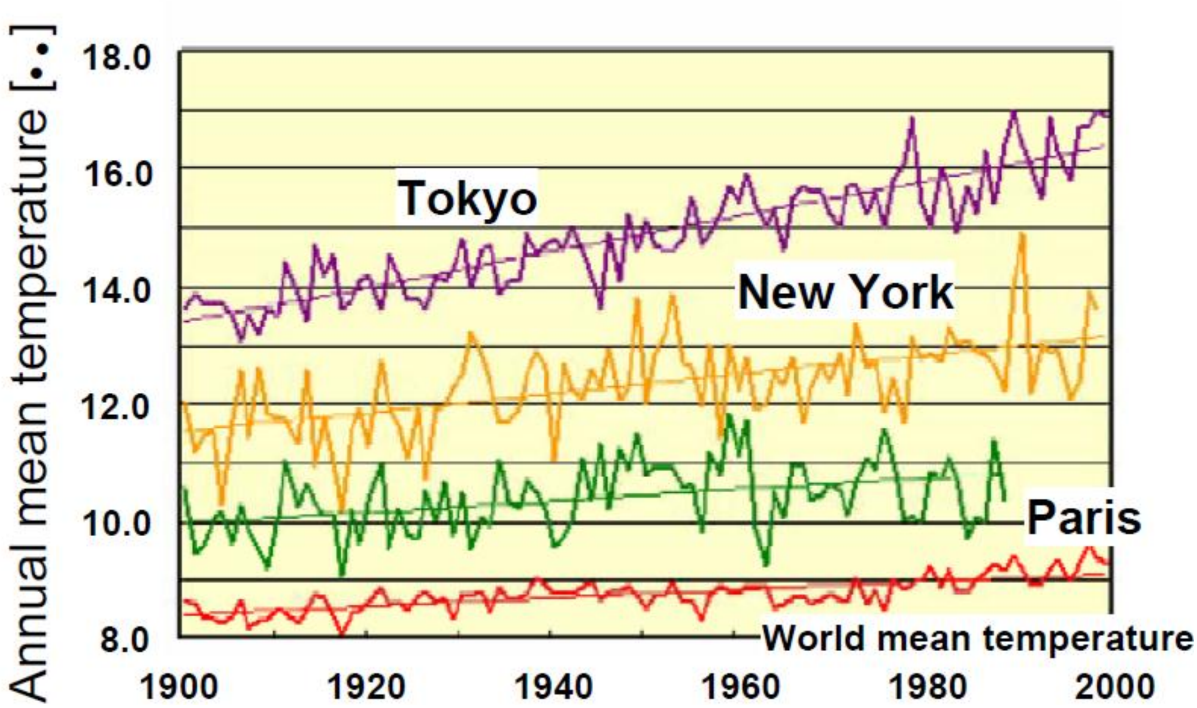


Fig2: Temperature rises in major cities around the world (Source: Compiled from Japan Meteorological Agency data)

8.4.1 THE CONSEQUENCES OF URBAN HEAT ISLANDS

Measurements and simulations demonstrate the broad impacts of urban heat islands on the health, energy consumption, and economy of cities. Some of these impacts are listed below:

i)Thermal discomfort*:* The urban heat island increases the duration and degree to which the residents will feel uncomfortably warm.

ii)Rates of formation of key air pollutants: An important insight from complex simulations and measurements is that higher temperatures, along with sunlight, accelerate the formation of ozone, nitrogen oxides, and photochemical smog. The rates of formation increase rapidly in the range of 30 – 40°C, that is, typical urban summer temperatures.

iii)Increased health risk:. The higher smog concentrations, combined with higher air temperatures, trigger or exacerbate a range of medical complications, including heat prostration, respiratory difficulties, and even cardiovascular failures.

iv)Increased air conditioning energy use*:*. Higher temperatures lead to greater reliance on mechanical cooling. Air conditioning demand often rises sharply as certain comfort thresholds are exceeded.

8.4.2 NEED FOR WATER FOR COUNTERMEASURES TO URBAN HEAT ISLANDS

It is very likely that urban heat islands will in the future have more severe consequences on cities and their occupants. These costs make an even stronger case for developing countermeasures so as to mitigate the impact of heat islands.

i) Water Retention Pavement

One of such technologies is a water retention pavement. The surface temperature is expected to be reduced since the water retained in the pavements consumes the heat around it when it evaporates. The water retention pavement is porous asphalt pavement with its voids filled with water-retaining materials. This pavement is to reduce temperature through the mechanism of evaporation heat. The water draws necessary heat from the surround when it evaporates, which results in the temperature reduction. The structure of the water retention pavements constructed in this study is shown in Figure 3 below.

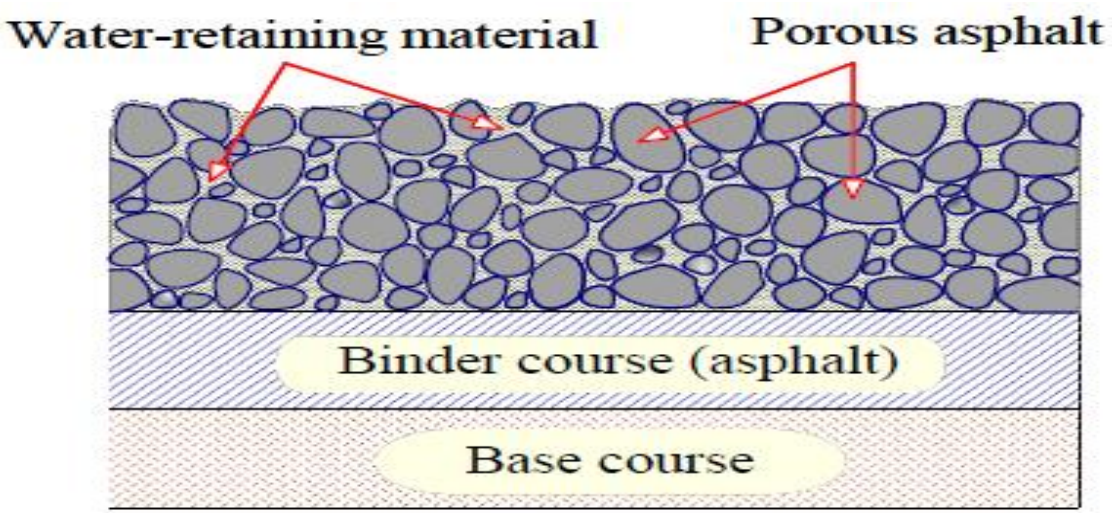


Fig3: Structure of water retention pavements(Study on pavement technologies to mitigate the heat island effect and their effectiveness, K. Kubo, M. ITO & H. KIDO)

ii) Spraying Fine Mist of Water::

In this method, cooling effect of evaporation is utilised. In this process fine droplets water is sprayed in the atmosphere. Temperature is reduced due to evaporation. This system was adopted by “World Expo 2005 Aichi, Japan” and also by Tokyo Metropolis as heat-island countermeasures.

Fig4: Exhaust nozzle of fine mist

iii) Recovery of Green Area and Water Area:

In this method also Reduction of temperature of temperature takes place due to evaporation. In this method, arrangement of buildings and greenery should be planned simultaneously, such way that free the transport of cool air by wind can take place (Fig. 5).

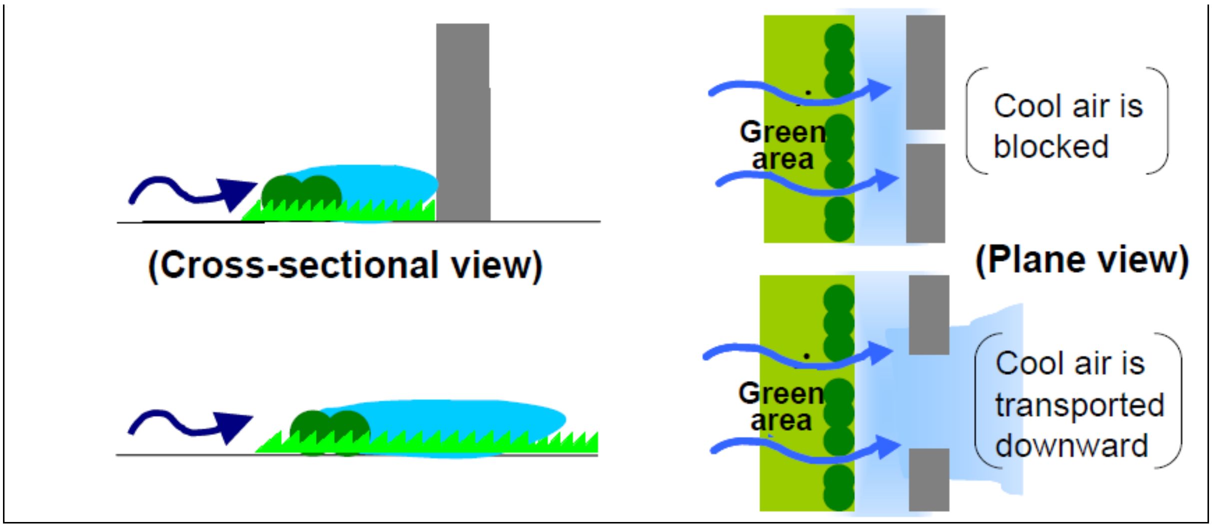


Fig. 5: Greenery and ventilation design around buildings (Source: Murakami, S 2006).

8.5 SUMMARY

Nearly 47% of the global population lives in cities; though cities cover barely 1.5% of the total land area of the earth. Though, the major attention has been on the mega cities, those with population of more than 10 million, however majority of urban dwellers live in cities with medium or small size. As per a recent UN survey, by 2050, nearly 70 % of the global population will be living in the cities. The migration will be most significant in Asia.

Although cities grew in size and population they were not fully sustainable. Use of large energy in industries, automobiles, concrete buildings became more and more common.

However, the infrastructure such as roads, bridges, drainage and water supply did not fully cope up with growing migration. This created a large divide in the quality of life between the richer and poorer section of population. Not only social and economic problems arose but also such growth led to problems related to environment and climate.

Cities concentrate population, infrastructure, economic activity and wealth, and will therefore be disproportionately affected by the local impacts of climate change. In addition, cities located in coastal areas and/or on the banks of rivers are particularly vulnerable to sea level rise and flooding. Cities are also characterised by the predominance of impermeable surfaces – which are less capable of absorbing increased rainfall and therefore increase the intensity of rainfall runoff – and are prone to the urban heat island effect which amplifies heat waves.

The urban heat island phenomenon involves much more than just higher temperatures in the city centre. It is linked to many other aspects of urban climate and human activities. Research has demonstrated that the heat island increases air conditioning, exacerbates air pollution, and can cause widespread health complications. There is good evidence that the costs of heat islands will increase.

Countermeasures that reduce the heat island and cool a city make sense because they translate into a range of lower costs to society. They result in less electricity consumption, fewer medical complaints, and greater longevity of materials. But effective countermeasures require further research so as to ensure that their benefits exceed the costs. Fortunately the results of this research can be shared because they will be applicable to cities around the world. Internationally coordinated research makes sense, too.

Finally, as population growth will overwhelmingly take place in cities, urban water managers will face a growing challenge to maintain safe and adequate water supplies and wastewater services for urban residents. Urban population growth in the next decades will take place at a very rapid scale and mostly in developing countries, exacerbating many of the problems linked to urban poverty, increasing the size of vulnerable populations in cities and placing additional pressure on dwindling supplies of resources such as water (Pageler, 2009).

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8.7 SUGGESTED READINGS

1. M. Yamazaki, M. Kanaya, T. Shimazu1, T. Ohashi1, N. Kato, T. Horikoshi*: "Passive cooling effect of RC roof covered with the ceramics having high water retention and evaporation capacity"*
2. David Satterthwaite, Saleemul Huq, Mark Pelling, Hannah Reid and Patricia Romero Lankao*;"Adapting to Climate Change in Urban Areas ,The possibilities and constraints in low- and middle-income nations"*

3. P. Shahmohamadi, A. I. Che-Ani, K. N. A. Maulud, N. M. Tawil, and N. A. G. Abdullah ***"****The Impact of Anthropogenic Heat on Formation of Urban Heat Island and Energy Consumption Balance"*

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8.8 QUESTIONS WITH ANSWERS

Q1: How does beginning of large scale urbanization affect water system?

Ans: The more land erosion the more sediment is washed into streams. This increases the chance of flooding and harms the water quality of the streams. Local flooding can occur. Some small streams are paved over (using culverts). Natural land that used to soak up runoff is replaced by roads and large areas of pavement (impervious areas). This means that the water that used to soak into the ground now runs off into streams. The runoff can also be collected by storm sewers and sent to small streams, which can flood. Increased sewage in streams causes pollution -- it can kill fish and make water unusable for other purposes downstream.

Q2: How does urbanization cause flooding?

Ans: As more people move in, more buildings are made to accommodate them. This flattens the land and puts impermeable concrete etc. over the soil along with the removal ofvegitation. So now there is no soil to soak up water, no vegetation to absorb water, so there is an increase in surface run off which flows into a nearby river which increases the risk of the river overflowing its banks and causing flood.

Q3: How do Lifestyle and Consumption Patterns within Urban Areas Contribute to global environmental change?

Ans: Urban populations are characterized in part by lifestyles and consumption habits that are distinctly different from rural livelihoods. There is considerable research on the relationships between income and environmental indicators (e.g., energy and water consumption, waste and emissions). However, research is needed that examines the interactions among income and class, lifestyles (values and behaviours, e.g. among expanding elites and middle classes), and contributions to global environmental change across spatial scales and in different regional settings that take into consideration the roles of institutions and policies (Sklair, 2002, UNCHS 2001, James, 2000, Newman 1999, Parikh and Shukla 1995,, Djursaa and Krang 1998). The core project will also seek to collaborate with other projects working on similar issues like the GCP or IT.

Q4: How does urban water demand impact upon regional and local fresh water supply, especially in water-scarce areas?

Ans: One of the big challenges facing urban areas is to guarantee their supply of water. Scholars have created a useful debate about this issue, but more attention is also needed to the potential impact of current and future water demand in urban areas and its impact upon global fresh water supply. Although direct water demand in urban areas is small compared to agriculture or other users, longstanding and new urban areas already compete for scarce water resources in some regions (e.g., south-western US, the Middle East, southern Africa, parts of central Asia, the Sahel). Meeting the MDG of providing potable water to the urban poor raises additional questions about longer term environmental sustainability of these urban systems. On top of the direct water demand, urban areas can also impact on regional fresh water resources through induced regional land use and land cover changes that modify the sustainability of watersheds. These include conversion of naturally vegetated areas to urban uses and to water-intensive recreational uses, e.g. swimming pools and golf courses (on the latter of which intensive fertiliser use also contributes to groundwater contamination). An integrated perspective of the impact of urban areas on these resources will enable a more comprehensive assessment of the consequences for the biophysical system. This is an area where fruitful collaboration can be established between with the Global Water Systems Project (GWSP), the Global Land Project (GLP), and with international organizations (International Water Commission, UNEP).

8.9 ASSIGNMENT

Q. How does urbanization change land use pattern?

Q. Explain the impact of climate change on terrestrial and aquatic ecosystems of urban area.

Q. How does urbanization change the rainfall activity?

Q. What are the anthropogenic activities that further increase the heat island phenomenon?

Q. How can Buildings be designed to mitigate heat islands?