CHAPTER # 1

INTRODUCTION
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Scientists have determined that our planet “The Earth” was born as a result of explosion in the sun. This event took place some 4.5 billion years ago. Initially it was a hot ball of fire. The initial atmosphere was made up of hot and poisonous gases like sulphur. Slowly the temperature cooled down. The first living cells formed on earth, used to inhale gases such as sulphur and give out oxygen. As a result of this process, over a period of around 2 billion of years, the oxygen - carbon atmosphere, suitable for carbon based life form came into existence. In this environment, the hydrogen and oxygen atoms combined forming water molecules. This water accumulated in the form of oceans, rivers, fresh water lakes, glaciers, ground water etc. Due to sunlight these waters evaporated and the vapours reached the upper and cooler reaches of the atmosphere and come down to earth, back as rain. The rain water cycle was thus established. Initially plant life came into existence, which released oxygen at day. When the environment was suitable, lower forms of life such as single celled organisms came into existence. Over a period of millions of years, as a result of mutation of genes, these single celled organisms slowly evolved into more complex forms of life. Slowly the lower mammals were born. These grew into more and more complex forms, till apes and finally mankind made its appearance on this planet.

Our ancient scriptures say “Jalam Jeevanamrut”, which literally means that water is the nectar of life. This implies that the importance of water was known from ancient times. More recently, - “Albert Szent-Gyorgyi (1972) has quoted – (quote reproduced below with citation).

Water is the Hub of Life.

Water is its mater and matrix, mother and medium.

Water is the most extraordinary substance!

Practically all its properties are anomalous, which enabled life to use it as building material for its machinery.

Life is water dancing to the tune of solids.

- Albert Szent-Gyorgyi (1972)"
“Water is the driver of Nature”, Leonardo da Vinci once said. Presently, water covers 71% of the surface of our planet “The Earth”. As referred above briefly, the chronological events in the history of our planet indicate that, the existence of life on earth is attributed to the presence of water. Water is an essential requirement that has led to the growth of plants, resulted in primate/mammal life, and is a critical requirement without which life on earth would not have been possible. Initially man was a nomad and hunting was the only source of his livelihood. Slowly, man learnt the use of fire and began to settle near river basins, which provided the earlier civilisations with fertile lands for farming. Thus there was a rise of ancient civilisations along the river banks, where water resources marked a beginning and an enhancement for agriculture, as water was required for farming, it met the requirements of plants, tended to animal life, and was a source of clean drinking water for the earliest civilisations. Slowly, industries and trade developed as a result of abundant water availability and water became a beacon for trade and industry. Worldwide, Rivers Systems (along with lakes, ponds and wells) have always provided mankind with fresh water. The utility of rivers systems is the story of ancient civilisations on “Earth”. The nomadic Stone Age man always wandered around rivers in search of food and livelihood. The greatest civilizations have flourished around the banks of great rivers in all five the continents of the world. Some major examples are given below:

- The assistance of “Nile River System” was critical to the development of Ancient Egypt in African continent
- The assistance of “Indus River System” was critical to the development of Mohenjo-Daro civilization in South Asia
- The assistance of “The Tigris & Euphtates River Systems” was critical to the development of Mesopotamian cultures around Europe,
- The assistance of “The Tiber River” was critical to the development of Ancient Roman culture in today’s Italy.

One main use of water was the provision of fertile soil and fresh water for agriculture. Cultivation of necessary fruits and vegetables trees/orchards would not have been possible without availability of clean water. Ever since man learnt the benefits of rivers systems, he has
used the river water for various purposes like drinking, cleaning - household use, irrigation & farming, industry, navigation, fishing etc.

As civilisation progressed, man invented new techniques to exploit river waters systems. As industrialisation grew and mass production in factories was started to take advantages of economies of scale, the industrial units which came up also began generating metal and chemical wastes. The river systems were seen as a convenient and economic way to dispose of industrial waste, sewage and other domestic waste. Over a period of time, the importance of industries in human civilisation grew to such an extent that in most developing or underdeveloped countries the index of industrial productivity became the barometer of success/failure of the society. Today, the world over, the success of human civilization mostly depends upon its industrial productivity, which leads to economic progress of the nation. However, urbanization, globalization and industrialization all have an associated indirect cost, which though or not specifically intended, leads to adverse effect on ecosystem (Tanner et al., 2001).

The disposal of human waste is another great challenge in both developed and developing countries (Zimmel et al., 2004). Water bodies in the form of seas, rivers and lakes have been considered as convenient, cheapest and effective path for disposal of human waste. Aquatic ecosystems the world over, have been threatened by pollution as a result of residential wastes (sewage, garbage etc) and industrial effluents (toxic wastes, hazardous materials, scrap etc.) being discharged into the River Systems. In modern times, the effect of poor quality of water on human health was first noted in 1854 by John Snow, who traced the outbreak of Cholera epidemic to London’s Thames River, being heavily polluted by sewage. Even today, several years after the incident that took a large number of lives, people around the world continue to use rivers waters to dispose sewage.

The Thales of Miletus had said that “Water sustains all”. Water naturally maintains its own quality through various processes. Processes, such as, water purification by physical, chemical and biological means routinely goes on in the environment. The physical process includes dilution of water, its volatilization and sedimentation/deposition of impurities. All these processes regularly take place in nature as a part of the environment cycle. The chemical process includes oxidation, reduction, dissolution, and nitrification. The biological processes include uptake or absorption and adoption by plants, microorganisms, microbial oxidation and reduction. But
the rate at which humans are destroying the water resources is much greater than the speed of natural purification through processes referred above. If this process continues without any checks and balances, the day is not far when mankind will not be left with sufficient water resources of adequate quality.

As referred above, water is an essential constituent of all life on earth and life cannot exist in the absence of water. The living cell contains around 70-80% water in its protoplasm. Water is an essential ingredient of most of the biochemical reactions (e.g. Metabolism) that go on in a cell, leading to its growth and development. Most of the diseases that humans are affected with are connected with impurities in the water consumed. Of all the resources available to mankind, water is the most precious; life on “Earth” would not have been possible without water. Civilisations itself cannot survive, if the natural environment itself collapses and man must balance the resources of the planet if he wants to survive.

Many of the human activities cannot be carried out without water. One of the properties of water, whereby many substances are dissolved in water, makes water useful for industries and other domestic uses. The used water contain certain impurities in the form of metals, chemicals etc, which are the result of the discharge of untreated wastes from industrial and residential units. These are referred to as pollutants.

Pure drinking water is therefore rare and should be used economically. In order to conserve water for future generations, concentrated efforts are required from all concerned to ensure that pollution of water is minimised. Water balance is causing changes due to human activities like industrialisation, deforestation and over population. (Trevedi, 1989-90). All the National Governments, World Health Bodies, State Governments, local and Municipal Authorities need to join hands, to ensure the success of this effort.

In urban and highly populated centres, methods followed for the disposal of industrial and domestic wastes are of prime importance. Solid wastes such as heavy metals and chemicals are a major source of pollution of water. These partly processed wastes when discharged on land/water bodies percolate into the ground water and are a potential source of danger to people staying nearby. The industrial effluents may include poisonous chemicals, in the form of suspended solids, heavy metals, acids, alkalis and fluro-compounds. Disposal from fertiliser units and wash
off from agricultural lands using pesticides and fertilisers, also result in pollution. The pollutants give water a colour, unpleasant taste and odour, turbidity and eutrophication. The pollution of water through various means results in –

- Spread of communicable diseases
- Affecting of flora and fauna and is detrimental to the endangered environment
- Disturbing the foods chains of natural species in the environment and humans, resulting in various diseases (which may also be fatal).

In India, only 12% of the people get clean drinking water and the rest 88% quench their thirst from polluted lakes, tanks, rivers and wells due to which more than a million people get affected or die of enteric diseases every year (Trivedi, 2004). In agriculture a large portion of water is lost by transpiration and evaporation (Petty John, 1972).

**Different Types of Water Pollution:**

As seen earlier, with the rise of industries, different materials, wastages are discharged into water bodies, leading to degradation in the quality of water, for different uses. This is referred to as “Water pollution”. Such pollution occurs, when it is beyond the capacity of the water body to break down such wastages, in the natural course. This implies that, pollution occurs when different untreated industrial discharges or wastages are released to water body, in excess of its capacity to break it down in its natural course. Sometimes pollution may occur in nature itself, such as, when water flows through soils with high metals/acidities. Usually, however, human actions are the direct cause of the different sources of pollution which enter the water.

The sources of pollution can be broadly classified into two – (i) point sources refer to sewage and industrial effluents discharged. Sometimes, treatment plants are used, to convert C, N and P into their oxides. After treatment they are discharged into water bodies like rivers. Since the impurities are soluble in water, it becomes unfit for human consumption, if the permissible limits are exceeded. (ii) Non-point sources include the polluted run off from agricultural fields, or wind-borne debris blowing out. Non-point sources are difficult to identify, extremely complex and their remediation are costly (Harnova, 2003). The main sources of pollution and their effects are elaborated below:
Effect of Excess Organic Matter on Water Quality

Sewage from households and fertilizers from farms are discharged into water bodies. Plants and algae which grow in water are enriched as a result of the nutrients received. In the course of time the “Plants and Algae” die; the dead matter settles down at the bottom. This dead matter is decomposed by micro-organisms present in the river waters. This process of “decomposition” results in consumption of oxygen dissolved in water. As a consequence, the levels of oxygen dissolved in water drop. When such reduction in levels of oxygen reach a threshold limit, the aquatic creatures which are dependant on oxygen, such as, fishes die. In biological terms, this process which results in oxygen being reduced to such low levels, so as to make aquatic life unhealthy/unfeasible is called “Eutrophication”. Such a process has an adverse effect on the entire ecosystem of the region. Some algae might also be toxic and cause harm to surrounding life.

Infections due to Organisms

In most natural waters, some micro-organisms which cause different types of diseases are always present. However, when such organisms enter sources of drinking water drinking water they are considered pollutants. Parasites like Giardia lamblia and Cryptosporidium parvum are occasionally present. Generally, infants, young children and very aged people (due to less immunity) are easily affected by such parasites. People already suffering from other diseases also easily fall a prey to these bacteria.

The cholera outbreak in London in the year 1854, is regarded as a classic of example of how infectious organisms spreading through water – causes diseases. London's water supply system consisted of (i) shallow public wells and (ii) water from the Thames River. London’s sewage system was quite old. The privies were not connected directly into sewer pipes, but were discharged into cesspools or cellars. The drainage sometimes leaked into the wells and Thames River. Hence, the Cholera causing bacteria reached the drinking water sources. As a result around 600 people were killed in the outbreak of Cholera epidemic.
Heavy Metals and its effects on Water Quality

Various sources from where Heavy Metals enter into water are industrial discharge, automobile exhaust, water runoffs from mines, and even natural soil. The concentration of metals in an organism increases progressively as a result of food cycle followed by plants animals and humans. Small plants growing near a polluted river or water body may absorb toxic elements from underground sources. These small plants are eaten up by animals which in turn become a prey to other animals or are killed by human beings for food. Thus the concentration of metals increases at each level. Long-term health problems result when the concentration of heavy metals reaches a threshold limit considered to be unsafe. A high level of metal absorption by the body can lead to diseases, adversely impact functioning of different organs of the body or may even lead to fatalities.

The Minamata disease at the Minamata Bay, Japan in the 1950’s was caused due to the consumption of fish containing Mercury (Hg). This Mercury had got into the bay water in the form of effluents from an acetaldehyde factory which used Hg as a catalyst. The symptoms of this disease were sensory impairment, hearing loss ataxia, speech disturbances. Though use of catalysts (like Hg) was discontinued, the effects were still felt for a long time after the incident, due to the accumulation of the metals in the food chain (bio - accumulation). Similarly, metals like Pb, As, Fe, Mn and Cd beyond permissible limits cause severe ill effects (Mc Cohan et al., 1989). Thus it is necessary to monitor and have a check on them.

Effect of Fertilizers

Most farmlands use some kinds of Pesticides and Herbicides which find their way into ground water, rivers or other water bodies as a result of farm water runoff. These chemicals which pollute water could be biodegradable or non-biodegradable. Though biodegradable chemicals interact (physical, chemical or biological interactions) with the surroundings and easily convert themselves to other form which have no or less adverse effects; the bio non-degradable chemicals do not degenerate themselves and hense retain their adverse effects for a long time.
Currently, chemicals such as chlordane and dichloro-diphenyl-trichloro-ethane (DDT) are used in pesticides/herbicides. When animals consume plants treated with such dangerous chemicals or drink polluted water, the various tissues and organs, such as, liver, heart, bones, kidneys etc., absorb these dangerous chemicals. These harmful chemicals are absorbed in the body of other animals or humans which feed on such animals having high levels of toxic elements in their body. Thus the concentration of toxic metal increases progressively at each stage and the adverse effects are multiplied/magnified. This process is referred to as bio-magnification. As a result of the widespread use of pesticides and fertilizers in agriculture, the water runoffs from agricultural fields, may find their way to underground sources of drinking water leading to a contamination of drinking water. DDT has accumulated in humans too; as a result of its rather wide spread usage. DDT is stored in our body primarily in such fatty form. Human organs like, adrenals, testes, and thyroid mainly absorb DDT. In smaller concentrations it is also absorbed by the liver and kidneys. Concentration of 6-10 mg/kg of DDT leads to such symptoms as headache, nausea, vomiting, confusion, and tremors. Fatalities result when concentrations of DDT reach above 236 mg per kg of body weight. DDT is known to be a probable carcinogenic source in human (Windolz, 1983). It also damage the liver, causes liver cancer, temporarily damages the nervous system, affects/reduces reproductive success, and damage reproductive system.

Wastes Classified as hazardous

All hazardous wastes are harmful to plants, animals and humans. They have different kinds of adverse effects on the surrounding environment. On the basis of certain properties of such wastes, these hazardous wastes or chemical wastes can be broadly be classified as under –

(i) Poisonous chemical compounds
(ii) Chemical compound which react with air/gases in the environment to cause an explosion
(iii) Chemical compounds which are capable of corroding steel, metals etc.
(iv) Chemical compounds which ignite spontaneously at room temperature (e.g. Petroleum products.)

Such chemicals need to be stored/disposed off with proper precautions. Pollution of water supplies results, when such wastes are stored or disposed off improperly. Certain hazardous
chemicals, which are used in different industries either as raw materials, catalyst or are used as indirect materials for making different kinds of manufactured goods can leak into the environment as a result of (i) improper disposal of the finished product (ii) disposal of bye products and (iii) leakages into the atmosphere from the manufacturing process. Toxic levels are reached through the food chain as a result of bio-accumulation.

Oil & Related Products

Oil and its derivative products find wide application in almost every industrial activity. It is not possible to give an exhaustive list of these. In the transportation sector, it is used as fuel in Cars and other vehicles, in ships and aircrafts. In the manufacturing and construction sector diesel is used to run most industrial machineries and equipments. Diesel is used as fuel to run locomotives by Railway Companies. Heating, lubrication and miscellaneous manufacturing are the other uses petroleum products and oils and chemicals derived there-from. However, leakage of Oil & related products to the environment results in adverse effects on plant, animal and human life.

As a result of various accidents, like leakages from tankers and trucks carrying oil and gasoline, leakages from oil pipelines carrying oil from oilfields to refineries and consumption centres, oil spills caused in the seas and oceans as a result of shipping accidents and leakages from tanks used for storage of oil there is a leakage of oil to the environment and to water sources. Many petroleum products can cause death if ingested by animals beyond a level. Even some contact with spilled oil may be dangerous to birds and their organs, flora and fauna in ecologically sensitive areas, fishes in fresh and sea water. Such damage can occur in sensitive eco-zones where a number of aquatic species exists and migratory birds flock during seasons. Different types of harmful compounds may further contaminate oils & related products.

Particulate Matter

Effective presence in large enough quantities renders even rock, or soil particles to be a pollutant. As a result of natural activities or man made incidents fine rock dust, soil particles may
settle down in river bed, ponds lakes or even oceans. The excessive presence of such particles in water for domestic or industrial use could act as a pollutant. Additionally, soil erosion may also result from cutting trees adjoining the river bank, which hold the loose soil together through the roots. Such soil erosion could also result from the flowing of excess water from agricultural fields. Particulate matter may be further enhanced by open blasting in mines, mountainous regions, construction of carriage ways etc. Such particulate matter may enter usable sources of water, like lakes or rivers, through the atmosphere or as a result of rain water run offs. Such particles then settle at the bottom of the water body, like ponds, lakes or rivers. Some fishes and aquatic creatures lay their eggs at the bottom of water in lakes or rivers. The soil particles settling down cover the breeding areas of fishes and other creatures thereby reducing oxygen and leading to eutrophication.

Heat related Pollution

In some cases, water which is drawn from different sources, like, wells, ponds, lakes and rivers or even oceans is used as a coolant in industrial units or other commercial activities. After using the water in the relevant process, it is discharged back into the water body from where it was drawn. As a result of the process there is usually a rise in the temperature of the water discharged. This results in a rise in the temperature of the water body from where the water was originally drawn. This results in a change in the composition of aquatic life in the water body. Certain species of fish are unable to adjust themselves to the rise in temperature and become extinct or flock to cooler regions. A new species of plants or fish may be attracted to the region as a result of the rise in temperature. The change in temperature of the water body can affect certain processes taking place in plants and animals, like metabolism, reproduction etc. This could lead to a reduction of oxygen dissolved in water and thereby result in the death of fish and other aquatic life forms near the water body where temperature has gone up. Cutting of forests, trees and vegetation can also contribute to this effect and substantially enhance the temperature of the region. This effect was observed in small cities, where forest, agricultural lands and other forms of cultivation was reduced to make way for residential and industrial units.

Structure and Properties of Water
The only substance that is found in nature in all its three forms viz. liquid, solid and vapours is water. Usually, water (H₂O) when it is clean is transparent, without smell, without taste and is generally available everywhere. A single water molecule consists of two hydrogen atoms and one oxygen atom. Most of the other molecules are heavier than water molecule. In an atom the electrons orbit the nucleus or the proton. In case of water molecule the two hydrogen atoms undergo covalent linkages with central oxygen atom by sharing pair of electrons. The pair of electrons is shared by the two nucleus of the two atoms, the central oxygen atom and the hydrogen atoms at the two ends. These bonds are called as a covalent chemical bond. The shape of the molecule is in the form of an obtuse angled triangle where the two hydrogen atoms make an angle of 104.5° with the central oxygen atom. Though the aggregate electrical charge of the Water molecule as a whole is zero, the positive and negative electrical charges are situated at the different ends of the molecule. The oxygen end of the molecule has a high negative (electronic) charge due to two reasons. Firstly, the non bonding electrons contribute to this. Secondly, the fact the the oxygen atom has a high nuclear charge also contributes to this effect. The high nuclear charge of the oxygen atom results in a greater attraction on its electrons. This effect is technically termed as “Electrical Dipole”. The positive charge is situated at the hydrogen end of the molecule. The positive hydrogen atom in one water molecule is also attracted to the negative oxygen atom in another water molecule. Technically, this effect is termed as “Hydrogen Bonding”. However, these bonds are very weak and last only for a very very small interval of time.

Density means the compactness of a substance. The general formula for determination of density is mass divided by volume. However, density also varies with temperature. As temperature increases, the density generally decreases. Normally in solid form substances are denser than liquids. However, the only substance to which this general rule does not apply is “pure water”. In its liquid form (at a temperature of 4°C), it has its highest density. Its density is 1000 kg/m³ in the liquid form at 4 °C and 917 kg/m³ in the solid form. This is why ice floats on water. The melting point of water is 0°C and the boiling point of water is 100°C. Due to property of water molecules undergoing hydrogen bonding, ice which is solid form gets quiet stable structure.

The specific heat capacity of water, which is 1 cal/ gm °C, is quite high. As a result a lot of energy has to be applied, to overcome the hydrogen bonds and increase the temperature of water.
Since, the Earth’s surface is covered 71% by water, the energy from the sun does not result in significantly wide variations in the temperature of the planet during day time or at night. Therefore, our planet ‘Earth’ does not display extreme swings in temperature. Life can exist on the planet only under moderate temperature variations. Also, in summer the oceans, seas and other water bodies absorb the heat from the sun. In the winter season when the environment is very cool, the heat stored by water earlier is released back to the atmosphere. Thus, the property of water having high specific heat lowers the temperature variations between different seasons.

A high quantum of energy is required to evaporate water. The vapours (gaseous form) being lighter, rises up into the atmosphere. As the vapours rise up, the cooler regions of the atmosphere are reached. Due to low temperature the vapours form rain drops, which come back to earth. This has an effect on the climate of the place.

This property of undergoing hydrogen bonding of water molecule with the compounds plays an important role in dissolving them and forming a quite stable solution. This enables the transport of various components in water. Gases such as oxygen and carbon dioxide can dissolve in water. These gases along with other types of matter provide nutrients to aquatic life forms, which makes possible different types of bio related processes. The oil molecules are big in size but they do not carry any charge. Therefore, they do not cleave into smaller molecules having charge and are immiscible in water. Further, since oil molecules are lighter than water they float on it. And since they do not mix in water they form a separate film on water. (http://www.atmosphere.mpg.de/enid/1vb.html).

In a compound the opposite electrical charges in different atoms attract each other. Dielectric constant is a term used for determination of the quantum of the forces in a compound, which attract of opposite electric charges. The dielectric constant and electrical conductivity of water at 18°C are 81 and $4.3 \times 10^{-8} \text{ohm}^{-1} \text{cm}^{-1}$. This means that in water the force of attraction between the two opposite charges is $1/81$ times the force in a vacuum. Ionic compounds tend to easily dissolve themselves in water. This ability of water can be accounted by two of its properties. Firstly, its dielectric constant is quite high and secondly the capacity of a water molecule to form a hydrogen bond with compounds, imply that these compounds are dissolved in water to form a quite stable solution. As a result of these factors, substances such as common salt (NaCl) are
easily miscible in water. A large number of chemical compounds get dissolved in water due to hydrogen bonding of water molecules with these compounds (capable of going ionization) *(Mark J Hammer., 1975).*

**Water Sources:**

Presently, 71% of the surface of the earth is covered by water. The general availability of water is a kind of prerequisite to all known forms of life. Water is the only natural resource which exists in all the three forms. Solid form (snow), liquid (water –fresh & salty) and gas (water vapour). Water is available in the liquid form in oceans, seas, rivers, lakes, ponds, and pools. The glaciers and polar ice caps are a solid form and water vapour (gaseous form) forms the hydrosphere. The breakup of total water availability on Earth is given below –

- Oceans comprise of around 96 - 97 % of the water resources
- Groundwater (in all the five continents) comprises of around 1.5 % of water resources.
- The glaciers in the high mountainous ranges and the ice caps comprise of around 2 % the water resources.
- Large rivers, lakes account for a very small percentage of water resources.
- The balance is in the form of evaporated water, clouds etc.

Fresh Water constitutes less than 3% of the aggregate water resources on the planet. Of this, nearly 99% of the aggregate fresh water resources are in the form of ice and groundwater. Major ice chunks are found in Antarctica, Greenland and high mountainous ranges. Scientists have observed that as a result of emission of various gases like carbon – dioxide etc., there has been a global rise in temperature, which has resulted in the melting of (snow) ice caps in the Artic, Antarctic regions and the high mountain ranges of Himalayas, Alps etc. The fresh water in lakes, rivers etc. constitute only a small fraction i.e. 0.3% of the aggregate freshwater resources. The bodies of all living creatures on earth hold some water. Similarly, some manufactured items, such as, processed foods etc. hold some water. However, these amount to an insignificant percentage of total water resources.
Water is a valuable natural asset. Human beings depend on water for many purposes, which can be broadly classified as domestic and industrial. These uses of water could be in the form of drinking, cleaning, cooking, agriculture, animal husbandry, ships – sea transport & river transport, hydropower etc. Fresh water is required for all these purposes. It is generally obtained from rivers, lakes, surface runoffs and ground water resource.

Rivers, lakes, Canals, artificial reservoirs, wells etc and underground water constitutes a major portion of fresh water in our country. Our country is gifted by nature with a system of different types of rivers. Some of these can be considered as big rivers. The aggregate area catered to by these big rivers is over 250 Million Hectares (M.Ha). The big rivers systems categorized in terms of the regional area under the river’s influence are –

- The Ganges, Brahmaputra and Meghna river system constitute the biggest network in terms of region under its influence. The aggregate area covered by this system is over 100 M.Ha. This accounts for more than 40% aggregate area of all the Big River systems in the country.
- Indus, Godavari, Krishna & Mahanadi are the other Big River Systems with the area under their influence being 32 M.Ha., 31 M.Ha., 26 M.Ha. and 14 M.Ha. respectively.
- Some of the River Systems can be categorized as medium in terms of the region under the river’s influence. The aggregate area under the influence of all the medium river systems in the country, is about 25 M.Ha. Among the Medium River systems the biggest is “Subaranrekha” which caters to an area of around 2 M.Ha.

The state wise details for states having longest network of rivers in terms of total length is given below –

- In terms of the aggregate length of its rivers, Uttar Pradesh takes the 1st rank. The aggregate length of the river in the state is over 31 thousand Kms. This accounts for 17% of the aggregate length of all the river systems in India.
- Jammu & Kashmir and Madhya Pradesh are the other states ranked 2nd and 3rd in this respect.

The Lakes, (excluding all River Systems) in aggregate account for no more than 7 M.Ha. of area under their coverage. Tanks & Ponds constitute the remaining means of water resources. The
aggregate area catered to by all Tanks & Ponds and artificial water reservoirs is 3 and 2 M.Ha. respectively.

The Central Ground Water Board is a body formed with the objective of developing Ground Water Resources in the country. Exploring with a view of finding additional sources of water and then drilling constitute the major works of the Board. Through its work the Board identifies different regions in the country where there is a paucity of water and which are prone to draught, remote and forest areas. Having identified such areas, it undertakes various ground and soil studies to discover water under different geological patterns. The BOARD has to date drilled over 30000 wells in different parts of the country. Once it is ensured that the well gives a regular and adequate yields, operations are transferred over to the concerned Governments/Municipal authorities for use in public supply. During the natural calamities, such as, earthquakes, cyclones & flood the Board comes forward with its help to the affected people. Such assistance was provided at Latur & Bhuj in the years 1993 and 2001 respectively. Similar assistance was given in the Orissa floods and the Tsunami which hit several parts of South India. The disaster mitigation plan in such cases includes digging wells to provide pure drinking water to the affected people.

**Mumbai's Water Sources**

In the year 1860, the aggregate water supply to the city was just 32 MLD (million litres per day); this was sufficient considering a then population of under a million people. The Vihar Lake met these requirements. Today the City’s population has risen and reached to more than 13 million people. The aggregate water supply from various sources has now reached around 3000 MLD. In order to develop new sources of water to meet the demands of increasing population new schemes were under taken on lakes and river systems far away from the City ([Refer Table 1 & Figure 1](#)).

The table below also shows how, as a result of projected growth of population from current level of 13 million to 16 million by 2021, the future water sources had to be identified in Vaitarna River basin and Ulhas River basin, which takes the total water supply to 6,382 MLD by the year 2021.
Previously, the sources of drinking water supply were within the City, as such, the cost of supplying water was lower. With the increasing population, water has to be brought to the city from far away locations. This increases the cost of pumping the water and supplying the same to the City. Though some of the new projects being undertaken are gravity sources others will involve pumping water which will add to costs. The project on Middle Vaiterna has progressed quite far and a new dam will shortly be completed. However, the new dam will submerge 3500 hacteres of land in different villages. The displaced people will have to be relocated. Similarly, the project on Ulhas River will require pumping of water. This will add to costs. Besides it will also submerge over 5000 Hactres of land and require relocating of the people. (Table on next page)
**Figure 1:** Figure shows the geographic location of all actual & projected water sources of Mumbai
Table 1: showing details of water supply in Mumbai

<table>
<thead>
<tr>
<th>Year</th>
<th>Water Scheme</th>
<th>River</th>
<th>Water Supply (mld)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1860</td>
<td>Vihar Lake Dam on Mithi</td>
<td>Mithi</td>
<td>32</td>
</tr>
<tr>
<td>1872</td>
<td>Vihar Lake Dam height raised</td>
<td>Mithi</td>
<td>36</td>
</tr>
<tr>
<td>1879</td>
<td>Tulsi Lake - Another Dam on Mithi</td>
<td>Mithi</td>
<td>18</td>
</tr>
<tr>
<td>1891</td>
<td>Powai Lake - Mithi Tributary (To Aarey Colony)</td>
<td>Mithi</td>
<td>4</td>
</tr>
<tr>
<td>1892</td>
<td>Tansa I - Dam on Tansa</td>
<td>Tansa</td>
<td>77</td>
</tr>
<tr>
<td>1915</td>
<td>Tansa II - Additional Water Pipeline</td>
<td>Tansa</td>
<td>82</td>
</tr>
<tr>
<td>1925</td>
<td>Tansa III - Dam height raised</td>
<td>Tansa</td>
<td>98</td>
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<tr>
<td>1948</td>
<td>Tansa IV 38 floodgates provided</td>
<td>Tansa</td>
<td>198</td>
</tr>
<tr>
<td>1948</td>
<td>Total Water Supply for Mumbai's 2 million population</td>
<td></td>
<td>541</td>
</tr>
<tr>
<td>1957</td>
<td>Vaitarna cum Tansa Dam on Vaitarna and tunnel between Vaitarna &amp; Tansa Lakes</td>
<td>Vaitarna</td>
<td>490</td>
</tr>
<tr>
<td>1967</td>
<td>Ulhas (entire water supply to Kalyan since 1994)</td>
<td>Ulhas</td>
<td>90</td>
</tr>
<tr>
<td>1973</td>
<td>Upper Vaitarna Dam upstream of Vaitarna Lake</td>
<td>Vaitarna</td>
<td>554</td>
</tr>
<tr>
<td>1981</td>
<td>Bhatsai I Pise pick weir</td>
<td>Bhatsai</td>
<td>455</td>
</tr>
<tr>
<td>1989</td>
<td>Bhatsai II</td>
<td>Bhatsai</td>
<td>455</td>
</tr>
<tr>
<td>Year</td>
<td>Source</td>
<td>Total Water Supply for Mumbai’s current 13 million population</td>
<td></td>
</tr>
<tr>
<td>------</td>
<td>--------------</td>
<td>-------------------------------------------------------------</td>
<td></td>
</tr>
<tr>
<td>1998</td>
<td>Bhatsai III</td>
<td>455</td>
<td></td>
</tr>
</tbody>
</table>

Sources Identified for Future Projects

Vaitarna River Basin

- Middle Vaitarna: 455
- Gargai: 455
- Pinjal: 865

Ulhas River Basin

- Kalu: 590
- Shai: 1067

<table>
<thead>
<tr>
<th>Year</th>
<th>Total availability of water for Mumbai’s projected 16 million population</th>
</tr>
</thead>
<tbody>
<tr>
<td>2021</td>
<td>6,382</td>
</tr>
</tbody>
</table>

The Bombay Community Public Trust – Internet – 31st October 2006


**Mithi River**

Mumbai City is a Metro and the financial capital of India. The Mithi River which flows through the heart of Mumbai City has become synonymous with all ills which a river experiences, such as, encroachment on its banks, storm water drainage, and disposal of untreated sewage and dumping of liquid & solid wastes. Its source lies in the hills at height of around 250 Metres above sea level. The said hills lie in the east of “Sanjay Gandhi National Park”. Further, it is strengthened by the overflow streams of the three lakes supplying water to Mumbai city.
Thereafter, it travels downstream, till it ends near Mahim bay around 18 Kms. On its route, the Mithi River flows through densely populated areas, which include permanent residential units and slums. Also, a number of commercial enterprises, industrial units, and automobile and scrap dealers carry on their activities along the river bank. The river flows through the following regions – Powai – Saki Naka – Airport – Kurla – Santacruz – BKC- before ending in Mahim Bay (Refer Fig. 2). The water shed of Mithi river is covered within latitude 19° 00’ to 19° 15’ and longitude 72° 45’ to 73°.00’ E. (NEERI, 2011). The river is narrow in its initial stretches, but widens gradually and is the widest at Bandra Kurla Complex. Also, in its initial stretches its course follows a rather steep gradient and hence the water flows quite fast, while in the later part (say after Andheri) it flows through a flat region and water and waste accumulate. The terrain through which Mithi River can be categorized into four distinct zones based on the slope of the region (Refer table 2 below).

Table 2: Topography of Mithi River

<table>
<thead>
<tr>
<th>Sr.No.</th>
<th>Segment</th>
<th>Slope</th>
<th>Type of slope</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Powai Lake boundary to Jogeshwari Vikroli Link road.</td>
<td>1:200</td>
<td>Steep</td>
</tr>
<tr>
<td>2</td>
<td>Jogeshwari Vikroli Link road to Sir M.V. Road</td>
<td>1:450</td>
<td>Steep</td>
</tr>
<tr>
<td>3</td>
<td>Sir M.V. road to C.S.T Bridge</td>
<td>1:850</td>
<td>Moderate</td>
</tr>
<tr>
<td>4</td>
<td>CST road to Mahim Causeway</td>
<td>1:4000</td>
<td>Flat</td>
</tr>
</tbody>
</table>

(Source: National Environment Engineering research Institute Report – 2011.)

The Figure 2 next page shows the flow of Mithi River from origin in Pawai Lake to its destination at Mahim creek.
As per the industrial policy on river catchments, department of Environment, Government of Maharashtra (GR. No. NMW/ 2000/326/22/TB-3 dt. 15th July 2000), the Mithi River has been classified under category A - IV. This implies that 500 metres on either sides of the river, is supposed to be a no development zone for any type of Industry. Only Green and Yellow type of industries, with effective pollution control systems can be set up within 500 Metres to 1 KM. Any other industry may be set up with pollution control system, beyond 1 KM on either side of the river. However, the river is ensconced within the city development, with many activities along its banks.
The river also acts as a natural drainage channel, discharging the excess waters flowing from overflowing lakes, storm water drains and catchment areas, during the monsoons. Also, this river has become more like an open drain. The residential and industrial units, adjacent to the river banks, discharge raw sewage, industrial waste, garbage without any pre-treatment into this River. This is in addition to the various, illegal activities, such as, rag pickers, throwing wastes by unauthorized automobile/scrap dealers, dye units etc. which are undertaken on both the banks of the river. The deposition of various wastes, industrial effluents etc. has also resulted in carrying capacity of the Mithi River being reduced significantly. This led to heavy flooding on both the banks of the river during heavy rains in July 2005.

The waters with mixture of sewage and industrial waste flow around Mahim Bay; it becomes a threat to marine life of the river as well as the Arabian Sea, where the river discharges its water. The nominated “Saleem Ali Bird Sanctuary” falls in this area. The area is also full of mangroves (Refer photographs –Methodology section). Different species of birds flock to this area in relevant seasons. This is therefore a fragile ecosystem which needs to be preserved and protected from pollution and destruction.

There is a plan to increase the width of the Mithi River. The table 3 showing the current and proposed width is given below. Figure 3, showing the existing width and proposed width Mithi River from origin to Mahim creek is given below;

Table 3: Current width & proposed width of Mithi River

<table>
<thead>
<tr>
<th>Sr. No</th>
<th>Phases</th>
<th>Original Width</th>
<th>Width will be</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Upstream Jogeshwari Vikroli Link road (JVLR)</td>
<td>15</td>
<td>40</td>
</tr>
<tr>
<td>2</td>
<td>JVLR to Andheri Kurla road</td>
<td>30</td>
<td>60</td>
</tr>
<tr>
<td>3</td>
<td>Andheri Kurla road – CST bridge</td>
<td>60</td>
<td>100</td>
</tr>
<tr>
<td>4</td>
<td>Dharavi to CST bridge</td>
<td>120-140</td>
<td>200</td>
</tr>
</tbody>
</table>

(Source: National Environment Engineering research Institute Report – 2011.)
Near its origin the mouth of the river is narrow; as it reaches Bandra-Kurla Complex it becomes wider. The river carries the storm water discharge (several drainages discharge wastes into the River), as well as the sewage & industrial effluents to Arabian Sea. The Mithi River flows through densely populated area, with a number of industrial units (authorized/unauthorized), slums of Dharavi, anthropogenic activity along its banks, cattle sheds, dumping of hazardous waste etc. Such activities affect the quality of water in the “Mithi River”. The extent of pollution keeps on increasing. The course of Mithi River also serves as a boundary for some Municipal wards.

The Mithi River is said to be one of the major reason for causing floods on 26 July, 2005 in Mumbai, in which about 1,000 people died. Several people were rendered homeless and several people had to leave their houses, till the waters receded after some days. The aggregate rainfall
as measured by IMD (Indian Meteorological Department) was 944 mm at Santacruz Station. Starting at 8:30 am on the 26th July 2005, the aggregate rainfall of 944 mm for a period of 24 hours exceeded the daily average rainfall even at Cherapunjee. The losses due to the floods were substantial. All transportation systems of the city had come to a standstill. Several people in their vehicles, trains and at the airport were stranded. Many people lost their lives, property, belongings, businesses suffered loss/closure and vehicles were damaged. The poor drainage systems of the city, failure of effective storm water drainage and the incapacity of the city’s only river to carry the rain water to the sea was blamed.

The major threats to the river are as listed below:

1. Contamination from domestic waste, garbage, sewage from neighboring settlements.

2. Contamination from industrial waste, solid & liquid wastes in form of toxic metals, oil-grease, tar etc. thrown in by small illegal industries on the banks of the river.

3. Encroachments around the river which has resulted in reducing the width of the river; at the mouth-end of the river has been reduced to 40-50 ft. (which was 120 ft. before).

4. The sludge on the river bed which is estimated to be equivalent to about 15000 truckloads.

5. River diversion – The course of the river has been changed drastically over the years by surrounding settlements, industries etc. Some important changes are listed below.

   i. Development of Bandra-Kurla Complex has affected natural flow of Mithi River. Since the diversion, unnatural turns have been introduced in some places.

   ii. Diversions have been introduced by the Airport Authorities at three places. The heavy flow of water on 26 July 2005 which had surpassed the unnatural man-made diversion had broken the Airport wall and flooded the runway and Airport.

   iii. Illegal diversion has been introduced by scrap dealers and illegal oil mixing business at Kurla.
iv. Present diversion just near Vihar Lake for huge construction, Jogeshwari-Vikhroli link road.

v. 90 degrees diversion near Kranti Nagar by Airport Authority. Mahim creek has shrunk drastically after land was reclaimed, for the Bandra-Kurla Complex, which has seriously affected the drainage.

In order to suggest various measures to reduce pollution in Mithi River and improve its drainage system, various committees have been formed by the Authorities. These committees have submitted their recommendation and some of the suggestions have been implemented, wherever possible. The major committees formed are *(Summarisations of report – National Environmental Engineering Research Institute January 2011)*

1. Natu Committee (1974)

2. Studies on proposed reclamation to be carried out near the place where the River meets Arabian Sea. This work was carried out by a Central Research Institute.


5. Report of NEERI ( National Environment Engineering Research Institute 1996), Supreme Court case

6. MPCB Report on Mithi river pollution & its recommendations


The Mithi River – Development and Protection Authority was established by the Government of Maharashtra, after the flood of 2005. This committee has held several meetings with the objective of reviewing (i) Status of Mithi River pollution (ii) The feasibility of implementing the suggestions/recommendations of several committees formed from time to time. Some of the major recommendations made by several committees include –

(i) Widening the river on both the banks,

(ii) Dredging and removing of silt/sludge to enhance the carrying capacity of the river

(iii) Installing sewerage treatment plants at locations where sewer water enters the river.
(iv) Minimising garbage/wastes that are thrown into the river

The Authorities have implemented these suggestions wherever possible. However, it may not be possible to implement all the suggestions made, since some of the problems are difficult to resolve. Considering the technical feasibility of certain critical issues and the financial costs involved it is difficult to foresee how some of the problems can be solved. In some cases there are mosques/temples along the banks of the river. Authorized industrial estates, several residential and commercial units and thousands of slum dwellers will have to be relocated, to increase the width of the river at certain places. There are a large number of unauthorized units which discharge drainage, throw garbage into the river. It is not easy for the Municipal Authorities to provide an alternative way to dispose wastes in all cases.

In the meantime, the above discussed factors continue to affect the river, enhancing its pollution levels.

The state of the river is a serious concern and needs to be given attention. My topic ‘A Study of Water Quality of the River ‘Mithi’ in Mumbai Metropolis’ is a sincere effort to evaluate the pollution levels of “Mithi River” waters and review the possible adverse impacts of high pollution levels, which is a threat to the environment. The study will be useful for the management plans to control the river water pollution and restore its healthy state.