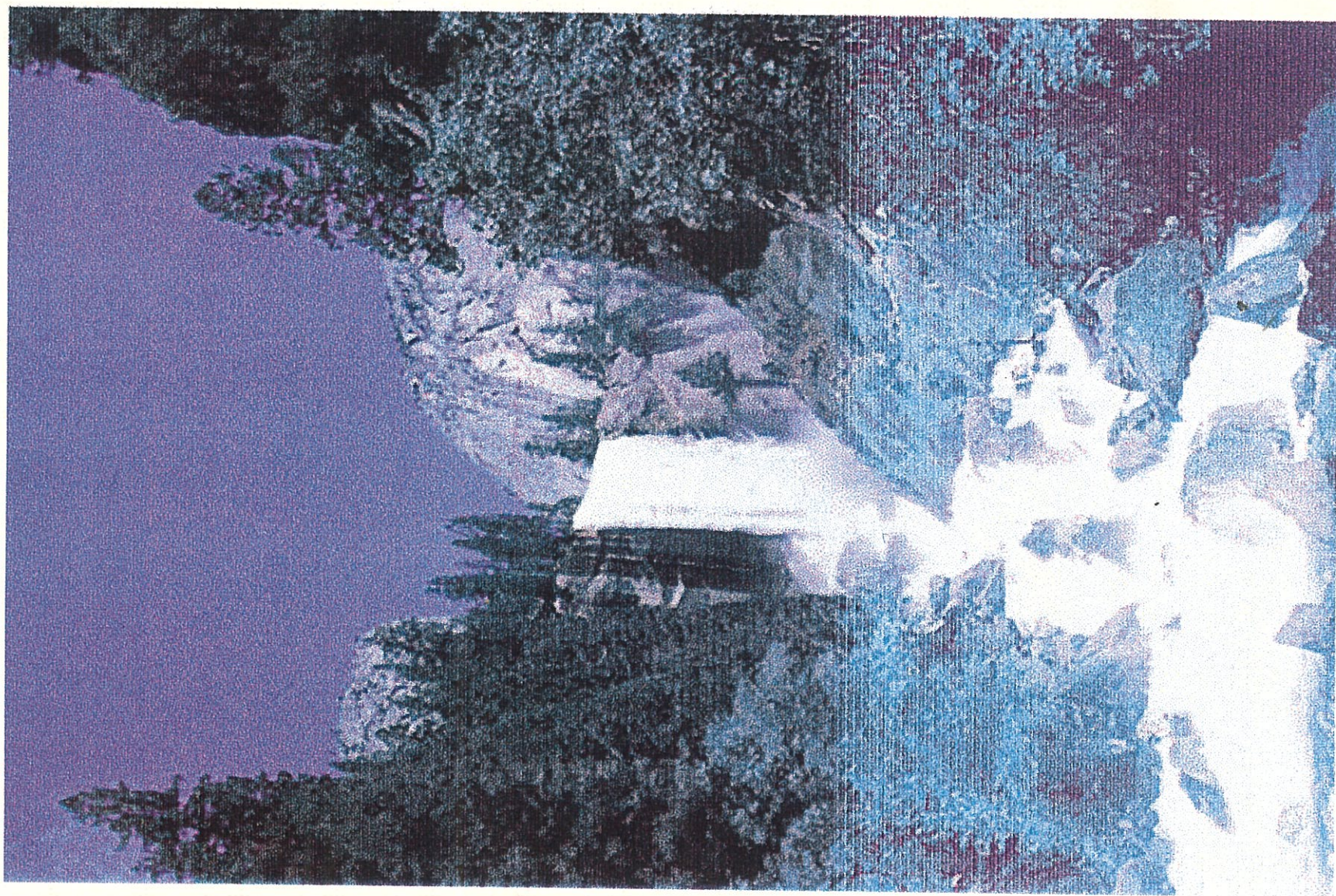




DRINKING WATER QUALITY ASSESSMENT

A REPORT
(1999 – 2002)

Investigators

Dr. (Mrs.) M. M. BAPAT AND Dr. T. N. MAHADEVAN

ASSESSMENT OF DRINKING WATER QUALITY IN
MUMBAI, ITS SUBURBS AND NAVI MUMBAI FOR
MICROBIAL AND PHYSICO-CHEMICAL
PARAMETERS

A PROJECT REPORT

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It was indeed a tiring and traumatic experience for the project JRF's, especially during field sampling in many affluent areas. The treatment meted out to them by many of the residents and the security personnel manning the Housing Societies, was truly testing and akin to those involved in sales promotion activities. In spite of all these disappointments, the courage and participatory zeal and enthusiasm shown by these young talents is truly praiseworthy.. In the same note we would also like to express our deep sense of gratitude and appreciation to all those residents whose cooperation and understanding of our efforts formed a strong base to the project progress.

The most crucial part of the work program was the assessment of supply water quality at the source end. This included the Bhandup Treatment Plant and the seventeen sub reservoirs located at different areas. This important task could not have been completed

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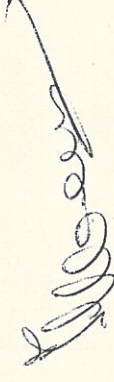
The untiring and painstaking reading of the final draft of the report by Dr. S.R Kshirsagar, Life Member, SOCLEEN and suggestions for improvements strengthened the report contents. We express our sincere thanks to such a good samaritan amongst us.

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SOCLEEN

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INTRODUCTION

That water function in a variety of ways within a cell cannot be disputed. Life originated in water, is thriving in water, water being solvent and medium. It is the matrix of life. All biological reactions occur in aqueous media and it is the integrated system of the biometabolic reactions in an aqueous solution that is essential for maintenance of life.

Water is vital for the existence of all life forms. It has always been a vital material for man's existence and is essential for all activities of human beings. No matter what the purpose for which water is required, it has long been recognized that other substances dissolved and / or suspended in the water can affect its suitability for that purpose. The number of impurities of concern has been continually increasing and smaller and smaller concentrations of many substances are becoming of interest. The concern with water quality is now a topic of importance in virtually all countries with respect to the drinking water.

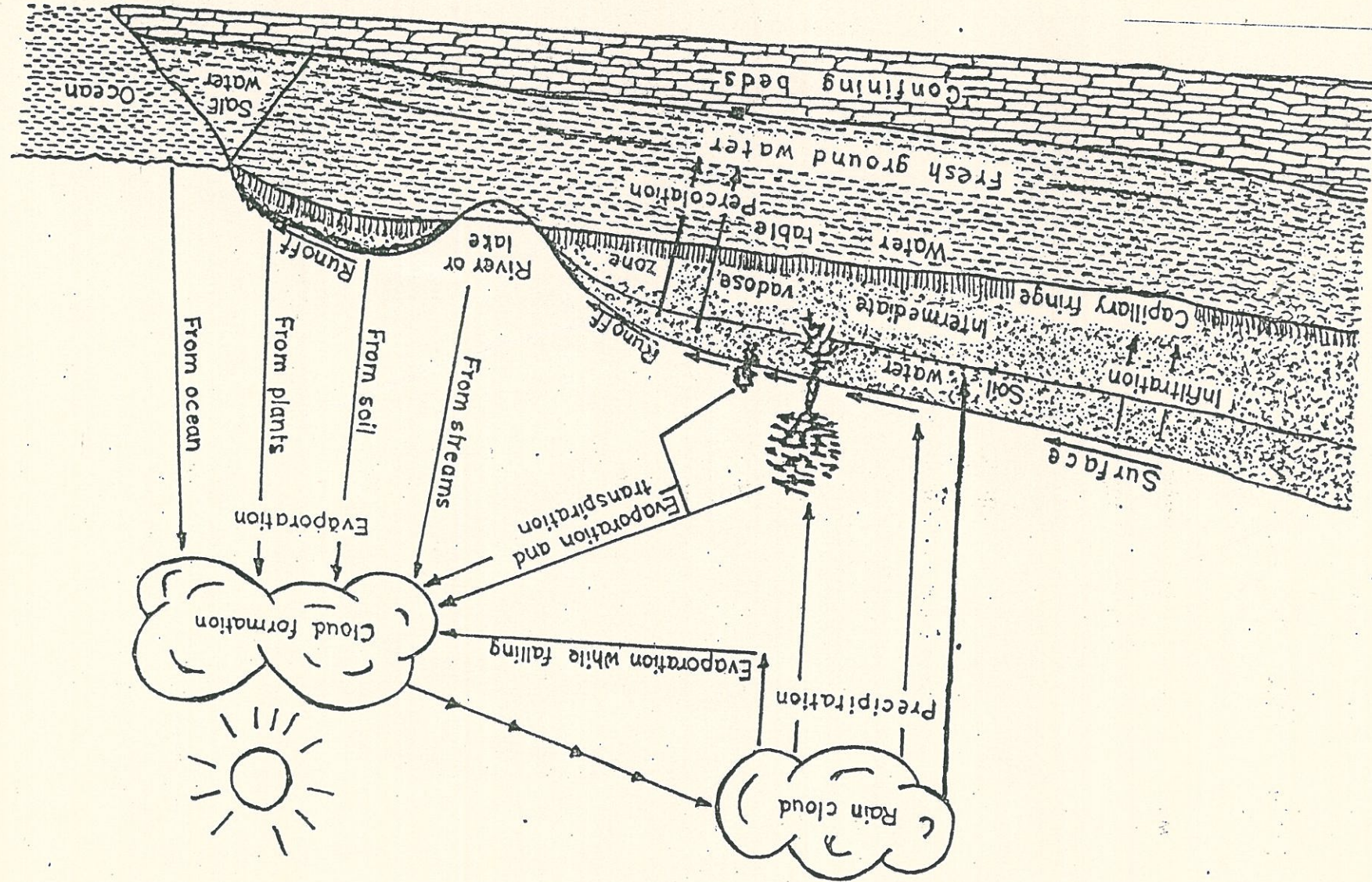
Water is one of the most abundant and widely distributed substances in nature. We are all familiar to it not only for forming the oceans, lakes and rivers but as vapors being everywhere around us. It also permeates even the solid mass of the earth. The Greek Philosopher Thales impressed by the all pervasiveness of the water, regarded it as the Universal principal underlying all forms of the matter. The unique physical and chemical properties of water have allowed life to evolve in it.

Approximately 80% of the water on the earth is in the ocean, 19% is in the pores of rocks beneath the earth's surface, 1% is in the form of ice, 0.002 % is in the streams and lakes and only about 0.0005 % is in the atmosphere. The most important source of drinking water for about 70% of Indian population is groundwater.

Despite predictions to the contrary, the world is not running out of water. World water supply is maintained by the Hydrologic cycle, also called as 'The water Cycle' (Fig. 1). This is because of the natural steam generated by the sun. Clouds are formed by the water evaporated from the earth's surface and transpired by the plants. As it cools, this atmospheric moisture condenses and replenishes water supplies as precipitation. Some of the precipitation may not reach the ground. If it does, it will either (1) surface flow to become streams ; or (2) shallow ground infiltration, to become soil moisture, or (3) deep ground infiltration to become ground water. Approximately 70% of precipitation is returned to the atmosphere by evaporation and transpiration, 20% is run off and the rest becomes ground water¹.

The rate with which water enters the ground and returns to the atmosphere may vary according to the soil conditions. At the beginning of the rain, water penetrates dry soil rapidly, but its flow decreases when a nearly constant rate of infiltration is reached. Frozen or saturated soil prevents water infiltration and promotes surface run off, a common cause of floods. If it rains long enough, the soil will eventually become saturated and water will begin to drain into the earth through gravity until the soil reaches its field capacity. Water held in the soil carries nutrients to the plant tissues, which in turn yield water to the atmosphere through transpiration².

Fig. 1 : The Hydrologic Cycle



Water being essential to sustain life a satisfactory supply must be made available to consumers. The effect of water pollution on human health is of serious nature. Every effort should be made to achieve a drinking water quality as high as practical. Protection of water supplies from contamination is the first line of defense. Source protection is almost invariably the best method of insuring safe drinking water and is to be preferred to treating a contaminated water supply to render it suitable for consumption. Once a potentially hazardous situation has been recognized, however, the risk to health, the availability of alternative sources and the availability of suitable remedial measures must be considered so that a decision can be made about acceptability of the supply. As far as possible, water sources must be protected from contamination by human and animal waste, which can contain a variety of bacterial, viral and protozoan pathogens and helminth parasites. Failure to provide adequate protection and effective treatment will expose the community to the risk of outbreaks of intestinal and other infectious diseases. Those most susceptible to water borne diseases are infants and young children, people who are debilitated or living under unsanitary conditions, the sick, and the elderly.

The potential consequences of microbial contamination are such that its control must always be of paramount importance and must never be compromised. The greatest microbial risks are associated with ingestion of water that is contaminated with human and animal excreta. Person-to-person contact, aerosols, and food intake may also transmit the diseases that are water borne. Under these circumstances, provision of safe water supply will reduce the chances of spread by these other routes. Water borne outbreaks are particularly to be avoided because of the capacity to result in the simultaneous infection of a high proportion of the community.

Groundwater, the most important source of drinking water is considered less polluted. But lack of sanitation, improper waste disposal, faulty well construction and lack of water source protection increase ground water contamination and 40% or more of the disease outbreaks were attributed to polluted ground water consumption. The enumeration of total viable count, aerobic heterotrophs, coliforms and *Escherichia coli* generally indicates the extent of the water pollution and has attracted the workers to assess the microbial quality of water.

Maintenance and safeguarding of this precious natural resource is, however, neglected. With the increasing population, industrialization and need for higher agricultural production, sustainable supply of this resource is seriously jeopardized due to lack of proper management. In the present circumstances groundwater is being polluted by intentional and unintentional discharges. The rapid pace of industrialization, which now a days has become need of developing country like India, is a major source of groundwater pollution. The effluent from the industries is either stored in landfills or is channelized into agriculture lands or river. The undesirable concentration of chemicals find their way in to the groundwater or by the uptake of autotrophs.

Groundwater has become an important water resource throughout the ages. As like other natural resources, ground water supplies are not unlimited and hence must be wisely managed and protected against undue exploitation and contamination by pollutants. Degradation of groundwater quality takes place in large areas from diffused sources, like deep percolation from intensively cultivated field or it can be caused by point sources, such as open dumps, sewage disposal, surface impoundment and septic tanks. a large number of monitoring studies have been carried out in the last 3 – 4 decades to assess the underground water pollution and its impact on human health, animals and agricultural crops.

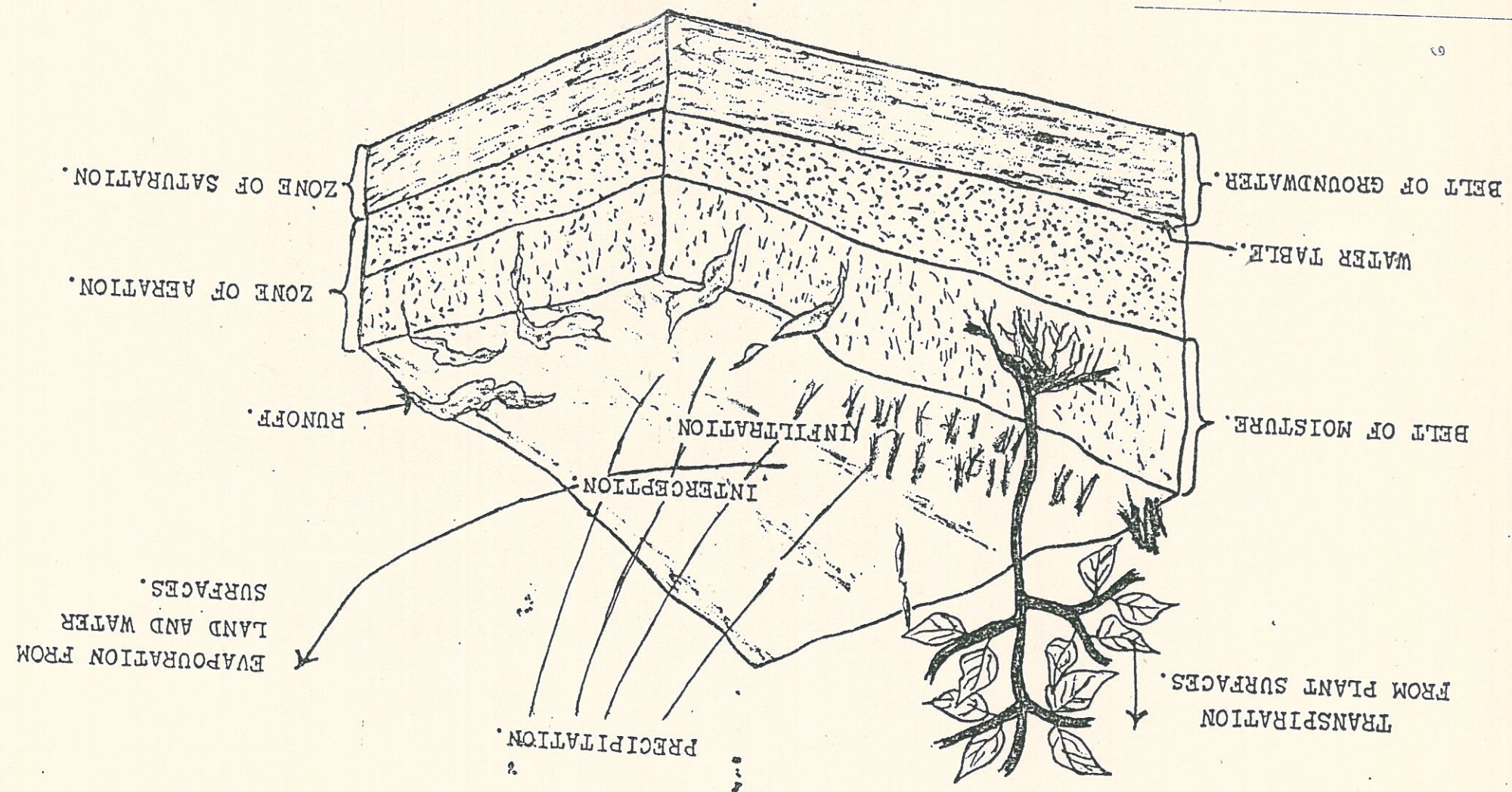


Fig. 2 : Belt of groundwater

Table 1 : Some Physico-Chemical Properties of Pure Water

Temperature for maximum density	4 ⁰ C
Freezing point	0 ⁰ C.
Boiling point	100 ⁰ C
Critical temperature	374.2 ⁰ C
Ionic product at 25 ⁰ C	1 X 10 ⁻¹⁴
Refractive Index NH ²⁰	1.33
Latent heat of fusion at Melting point	79.72 Cal/gm
Latent Heat of vaporization at Boiling Point	539.4 Cal/gm
Surface Tension at 25 ⁰ C	71.97 dynes/cm
Viscosity at 25 ⁰ C	8.987 millipoises
Ionic Mobility at 18 ⁰ C: K Cl	64.2
	65.2
Solubility at 25 ⁰ C: NaCl BaCl ₂	0.359 gm/gm of Water
	0.357 gm/gm of Water
Heat of formation at 25 ⁰ C	68.32 K cal/mol

It has been estimated that 80% of all diseases worldwide is due to improperly sanitized food and water simply because most people in the world do not have access to clean water for drinking. Contaminated water causes diarrhoea and as many as 25,000 deaths in infants and in young children daily.

The most common and widespread health risk associated with drinking water is contamination either directly or indirectly by human or animal excreta particularly faeces, if such a contamination is recent and those responsible for it include carriers of communicable enteric diseases. Some of the pathogenic organisms that cause these diseases may be present in water. Drinking such water or using it in food preparation may then result in new infection. All the water-borne diseases claim a large number of lives every year in spite of better health facilities and increased expenditure on health. Water intended for human consumption should be safe and wholesome. The quality of water is of paramount importance for the sustenance of life.

The pathogenic agents involve bacteria, viruses and protozoa that may cause disease that varies in severity from mild gastroenteritis to severe or fatal dither, dysentery, hepatitis and typhoid fever. Most of these pathogens are widely distributed in the whole world. Poor quality has direct detrimental effect on human health. Thus the control of microorganisms, disinfections and prevention of bacterial growth in drinking water are critical for public health and hence it is important to carry out the assessment of quality of drinking water from time to time.

In Indian cities, major water supplies generally remain unmanaged due to various factors such as inadequate finances, low political priority, inadequately trained personnel, and lack of proper disposal sites. As a result, residents are prone to diseases like hepatitis, malaria, dengue fever, elephantiasis, cholera, etc.

India has had environmental legislation dealing with water pollution since the Indian Penal Code in 1860. However, this law and similar laws over the next 100 years deal with only public springs and reservoirs used for the purpose of drinking. It was not until the 1974 Water (Prevention and Control of Pollution) Act, that water quality was considered legally as an environmental issue. This act, and the Environment Protection Act which followed in 1986, empowered the Central Pollution Control Board to lay down and maintain ambient water standards, to demand information regarding effluent emissions, to shut down polluting activities, and to prevent new discharges of effluent and sewage. Although these regulations give the national bodies and their state-level counterparts broad powers to control the problem of water pollution, until recently, enforcement has been rather weak, and there is still ample room for improvement. In 1987, the first year after the passage of the Environment Protection Act, there were less than 1700 cases nationwide launched regarding water quality. This figure increased to 4400 in 1992³. The success rate of prosecution in these court cases has, however, showed a gradual decline over this time, from 81 percent in 1988, to only 62 percent in 1992³.

Water that is free from disease producing microorganisms and chemical substances, which are deleterious to health, is called potable water. It is contaminated when it contains infective and parasitic agents, poisonous chemical substances, industrial or other wastes or sewage.

Though ground water is considered to be free of pathogens since it is protected by impervious strata, this protection is frequently not available and ground water is becoming polluted with increasing frequency. The pollution of ground water by seepage from sewer lines and industrial effluents may increase the concentration of organic, inorganic and toxic materials. It is therefore essential to assess the

quality of the water from its bacterial count i.e. MPN and also other relevant parameters over the year.

The chief characteristics⁴ which must be present in drinking water are earmarked by World Health Organization (WHO) and also by the Indian Standard Institution or named as Indian Bureau of Standards. In all published drinking water standards, the contaminants or constituents of interest are subdivided in various ways (Table 2)

Table 2 : Contaminants / Constituents of Drinking Water

Contaminants/ Constituents	Examples
Microbiological	Bacteriological, e.g. <i>Escherichia coli</i> , coliform organisms Virological
Biological	Algae Animals
Chemical substances related to health	Inorganic, e.g. trace metals (particularly lead), toxic substances (arsenic, cyanide), fluoride, nitrate, nitrite. e.g. pesticides, polymorphic hydrocarbons, trihalomethanes
*Chemical substances related to aesthetic considerations	Taste and odour e.g. chlorophenols Appearance, e.g. colour , turbidity
*Control parameters	e.g. pH, corrosivity

* Some scientists consider these parameters under physical parameters.

QUALITY PARAMETERS :

I. PHYSICAL PARAMETERS :

Parameters like turbidity, salinity, foam, froth, colour, odour and temperature, etc., are the physical parameters, which must have limiting values as, prescribed by WHO. Turbidity, colour, taste and odour are also considered to be aesthetic parameters as they can be detected by senses. They are important in monitoring community water supplies because they may cause the water supply to be rejected or alternatively poor quality sources to be adopted.

➤ **pH :**

It is important to measure pH since the efficacy of disinfection with chlorine is highly pH dependent. Where the pH exceeds 8.0, disinfection is less effective.

➤ **Turbidity :**

Turbidity is important because it affects both the acceptability of water to consumers, and the selection and efficiency of treatment processes, particularly the efficiency of disinfection with chlorine since it exerts a chlorine demand and protects microorganisms and may also stimulate growth of bacteria.

➤ **Colour :**

Colour in drinking water may be due to the presence of coloured organic matter, e.g. humic substances, metals such as iron and manganese. Or highly coloured industrial waste.

➤ TASTE AND ODOUR :

Odours in water are caused mainly by the presence of organic substances. Some odours are indicative of increased biological activity, others may result from industrial pollution. Taste problems like contamination with ions like magnesium, calcium, sodium, copper, iron, and zinc are generally detected by the taste buds in the oral cavity. Taste problems usually account for the largest single category of consumer complaints.

II. CHEMICAL PARAMETERS:

Chemical parameters which influence the quality of the drinking water are pH, alkalinity, redox substances present, dissolved oxygen, biochemical oxygen demand, chemical oxygen demand etc. Besides these, salts, like ammonium or ammonia, nitrates, phosphates, chlorides, silica, calcium, magnesium, iron, heavy metals, sodium, potassium, detergents and pesticides.

➤ ALKALINITY:

Alkalinity is defined as the quantity of ions that will react to neutralize hydrogen ions. Alkalinity of the water is thus a measure of the capacity of water to neutralize a strong acid. Alkalinity in natural waters is due to free hydroxyl ions and hydrolysis of salts formed by weak acids and strong bases, and especially due to dissolution of carbon dioxide in water. These compounds result from the dissolution of mineral substances in the soil and atmosphere. Alkalinity in itself is not harmful to human beings; still the water supplies with less than 100 mg/l are desirable for domestic use.

➤ ACIDITY:

Acidity is defined as the power of water to neutralize hydroxyl ions and is expressed in terms of calcium carbonate. It is usually caused by the presence of free carbon dioxide, mineral acids such as H_2SO_4 and weakly dissociated acids. Iron and aluminium salts hydrolyze in water to release mineral acidity.

➤ HARDNESS:

Hardness is defined as the concentration of multivalent metallic cations in solution. At supersaturated conditions, the hardness cations will react with the anions in the water to form a solid precipitate. Hardness in water is caused by dissolved calcium and to a lesser extent magnesium. Hardness is classified as carbonate hardness and non-carbonate hardness, depending on the anions with which it associates.

The degree of hardness in water may affect its acceptability to the consumer in terms of taste. It is usually expressed as equivalent quantity of calcium carbonate. Depending on pH and alkalinity, hardness above 200 mg/l can result in scale deposition, particularly on heating. Soft waters with a hardness of less than about 100 mg/l have a low buffering capacity and may be more corrosive to water pipes. Although a number of ecological, analytical and epidemiological studies have shown statistically significant inverse relationship between hardness of drinking water and cardio-vascular disease, the available data are inadequate to permit a conclusion that the association is causal. There is some indication that very soft waters may have an adverse effect on mineral balance, but the detailed studies were not available for evaluation.

➤ NITRATE AND NITRITE:

Nitrate and nitrite are naturally occurring ions that are part of the nitrogen cycle. Naturally occurring nitrate levels in surface and ground water are generally a few mg/l. In many ground waters, an increase of nitrate levels has been observed owing to the intensification of farming practice. Contamination with nitrogen containing fertilizers as well as animal or human natural organic waste can raise the concentration of nitrate in water. Wastes containing organic nitrogen are decomposed in soil or water by microbial action to first form ammonia, which is then oxidized to nitrite and nitrate. Because nitrite is easily oxidized to nitrate, it is nitrate that is predominantly found in ground and surface waters.

Nitrate presents some unique problems as a groundwater threat. Water soluble, it moves quickly through soils causing a potential contamination. Large concentrations in drinking water have been blamed to cause methemoglobinemia in babies. Cases of rare disease are normally associated with water contaminated with both nitrate and sewage bacteria. There is also concern that the incidence of stomach cancer may be related to nitrate in drinking water. Other health problems associated with nitrate toxicity include goiter, oral cancer, cancer of colon, rectum or other gastrointestinal cancers, lymphoma, dyspnea etc.⁵

In humans, ingested nitrate is rapidly absorbed from the proximal small bowel and distributed throughout the body. Nitrate then enters the large bowel from the blood where it is rapidly converted to highly reactive nitrite, in part by fecal microorganisms. The formed nitrite is reabsorbed into the blood where it reacts with ferrous (Fe^{+2}) iron of deoxy hemoglobin, forming methemoglobin with iron in the ferric (Fe^{+3}) state. Fe^{+2} iron is unable to transport oxygen. Nitrates are rapidly converted in the liver to the nitrated metabolites and inorganic nitrite,

which are then excreted in urine. Methylene blue is an effective antidote for most patients with methemoglobinemia.

Gastroenteritis with vomiting and diarrhea can exacerbate nitrite formation. Infants less than four months of age are at a particular risk of nitrate toxicity from contaminated water. By proper management, nitrate leaching can be reduced and the resulting pollution minimized⁵.

➤ SULPHATE:

Gastrointestinal effects have been observed resulting from ingestion of drinking water containing high sulphate levels. The presence of sulphate in drinking water may also cause noticeable taste and may contribute to the corrosion of distribution systems.

➤ TOTAL DISSOLVED SOLIDS:

Total dissolved solids (TDS) comprises of inorganic salts (calcium, magnesium, potassium, sodium, bicarbonates, chlorides and sulfates) and small amounts of organic matter that are dissolved in water. The TDS concentration is a secondary drinking water standard. Though elevated TDS concentration is not a health hazard can result in water having a bitter or salty taste. Therefore, it is regulated out of an aesthetic sense rather than a health hazard. Elevated total dissolved solids can result in incrustations, films, or precipitates on fixtures; corrosion of fixtures, and reduced efficiency of water filters. Presence of high level of TDS in drinking water may be objectionable to consumers. TDS in drinking water originates from natural sources, sewage, urban run-off and industrial wastewater and chemicals used in the water treatment process, and the nature of the piping or hardware used to convey the water, i.e., the plumbing.

Water is a good solvent and picks up impurities easily. Pure water, which is tasteless, colorless, and odorless, is often called the universal solvent. "Dissolved solids" refer to any minerals, salts, metals, cations or anions dissolved in water. In general, the total dissolved solids concentration is the sum of the cations (positively charged) and anions (negatively charged) ions in the water. Therefore, the total dissolved solids test provides a qualitative measure of the amount of dissolved ions, but does not tell us the nature or ion relationships. The total dissolved solids test is used as an indicator test to determine the general quality of the water.

Following table can be used as a generalization of the relationship of TDS to water quality problems.

Cations combined with Carbonates e.g. CaCO_3 , MgCO_3 etc.	Associated with hardness, scale formation, bitter taste
Cations combined with Chloride NaCl , KCl	Salty or brackish taste, increase corrosivity

➤ CHLORIDES:

Chlorides occur naturally in all types of water. In natural freshwaters however, its concentration remains quite low. It is harmless up to 1500 mg/l concentrations but produces a salty taste at 250-to 500-mg/l levels. High concentrations of chloride give an undesirable taste to water and beverages.

The most important source of chloride in water is the discharge of domestic sewage. Human and animal excreta have a very high quantity of chloride together with nitrogenous compounds. A person per day excretes about 8-15 grams of NaCl. Therefore the chloride concentration serves as an indicator of pollution by sewage.

II. TRACE ELEMENTS:

Increasing quantity of heavy metals in natural resources is currently an area of great concern, especially since a large number of industries discharge their metal containing effluents to fresh waters without adequate treatment. Many metals are essential for animal and plant life e.g. Cobalt, Copper, Molybdenum etc. However, excess concentration, particularly of heavy metals, those having a density more than five times higher than that of water, in water system may be harmful due to their acute toxicity. They may cause physiological disorders, many of them quite serious. Though these metals are usually present in trace amounts in natural waters, many of them are toxic even at very low concentrations. Metals such as arsenic, lead, cadmium, mercury and selenium are highly toxic even in small amounts. Their concentrations increase in water due to addition of industrial waste and sewage.

Metal ions and their complexes exhibit a wide range of the toxicity to the organism that ranges from sub-lethal to lethal depending upon the time of exposure and the prevailing conditions in the ambient water conductivity is linked to the concentration of electrolytes in water which in turn is linked to mineral constituents. High content of **sodium** in combination with **chloride** and **nitrate** in water raises blood pressure and often damages the kidney. Some metal, such as Cu, Zn, Fe are toxic in high quantities for human health while Pb, Cr, As, Hg are

highly toxic even in low concentrations. Higher concentrations of **Chromium** in drinking water cause disorders of skin and respiratory tract.

SOURCE AND POTENTIAL HAZARDS OF SOME TRACE ELEMENTS:

➤ CADMIUM:

Cadmium metal is used in the steel industries and in plastics. Cadmium compounds are widely used in batteries. Cadmium is released to the environment in wastewater and diffused pollution is caused by contamination from fertilizers and local air pollution. Contamination in drinking water may also be caused by impurities in the zinc of galvanized pipes and solders and some metal fittings. Absorption of cadmium compounds is dependent on the solubility of the compounds. Cadmium accumulates primarily in the kidneys and has a long biological half-life in humans of 10-35 years.

➤ COPPER:

Copper is widely distributed in nature. It is an essential metal required by almost all living organisms in some of their enzyme systems, but at higher concentration it works essentially as a pollutant. Copper levels in drinking waters are usually low at only a few micrograms per liter but copper plumbing may result in greatly increased concentrations. Concentrations can reach several mg/l following a period of stagnation in pipes. Copper is toxic in high quantities for human health. Acute gastric irritation may be observed in some individuals at concentrations in drinking water above 3 mg/l. In adults with hepatolenticular degeneration, the

copper regulatory mechanism is defective and long-term ingestion can give rise to liver cirrhosis. Copper can also give rise to taste problems.

➤ IRON:

Iron is one of the most abundant metals in the earth's crust. It is mostly a naturally derived metallic pollutant. Maximum permissible limit prescribed by WHO is 0.1 ppm. It is found in natural fresh waters at levels ranging from 0.5 to 50 mg/l. The high values of iron are undesirable and may cause the health problem especially the diseases related to abdomen trouble.

Iron may also be present in drinking water as a result of the use of iron coagulants or the corrosion of steel and cast iron pipes during water distribution.

➤ LEAD:

Lead is a highly toxic metal. Maximum permissible limit 0.1 ppm prescribed by WHO⁶.

Intake from drinking water constitutes a greater proportion of total intake. Lead is present in tap water to some extent as a result of its dissolution from natural sources but primarily from household plumbing systems containing lead in pipes, solder, fittings or service connections to homes. The amount of lead dissolved from the plumbing system depends on several factors including pH, temperature, water hardness, and standing time of the water, with soft, acidic water being the most plumb solvent. Lead is used principally in the production of lead- acid batteries, solder and alloys. Owing to the decreased use of lead containing

additives in petrol and of lead containing solder in the food processing industry, concentrations in air and food are declining.

Placental transfer of lead occurs in humans as early as twelfth week of gestation and continues throughout development. Young children absorb 4-5 times as much lead as adults and the biological half-life may be considerably longer in children than in adults.

Lead is a general toxicant that accumulates in the skeleton. Infants, children up to six years of age and pregnant women are more to susceptible its adverse health effects. Higher concentration of lead in drinking water causes disruption of hemoglobin synthesis, anemia, damage to nervous system, kidneys and brain. Lead also interferes with calcium metabolism, both directly and by interfering with vitamin D metabolism. Lead is toxic to both the central and peripheral nervous systems, inducing subencephalopathic neurological and behavioral effects.

➤ MANGANESE:

Manganese is one of the most abundant metals in the earth's crust and usually occurs together with iron. Dissolved manganese concentrations in ground and surface waters that are poor in oxygen can reach several mg/l. On exposure to oxygen manganese can form insoluble oxides that may result in undesirable deposits and colour problems in distribution systems. Evidence of manganese neurotoxicity has been seen in minors following prolonged exposure to dust containing manganese. But no evidence has been observed regarding toxicity in humans associated with the consumption of manganese.

➤ **MERCURY:**

Mercury is a highly poisonous substance and increases in natural waters by the industrial wastes. It affects the central nervous systems in humans and at higher doses may be fatal.

➤ **ZINC:**

Zinc is present in high concentrations in industrial wastes. Although zinc is a very essential micronutrient in humans, at high concentrations it may cause some toxic effects. Zinc salts produce an undesirable taste to the water.

➤ **ARSENIC:**

Environmental interest in arsenic and arsenic compounds arises from their toxicity to humans on ingestion and their inflammations caused by skin contact. Sources of arsenic in water are mainly from herbicides and wastes from industries such as nonferrous metal refining, fertilizer, petroleum refining and steel works. Generally drinking water contains either negligible or micro-amounts of arsenic. Due to its high toxicity, a tentative limit of 0.05 mg / l of arsenic in drinking water has been recommended by WHO and ICMR, India.

The principal sources of water pollution are shown in Fig. 3

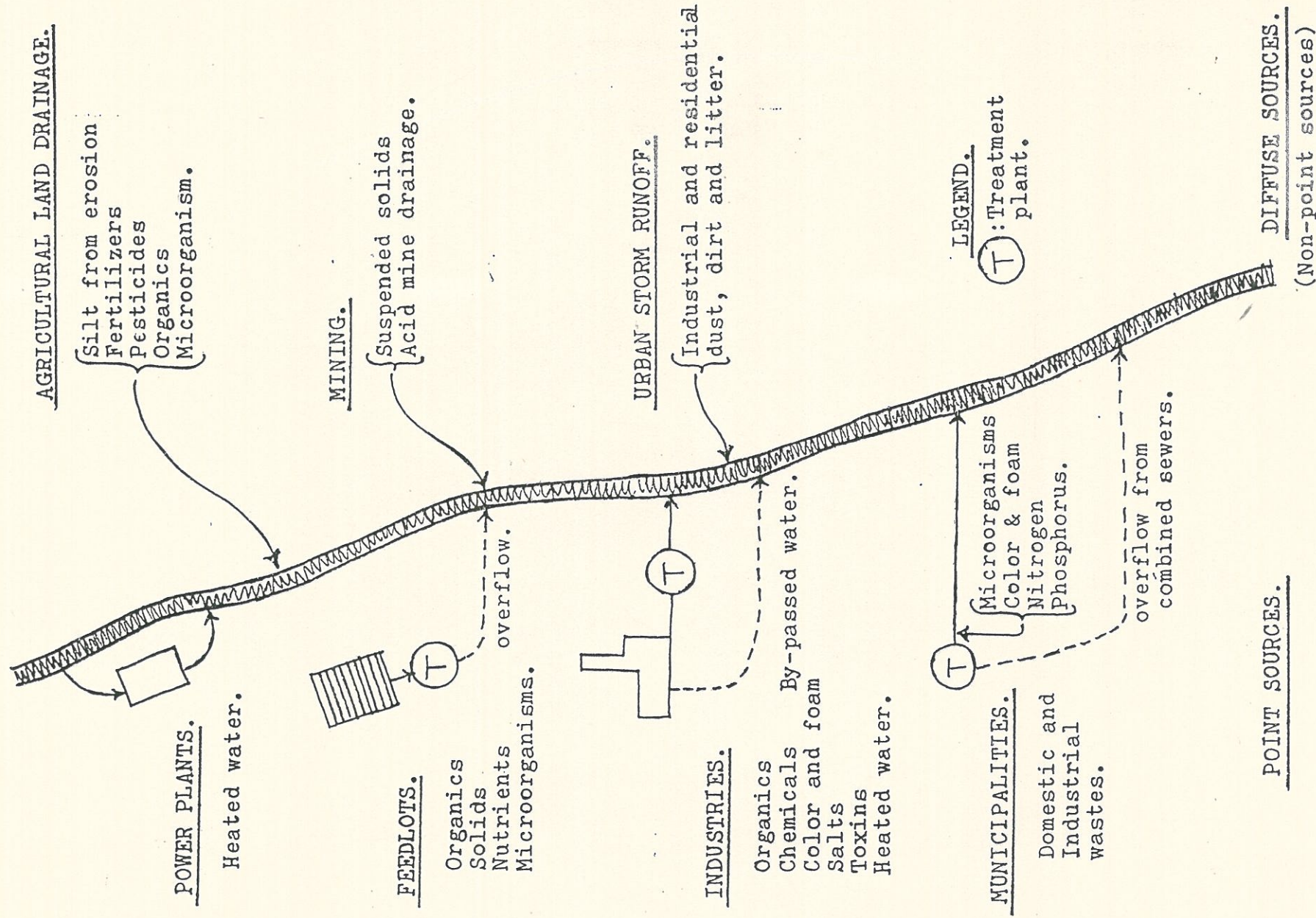


Fig. 3 : Principal Sources of Water Pollution

III. BIOLOGICAL PARAMETERS :

Pathogenic bacteria coli forms and some algae, fungi, viruses etc., influence the quality of drinking water.

Table 3 : Classification of water related infective diseases ⁷

No.	CATEGORY	EXAMPLES
1	Water borne infections (WBI)	
	a. Classical	Leptospirosis, Cholera, Typhoid, Tuleremia
	b. Non-classical	Infective hepatitis, Paratyphoid
2	Water washed infections (WWI)	
	a. Skin and eyes	Scabies, Trachoma, Skin sepsis, Ulcers, Conjunctivitis
	b. Diarrheal and Classical WBI	Bacillary and amoebic dysentery Gastrointestinal and ascariasis
3	Water based infections	
	a. Penetrating skin	Schistosomiasis
	b. Ingested	Guinea worm
4	Infection with water related insect vectors	
	a. Breeding near water	Sleeping sickness
	b. Breeding in water	Yellow fever, Onchoerciasis, Malaria
5	Infection primarily of defective sanitation	Hook worm

- Water borne diseases : Infection spread through water supplies
- Water washed diseases : Diseases due to lack of water for personal hygiene
- Water based diseases : Infections transmitted through an aquatic invertebrates
- Water related insect vectors : Infections spread by insects that depend on water.

MICROBIAL QUALITY:

Frequent examinations for faecal indicator organisms remain the most sensitive and specific way of assessing the hygienic quality of water.

The major indicator organism of faecal pollution is *Escherichia coli* (*E. coli*). *E. coli* is the indicator of first choice when resources for microbiological examination are limited. Because enteroviruses, amoebae, and other parasites are known to be more resistant to disinfections than *E. coli* and faecal streptococci, the absence of latter organism will not necessarily indicate freedom from the former. *E. coli* is found in abundance in the intestinal tract of man as well as other animals because of which it was logically assumed that water could not become polluted with faecal material without this organism being present and hence its presence might be considered *prima facie* evidence of pollution with faecal material. *Escherichia coli* is a member of the family *Enterobacteriaceae*. It grows at 44 - 45°C on complex media, ferments lactose and mannitol with the production of acid and gas. *E. coli* is abundant in human and animal faeces, sewage, treated effluents, and all natural waters and soils that are subject to recent faecal contamination, whether from humans, agriculture or wild animals and birds.

The tests for potability of a water supply are generally based on the presence or absence of this organism. Its presence in water does not mean necessarily that disease organisms are present but that they *may be* present. The most important bacterial diseases transmitted by water are dysentery, cholera and typhoid. Since they are intestinal diseases, the causative agents are found in the intestinal contents. Therefore, the presence of sewage in a water supply means that one or more of these disease organisms may be present. In other words all sewage-polluted waters are potentially dangerous for human consumption.

The test for coliform bacilli, particularly *E. coli*, is universally regarded as the best available criterion for the bacteriological quality of water. The essential facts in support of this test are:

- There is no practicable test for specific pathogens.
- All enteric infectious agents disseminated through drinking water find their way into the water through sewage.
- Fresh sewage always contains large numbers of *E. coli*.
- *E. coli* normally is found only in the intestinal tract of vertebrates, or faeces polluted material.
- *E. coli* is easily tested for, and the test is extremely delicate. At the present time a water found to contain appreciable numbers of *E. coli* is universally regarded as potentially dangerous and hence, unsatisfactory for domestic purposes unless purified.
- The enteric bacterial pathogens are known to be equally as sensitive to environmental conditions outside the intestinal tract as is *E. coli*.

Environmental factors generally produce marked fluctuations in the bacterial counts. Disease and other organisms whose natural habitat is the intestinal tract of man and animals tend to die very rapidly. The forces, which tend to produce bacterial self-purification, are sedimentation, activities of other organisms, ultraviolet light, temperature etc.

The effect of storage is to decrease greatly the numbers of organisms in water. Bacteria have a specific gravity slightly greater than that of distilled water, which means that they will slowly settle in a still body of water. However, the greatest factor responsible for the sedimentation of bacteria is their attachment to

suspended particles. The suspended particles in settling mechanically remove the organisms from the upper layers of the water.

Mumbai's Water Supply

Mumbai with a population of nearly 12 million, is one of the most densely populated mega-cities of the world. Its water supply system has grown over the last 135 years and is currently rated amongst the eighth largest in the world. The current rate of consumption of water in the city is 2,893 million liters per day. The supply system is unique and complex. Six sources, viz. Bhatsa, Modak Sagar, Tansa, Tulsi, Upper Vaitarna and Vihar lakes together fulfill the city's almost limitless thirst for fresh water.

Vihar

Vihar was Mumbai's first piped water supply scheme and was commissioned in 1860. Three earthen dams and stone masonry overflow sections were constructed to impound the Mithi river 20 Kms north of Mumbai. The impoundage is called Vihar lake. The initial supply was 32 million liters a day (mld), which was increased by raising the height of the dam in 1872, to 68 mld.

Tulsi

Due to the critical situation of water shortage a Tulsi lake was developed on the river Mithi, upstream of the Vihar lake. The scheme consisted of an earthen dam and a masonry dam and a 600mm diameter pipeline to carry 18mld of water to the service reservoir at Malabar Hill.

FROM MODAK SAGAR
UPPER VAITARNA

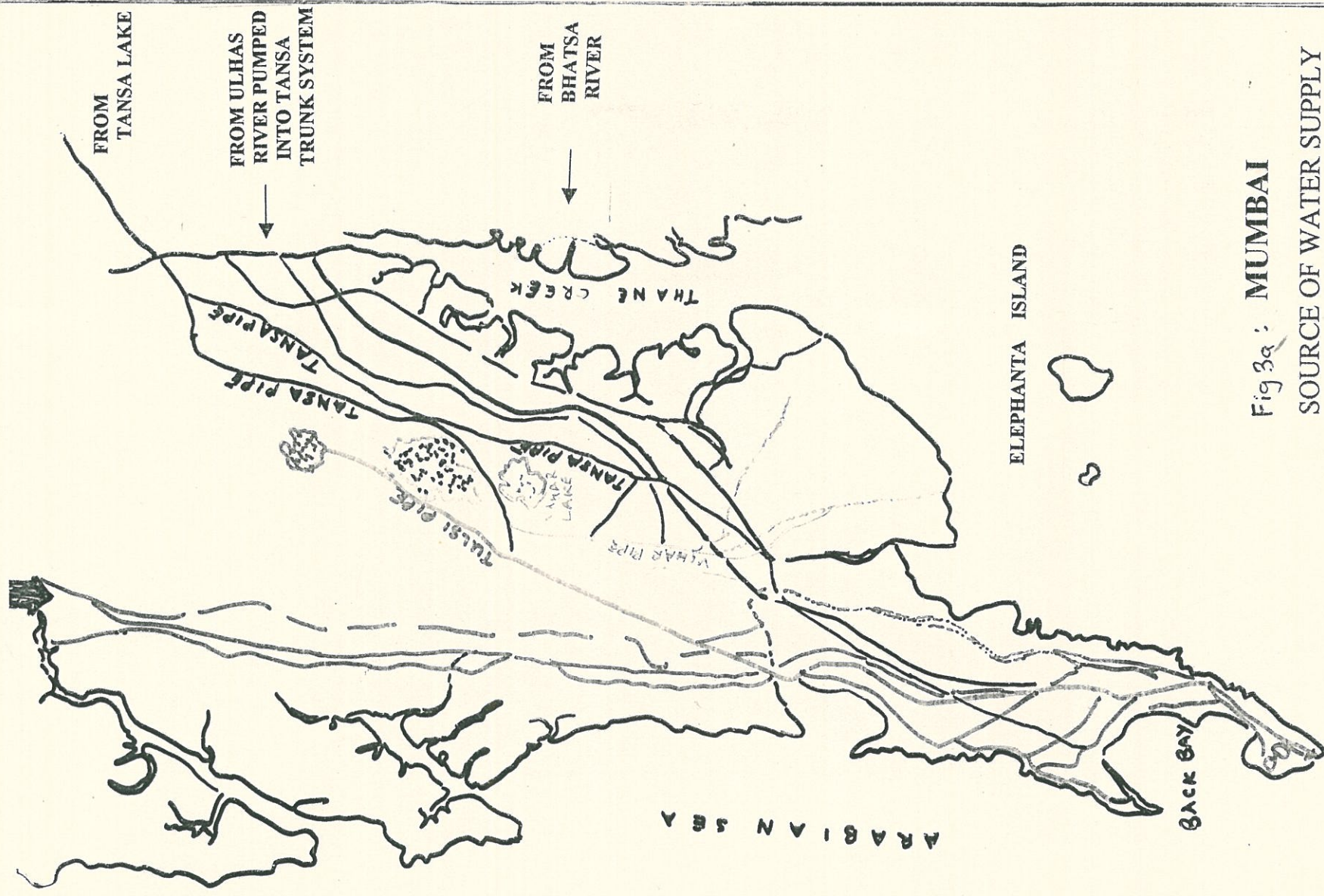


Fig 3a: **MUMBAI**

SOURCE OF WATER SUPPLY

Powai

Powai scheme was taken up on a tributary of the Mithi river as a water famine was anticipated in 1891. The lake proved too shallow to collect water of acceptable quality for domestic purpose. Moreover it was too low-lying to facilitate a proper gravitational flow into the city. Due to the inferior quality of water from this catchment, the water supply was diverted for dairy and agricultural use.

Tansa

The total supply from the Tansa, the dam that is situated about 110 Km to the north of Mumbai, constructed on Tansa River, is 410 mld. This source was developed in four stages and was completed in 1948.

Lower Vaitarna (Modak Sagar)

To meet the increased demand of the city because of the spurt in industrial and commercial activities after independence, the Vaitarna –cum-Tansa scheme was conceived. It is a concrete gravity dam constructed using pre-cooled control concrete, the first of its kind in the country, and is called Modak Sagar. A 7.2 Km tunnel is constructed between Modak Sagar and Tansa, with the higher elevation of the water level in Modak Sagar facilitating flow by gravity. The Vaitarna scheme, completed in 1957, brought an additional 490 mld of water to the city.

Upper Vaitarna

This scheme was designed as a hydro-electric-cum-water-supply scheme and was completed in 1972. The water from Upper Vaitarna, after generation of power, owes to Lower Vaitarna. Additional 544 mld of water was made available to the city through this scheme.

Bhatsa

Water was extracted from a small impoundage of Pise, 48km downstream of the Bhatsa dam. Pumping, treatment and conveyance facilities were constructed at Pise, Panjrapur and Bhandup. This scheme supplies 1365mld of water to Mumbai.

Salient features of the distribution system

- Comprises of 26 service reservoirs.
- Network of water mains has a total length of about 2400 km.
- The entire distribution network is divided into 106 water supply zones.
- Supply from each reservoir is monitored by the three local control stations located in the southern, western and eastern parts of the city.
- The master control center located at Bhandup complex does the budgeting of the available water supply from different sources.

Table 4 gives the current water situation for the Mumbai City at a glance.

Table 4 : The current water situation[#]

Source	Water supply in mld*	Percentage
Vihar	68	2.35
Tulsi	18	0.62
Tansa	408	14.10
Vaitarna	490	16.94
Upper Vaitarna	544	18.80
Bhatsa	1365	47.18
Total supply	2893	100

Source : BMC

* mld = million liters per day

Mumbai is located on the Western Sea Coast of India at $18^{\circ} 53' \text{ N}$ to $19^{\circ} 16' \text{ N}$ latitude and 72° E to $72^{\circ} 59' \text{ E}$ longitude. It occupies an area of 437 sq. km. which is 0.14% of the total area of the State of Maharashtra. Mumbai experiences tropical savanna climate, it receives heavy southwest monsoon rainfall, in the range of 1850mm to 2000mm per year. On an average, the temperature ranges from 17°C to 35°C , with trivial difference between summer and winter months, whereas relative humidity ranges from 50% to 75%.

Greater Mumbai is divided into 2 Districts: City & Suburban and for administrative purpose into 23 municipal wards. The areas under these wards are shown in Table 5. These extend from South Mumbai to Borivali / Dahisar on the Western line, to Mulund on the Central line, and up to Chembur / Mankhurd on the Harbour line. Fig. 4 gives the map of these wards.

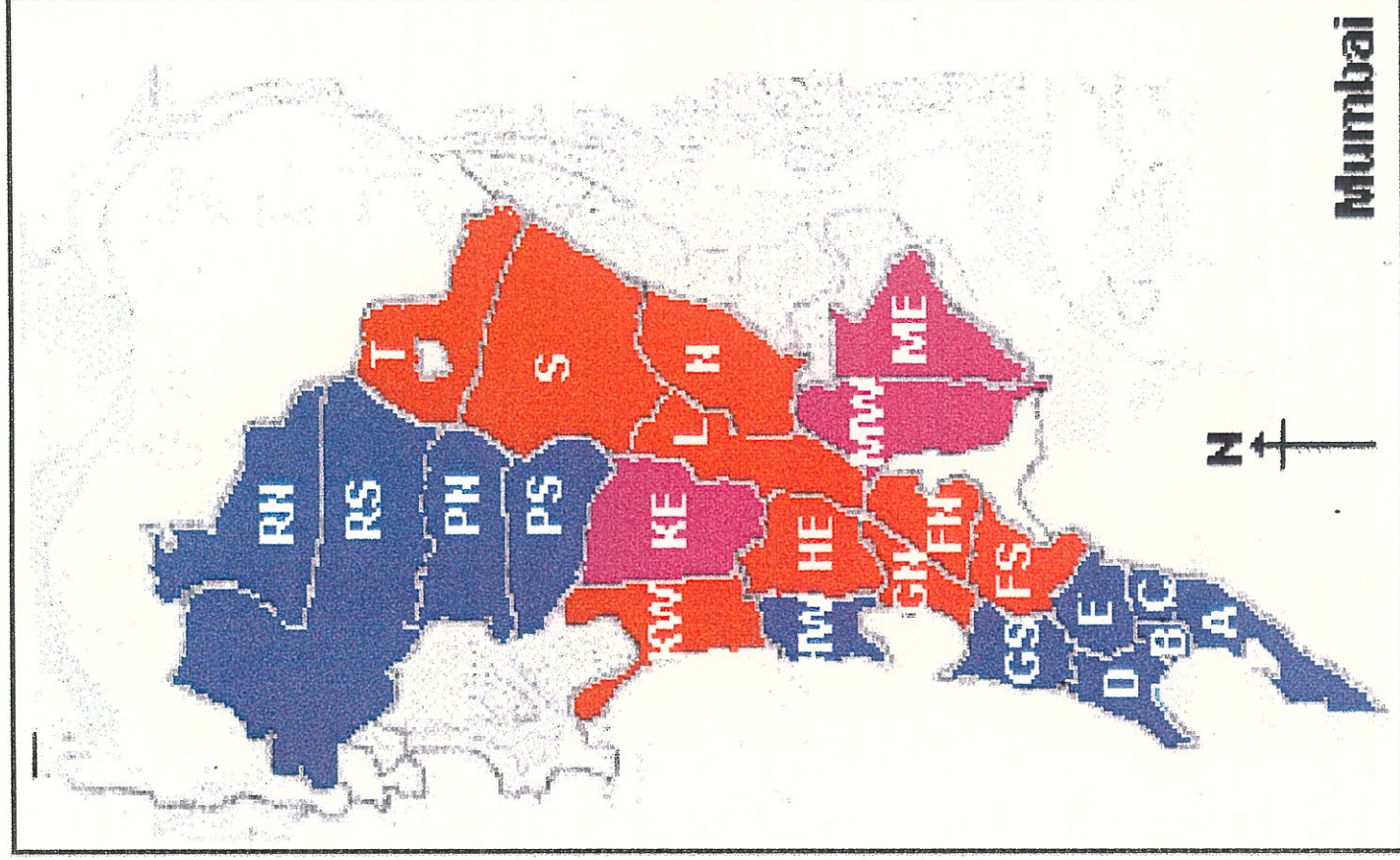


Fig- 4 : Map of Mumbai showing various wards

MAP OF POPULATION DENSITY OF MUMBAI



Fig: 4a

Table 5 : Municipal wards and the area under these wards

No.	WARD	AREAS
1	A	Colaba, Navy Nagar, Fort, Cuffe Parade (Colaba to Churchgate, and Fort)
2	B	Masjid, P, D'Mello Road, Muhammad Ali Road (Mandvi, Umarkhadi, Dongri)
3	C	Grant Road, Islampur, (Marine Lines, Girgaon, Paydhuni)
4	D	Bombay Central, Kamatipura, Girguam (Grant Road, Malabar Hill, Mahalaxmi)
5	E	Byculla, Mazgaon, Agripada (Tardeo, Byculla, Bombay Central, Mazgaon)
6	F / S	Parel, Sewri (Lal Baug, Parel, Sewree)
7	F / N	Sewri, Wadala (Wadala, Antop Hill, Matunga, Sion)
8	G / S	Prabhadevi (Worli, Prabhadevi, Elphinstone Road)
9	G / N	Dharavi, Sion, Koliwada (Dadar, Mahim, Dharavi)
10	H / E	Bandra (E) to Santa Cruz (E), Vakola (Eastern sides of Bandra, Khar, Santacruz, Kalina)
11	H / W	Bandra (W) to Santa Cruz (W) (Western sides of Bandra, Khar, Santacruz)
12	K / E	Vile Parle (E) to Jogeshwari (E) (Eastern side of Vile Parle, Andheri, Jogeshwari)
13	K / W	Vile Parle (W) to Jogeshwari (W), Juhu, Versova (Western sides of Vile Parle, Andheri, Jogeshwari)
14	L	Kurla, Sakinaka (Kurla, Saki Naka)
15	M / E	Chembur, Govandi, Mankhurd, Deonar (Eastern Chembur, Mankhurd, Govandi, Deonar, Trombay)
16	M / W	Tilaknagar, Thakkar Bappa, Ghatla (Western Chembur)
17	N	Vikhroli, Ghatkopar, Pantnagar, Barvenagar (Ghatkopar, Vikhroli)
18	P / S	Goregaon (East and West) (Goregaon)
19	P / N	Malad (East and West) (Malad, Kurar Village)
20	R / S	Kandivili (East and West) (Kandivili, Borivali)
21	R / N	Borivili and Dahisar (East and West)
22	S	Bhandup (Kanjur, Powai, Bhandup)
23	T	Mulund

• 60 % of the city's population lives in slums

AIMS AND OBJECTIVES:

Municipal authorities and other Government and Semi- Government organizations regularly analyze the water supplied to the city and try to monitor its quality. However, it is learnt that representative samples are collected from fixed sites for a particular pocket of population. Further, this system is not transparent enough in the sense that the results of these analyses are generally not communicated to the masses and people remain unaware of the findings. Hence, through this study, attempts are being made to apprise the public of the quality of drinking water supplied to them. Besides, mass education for maintenance of water quality is also essential so that chances of contamination and breaking of epidemics can be minimized. Though 10 percent of city's water is unfit for drinking⁹, there are no programs to identify these samples and educate the people about the situation. Through the present project we intend not only to analyze the water samples but also to educate the people and to identify the trouble making situations.

Plan of Work:

1. To collect drinking water samples from the various wards covering the cross sectional areas in Mumbai so as to cover the water supply of maximum population.
2. To collect the water samples from the reservoirs.
3. To assess the suitability / quality of the samples, collected from various areas, for drinking purpose by analyzing various physical and chemical parameters.
4. To assess the microbiological contamination by MPN technique.
5. To create public awareness for the desirable quality of drinking water. Try to detect the root cause of deterioration of the quality of drinking water.

MID - DAY

Vol XXII - No 131

★★ Mumbai, Saturday, December 2, 2000

HOW SAFE IS THE WATER YOU DRINK?

BMC'S TESTS CONFIRM 10 PER CENT OF CITY'S WATER IS 'UNFIT FOR DRINKING'

By Archana Sharma

TEN per cent of the water consumed in Mumbai daily is "unfit for drinking" according to tests conducted by the Brihanmumbai Municipal Corporation's own Laboratory for Water and Food. This is double the permissible level of five per cent contamination set by the World Health Organisation (WHO) for water supply the world over.

In fact, only last month five of the about 6,000 water samples from across the city and suburbs revealed the presence of *Escherichia Coli*, the bacteria responsible for the deadly gastroenteritis infection. WHO does not allow for the presence of such *E coli* bacteria. Last week two persons died and about 250 people were affected by cholera and gastroenteritis which is believed to be under control.

However, Municipal Analyst CH Dalvi dismissed fears of the possibility of the disease spreading to Mumbai, saying that recent water tests did not reveal *Vibrio cholerae* which is responsible for cholera.

Two months ago, one person died and more than 50 were affected by gastroenteritis in Parel due to water that was contaminated by sewage. Dalvi said that the Parel water supply contained typhoid and dysentery-causing bacteria as well as *E coli*, but there was no sign of the cholera germs. Lab test results available to MID-DAY indicated that of the 161 samples from non-slum areas analysed on Tuesday, 12 were unfit for drinking. Of the 39 samples collected from slum areas, nine were unpotable. These samples contained bacteria from the *Coliform* group that includes the *E coli* bacteria.

On November 23, of the 151 samples from non-slum areas that were tested, nine were unfit for drinking, whereas only one out of 39 samples from slum areas was declared unfit. None of the samples contained *E coli* bacteria. Dalvi explained that though the water containing bacteria from the *Coliform* group may not be harmful "we declare it unpotable in keeping with WHO standards."

The problem arises because drainage pipelines and water mains are very old and some water lines passing through drainage channels get contaminated with sewage seeping in through corroded water pipes, says Dalvi. The municipal health authorities have already declared 50 areas that face a high risk of gastroenteritis due to the bad sanitary conditions in these areas.

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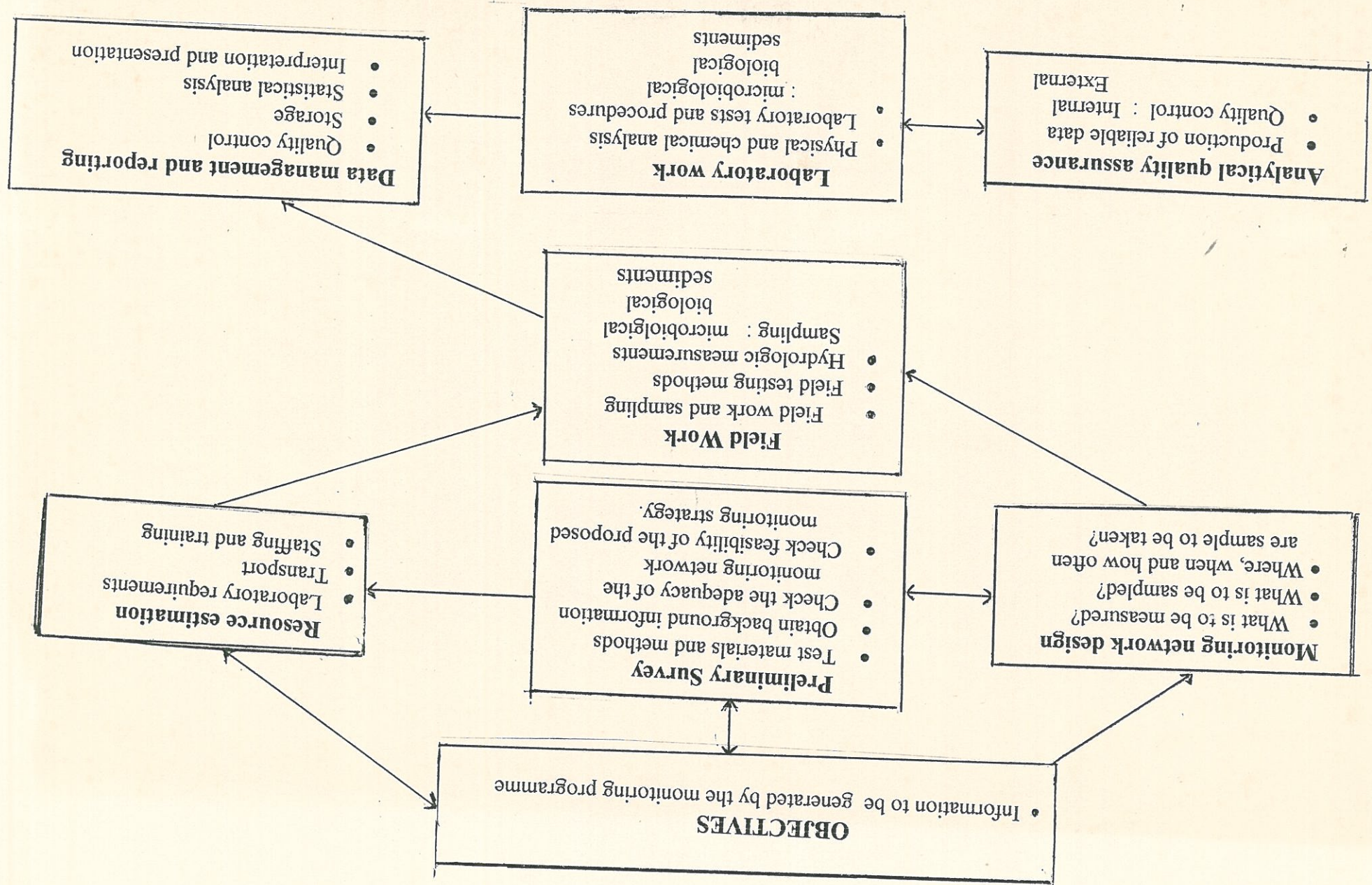


Fig. 5 : Water Quality Monitoring Elements

METHODS

In order to have a measure of the overall quality in a water distribution network, the following monitoring system was evolved:

Sample Collection → Laboratory Analysis → Data Handling → Data Analysis
→ Information Utilization → Decision Making .

In evaluating the total pollution , all parameter values at each node had been taken into account.

Collection of water samples :

This is a very important and significant part of the analysis of water. A sample denotes a portion of water of interest, when is transferred from a sampling point in a container to another position where the analysis is carried out. Any sample taken for analysis from a proper source is assumed to be not having received any treatment, apart from physical processes so involved in transference of water of interest.

➤ Sampling Protocol:

The samples were collected between 11.00 am and 2.00 pm for maintaining as much uniformity as possible. Water samples meant for physico-chemical parameters were collected in hard, white first quality jerry cans of 1 Liter capacity which had been rinsed with 1:1 nitric acid followed by distilled water and later with the samples before filling the cans with water samples to be tested. After sample collection, the cans were closed tightly and labeled. They were brought into the laboratory and tested.

Water samples for microbiological analysis were collected in sterilized plastic containers of 100 ml capacity each. Before sterilization, 2-3 drops of 0.1 N sodium thiosulphate (dechlorinating agent) were introduced into the containers to prevent the germicidal action of chlorine. In order to obtain a representative sample from a tap, the water was allowed to run for at least 5 minutes to remove any contaminating organisms present around the opening of the faucet. The following sampling protocol was observed during the sampling for the microbial parameter:

The bottle was held tightly in the right hand and the stopper was removed with the left hand. The water was filled up to half inch below the stopper level to permit mixing of the contents. After the sample was collected, the stopper was carefully replaced to avoid contamination. The precaution was taken to avoid dipping of the fingers inside the neck or touching the stopper. This eliminated the possibility of external contamination of the contents of the bottle that might lead to erroneous results (Fig. 6).

In sampling a still body of water like Under Ground Tanks (UGTs) and Over Head Tanks (OHTs), the cap was first removed with the left hand. The bottle was plunged mouth downward to a depth of about one foot, then inverted. When filled, the bottle was removed and stoppered.

All the samples were analyzed within few hours of collection.

Sample analysis for the different physico-chemical and microbiological parameters (Fig.7) was carried out as per Standard methods (APHA, 15th edition).

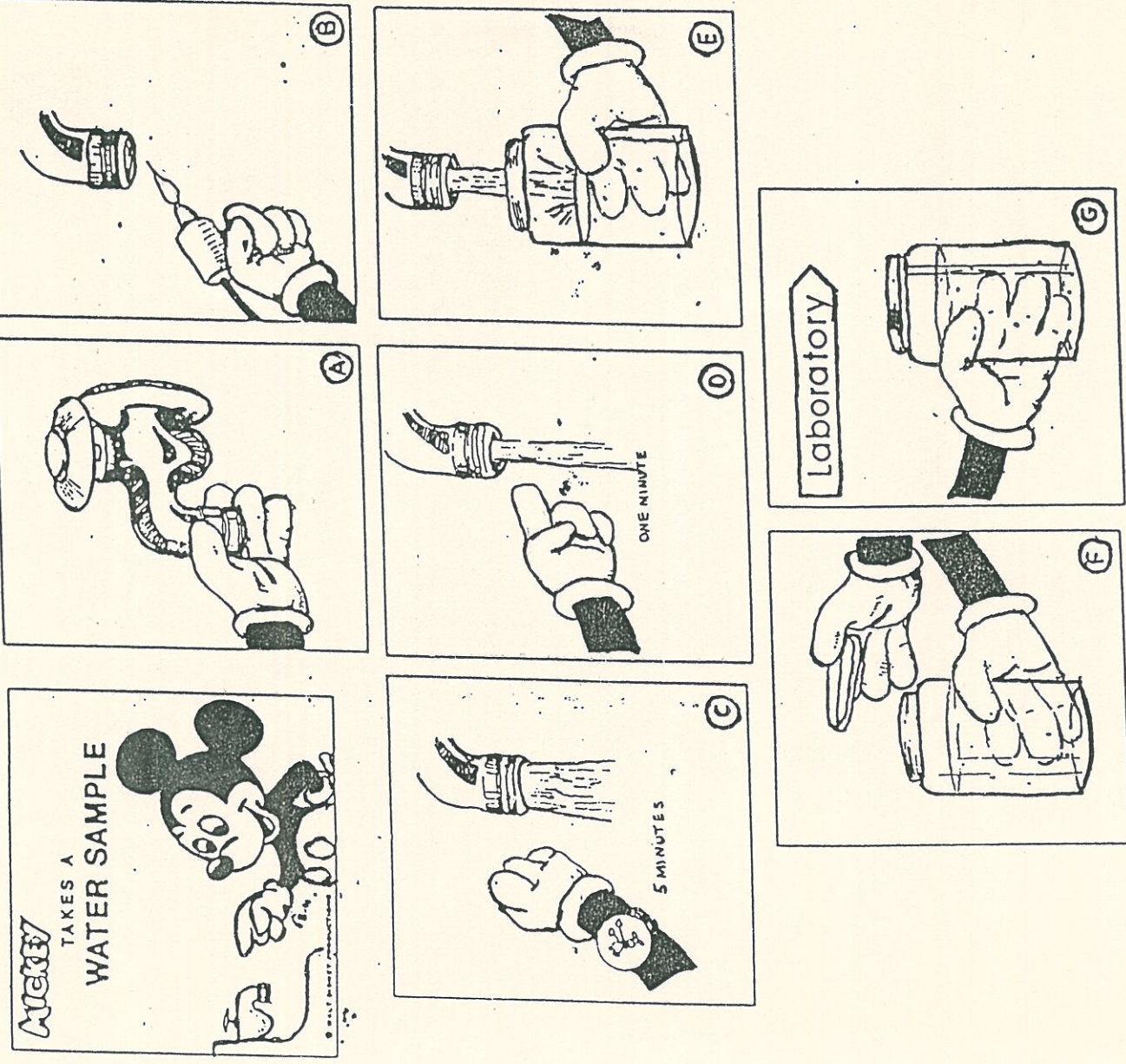


Fig. 6 : Checklist for collection of samples.

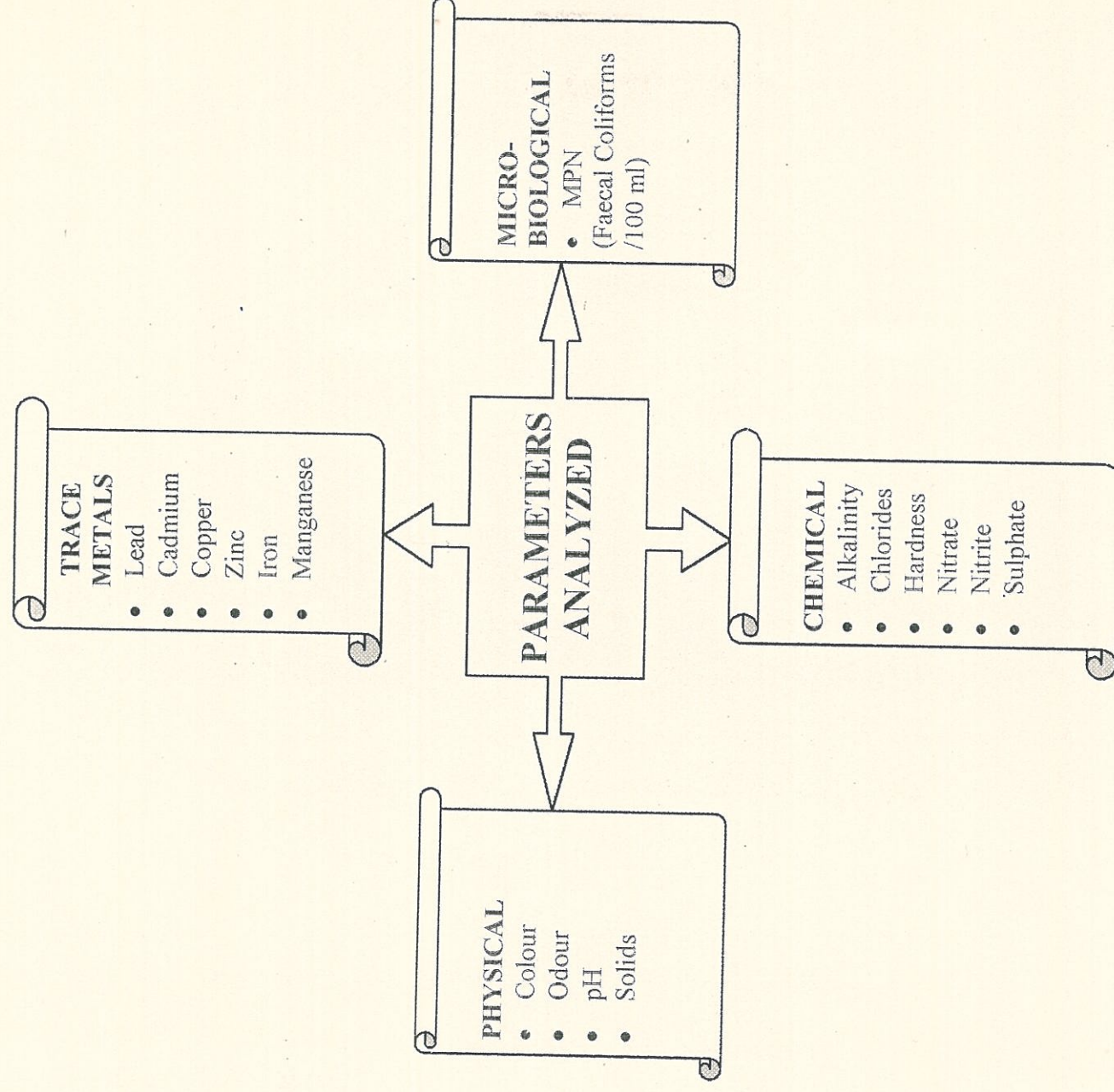


Fig. 7 : Parameter Analyzed in the present work

➤ **pH**

pH of all the samples was measured using Elico pH meter with glass electrode.

➤ **TEMPERATURE**

Temperature of the water samples was measured at the site with the help of the thermometer after the collection of the sample.

➤ **COLOUR**

The apparent colour was determined on the original sample without filtration or centrifugation.

➤ **ODOUR**

The palatability of the water as expressed by the users was accepted as the test for odour. Special complaints regarding the odour were attended to immediately. The samples were checked for foul smell or excessive chlorine smell while heating the sample.

➤ **ALKALINITY**

Principle: Alkalinity can be obtained by neutralizing OH^- , CO_3^{2-} and HCO_3^- with standard H_2SO_4 . Titration to pH 8.3 or decolorization of phenolphthalein indicator will show complete neutralization of OH^- and half of CO_3^{2-} while at pH 4.4 a sharp color change from yellow to pink of Methyl Orange indicator will indicate total alkalinity i.e., CO_3^{2-} and HCO_3^- .

Procedure: 0.02N HCl solution was standardized by titrating it against standard Na_2CO_3 solution using phenolphthalein indicator.

50ml of sample was taken in a conical flask and was titrated against 0.02N HCl using phenolphthalein indicator. The end point is a colour change from pink to colorless. This was reading 'A'.

The titration was continued using Methyl Orange indicator till orange color changed to pink. This was reading 'B'.

Total, phenolphthalein and Methyl Orange alkalinity was calculated as :

$$\text{Phenolphthalein Alkalinity in mg CaCO}_3/\text{L} = \frac{A \times N \times 50000}{\text{ml sample}}$$

$$\text{Methyl Orange Alkalinity in mg CaCO}_3/\text{L} = \frac{B \times N \times 50000}{\text{ml sample}}$$

$$\text{Total Alkalinity in mg CaCO}_3/\text{L} = \frac{(A + B) \times N \times 50000}{\text{ml sample}}$$

➤ CHLORIDES

Principle: Chloride ion is determined by titration with standard AgNO_3 in which AgCl_2 precipitates out. The end point of the titration is indicated by formation of silver chromate from excess of AgNO_3 . In this titration Potassium Chromate is used as an indicator in neutral to slightly alkaline solution.

Procedure: AgNO_3 solution was standardized with NaCl using K_2CrO_4 indicator. 50 ml of sample was taken in a conical flask to which 1 ml of

K₂CrO₄ indicator was added. It was then titrated against AgNO₃ solution. (A ml). Same procedure was carried out for the blank titration using distilled water instead of sample (B ml).

$$\text{Mg Cl/L} = \frac{(A - B) \times N \times 35450}{\text{ml sample}}$$

➤ TOTAL SUSPENDED SOLIDS

Principle: A well mixed sample when filtered through a weighed standard Whatman filter paper and the residue retained in the filter paper is dried to a constant weight at 100 ° C, the increase in the weight of filter paper represents the total suspended solids. The difference between the total solids and the total dissolved solids can provide an estimate of Total Suspended Solids .

Procedure: The water sample was filtered through the pre-weighed filter paper, the filter paper was dried at 100 ° C for constant weight.

➤ TOTAL DISSOLVED SOLIDS

Principle: A well-mixed sample when filtered through a weighed standard glass fiber filter and the filtrate is evaporated to dryness in a weighed dish and dried to constant weight at 180°C, the increase in weight of the evaporating dish represents the total dissolved solids.

Procedure: measured volume of well-mixed sample was filtered through a glass fiber filter. Filtrate was transferred to a weighed evaporating dish and evaporated to dryness. The sample obtained was dried at least for 1 hour in an

oven at 180°C . Dish was cooled in a desiccator to balance temperature and then weighed. Cycle of drying, cooling, desiccating and weighing was repeated until a constant weight was obtained.

➤ TOTAL SOLIDS

Principle: A well-mixed sample is evaporated in a weighed evaporating dish and dried to constant weight in an oven at $103\text{-}105^{\circ}\text{C}$. The increase in weight over that of the empty dish represents the total solids.

Procedure: 100 ml of well-mixed sample was taken in a pre-weighed dish and evaporated to dryness in an oven. Evaporated sample was dried for at least an hour in an oven at $103\text{-}105^{\circ}\text{C}$, dish was cooled in a desiccator to balance the temperature and weighed. Cycle of drying, cooling, desiccating and weighing was repeated until a constant weight was obtained.

➤ HARDNESS

Principle: In alkaline condition, EDTA reacts with Ca^{2+} and Mg^{2+} to form a soluble chelated complex. Ca^{2+} & Mg^{2+} ions develop wine red colour with Eriochrome Black T (EBT) Indicator under alkaline condition. When EDTA is added as a titrant the Ca & Mg divalent ions get complexed resulting in sharp change from wine red to blue, which indicates end point of the reaction. The pH for this titration has to be maintained at 10.0 ± 0.1 . At a higher pH (i.e. about 12.0) Mg^{2+} ion precipitates and only Ca^{2+} ion remains in solution. At this pH Murexide indicator gets complexed with Ca^{2+} resulting in a change from pink to purple, which indicates end point of reaction.

Procedure: (a) Total Hardness : A sample volume was selected that required less than 15 ml EDTA titrant and complex titration within 5 minutes measured from the time of buffer addition. 1 ml of Ammonia buffer solution and a pinch of EBT was added and titrated against standard EDTA solution till colour changed from wine red to blue indicating end point of the titration. (A ml)

(b) Calcium Hardness: To the suitable volume of sample app. 2 ml of 2N NaOH was added and titrated against standard EDTA solution from burette till colour changed from Pink to Violet indicating point of titration (B ml).

Therefore,

$$\text{Hardness (EDTA) as mg /L CaCO}_3 = \frac{A \times B \times 1000}{\text{ml Sample}}$$

➤ NITRITE

Principle: Nitrite (NO_2^-) is determined through formation of reddish-purple azo dye at pH 2.0 to 2.5 by coupling di-azotized sulfanilamide with N-(1-naphthyl)-ethylene diamine dihydrochloride (NED dihydrochloride). The applicable range of the method for spectrophotometric measurements is 10 μg to 1000 $\mu\text{g NO}_2^-$. The color complex obeys Beer's law up to 180 $\mu\text{g N}_2 / \text{L}$ with 1 cm light path at 540 nm. Higher nitrite concentrations can be determined by diluting the sample.

Procedure: The sample was filtered through a 0.45 μm pore size membrane filter to remove suspended solids, if present. If sample pH is not between 5 and 9, it was adjusted to that range with 1N HCl or NH_4OH solution as required.

To 50.0 ml sample, or to a portion diluted to 50.0 ml, 2 ml color reagent (NED) was added and mixed. After the addition of the color reagent to samples and standards, absorbance was measured at 540 nm between 10 min and 2 h.

A standard curve was plotted for absorbance against NO_2 -Nitrogen concentration. Sample concentration was directly computed from curve.

➤ NITRATE

Principle: This technique is used totally for screening samples that have low organic matter contents, i.e., uncontaminated natural waters and potable water supplies. The NO_3^- calibration curve follows Beer's law up to 11 mg N/L. Measurement of UV absorption at 220 nm enables rapid determination of NO_3^- . Because dissolved organic matter also may absorb light at 220 nm and as NO_3^- does not absorb light at 275 nm, a second measurement made at 275 nm may be used to correct the NO_3^- value. Acidification with 1N HCl is designed to prevent interference from hydroxide or carbonate concentrations up to 1000 mg CaCO_3/L .

Procedure: To 50 ml clear sample, (filtered to remove possible interference from suspended particles if necessary), was added 1ml HCl solution and mixed thoroughly. Prepared NO_3^- standards for calibration curve in the range of 0 to 7 mg NO_3^- N/L by diluting 0, 1.0, 2.0, 4.0, 7.0.....35.0 ml volumes of nitrate solution to 50 ml. NO_3^- standards were treated in the same manner as samples. Absorbance was read against redistilled water. A reading was taken at a wavelength of 220 nm to obtain NO_3^- reading and a wavelength of 275 nm was used to determine interference due to dissolved organic matter.

For samples and standards, two times absorbance reading at 275 nm was subtracted from the 220 nm reading to obtain absorbance due to NO_3^- . The standard curve was plotted for NO_3^- -N concentration of standard on X-axis against absorbance due to NO_3^- on Y-axis. Using corrected sample absorbance; concentrations for samples were obtained directly from the standard curve.

➤ SULFATES

Principle: Sulfate ions are precipitated in HCl medium with BaCl_2 so as to form a uniform suspension of BaSO_4 crystals. The absorbance of suspension is measured at 420 nm by Spectrophotometer.

Procedure: A sample volume containing 0.5 to 3 mg sulfate was pipetted in a 250 ml flask. The total volume was adjusted to 50 ml. A series of SO_4 standards (0.25, 0.50, and 0.75 to 3 mg) were prepared making the volume to 50 ml with distilled water. The blank and the samples were prepared exactly as the standards throughout the procedure. 10 ml each of acid-salt reagent was added into blank, standards and sample and mixed. 5 ml of conditioning reagent (1:1 glycerol-alcohol) and a spoonful of BaCl_2 crystals was added to each flask and immediately stirred for 1 minute at constant speed. The turbidity was measured at 420 nm using Spectrophotometer.

$$\text{SO}_4^{2-} \text{ (mg/l)} = \frac{\text{Mg of SO}_4 \times 1000}{\text{ml of sample}}$$

> ESTIMATION OF BACTERIAL DENSITY

Principle: The coliform group comprises all aerobic and facultative anaerobic, gram negative, non-spore forming rod shaped bacteria that ferment lactose with gas and acid formation within 48 h at 37° C. The standard test for the coliform group may be carried out by the multiple tube fermentation technique. For this, results of the examination of replicate tubes and dilutions are reported in terms of the Most Probable Number (MPN) of organisms present. This number, based on certain probability formulae, is an estimate of the mean density of Coliforms in the sample.

The test is called 'presumptive' because the reaction observed may occasionally be due to the presence of some other organisms and the presumption that the reaction is due to coliform organisms has to be confirmed.

Procedure: Multiple tube technique : An estimate of the number of coliform organisms was made by adding varying quantities of water (0.1 ml - 50 ml) to bile salt lactose peptone waste (with an indicator for acidity) and incubating at appropriate temperatures. Acid and gas formation indicated growth of coliform bacilli. Thus it was possible to identify the smallest quantity of water containing a coliform bacillus and to express the degree of contamination with this group of organisms. Mac Conkey's fluid medium (modified) was used.

The tubes were prepared as follows :

Test No.	No. of tubes	Water sample (ml)	media
1	5	10.0	10 ml double strength
2	5	1.0	10 ml single strength
3	5	0.1	10 ml single strength

Broth tubes were incubated (with inverted Durham's tubes inserted) at $44.5^{\circ}\text{C} \pm 0.2^{\circ}\text{C}$ for $24 \pm 2\text{h}$. The 'presumptive positives' were read and remaining negative tubes were further incubated for another 24 hours. Any further positives were added to the previous figures. The probable numbers of coliforms per 100 ml were read from the probability tables of Mac Crady.

Gas production in a broth culture within 24 h or less was considered a positive fecal coliform reaction. Failure to produce gas constituted a negative reaction indicating a source of bacterial contamination was other than the intestinal tract of warm-blooded animals.

Table 6: Classification of water based on the Presumptive test

Quality of Water	Single Portions (ml)		
	10	1.0	0.1
Safe	-	-	-
Reasonably Safe	+	-	-
Questionable	+	+	-
Unsafe	+	+	+

QUALITY ASSUARANCE OF DATA FOR NITRITE, CHLORIDE AND MPN :

➤ NITRITE:

The azo-dye method was calibrated in the concentration range of 0.001-1 mg/l. Determination of the red colour developed by azo-dye both for reagent blanks and standards were carried out at 540 nm on UV-Vis spectrophotometer. Distilled water was used as reference against which the absorbance was measured. The reagent blank replicated over a month's period gave concentration variations with a maximum value of 0.003 mg/l, which was taken as the minimum detection limit. Three times this value was considered as the method detection limit, which is 0.01 mg/l. The error at this level was in the range of 8 to 20% depending on the blank values. The errors at concentrations greater than 0.05 mg/l are found to be 5 to 8%. Since the concentration of nitrites in the drinking water samples were mostly in the range of 0.01 to 0.06 mg/l, the accuracy in the reported concentration levels for the samples is well within the errors, as shown above. At concentration levels greater than 0.1 mg/l, observed in some, the error will be less than 5%. The quality of the method was therefore confirmed.

➤ CHLORIDE:

The QA/QC procedure was repeated for chloride measurements by the Argentometric titration method. The drinking water quality standards stipulated by BIS is 250 mg/l. This is based on ground water quality where the expected potential concentration of chloride is high because of the leaching of the geological matrix and the ingress of seawater at coastal sites. This is not true for surface waters like rivers and lakes. The Mumbai water supply is predominantly from surface water resources. Since the measured concentrations in most of the

samples from various residential areas are in the range of 7 to 13 mg/l, which is slightly lower than the values reported for the Bhandup Treatment Plant. The laboratory studies indicate that the error is between 3 to 8% at 1mg/l chloride and less than 3% at higher concentrations. This has confirmed the validity of the results.

➤ MPN:

MPN is recognized as the most important parameter for the assessment of drinking water quality by the various regulatory agencies. The three-tier analysis protocol sufficiently covers the QA/QC of the result. However it was observed that time delays in the analysis program and also storage under room temperature/incubation at 4°C gave underestimated results excepting for samples with > 1600 FC counts/100 ml. This aspect is being studied under laboratory conditions. Since small volumes of grab samples are collected in autoclaved bottles these differences in analysis results is possible. However, in case of under ground storage tanks, wherein large-scale contamination occurs such a limitation as encountered in laboratory analysis may not be valid.

The British manual "*The Bacteriological Examination of Water Supplies*" suggests that if a presumptive test for coliform organisms is frequently positive or less, then it may be assumed without any further tests that the water is subject "to serious and possibly dangerous pollution".

It is customary to report the results of the coli test by the multiple tube fermentation process as a MPN index. It should be realized that this is merely an index of the number of coliform bacteria that, more probable than any other no. , would give the results shown by the laboratory examination. It is not an actual enumerate of the coliform bacteria. Coliform density is reported conventionally as the MPN count / 100ml¹⁰.

IS 10500 : 91 Drinking Water Compared To W.H.O. Guidelines (1993)

Indian Water Works Association, July- September, 1998

Comparison of IS 10500-91 to 1993 W.H.O. Guidelines has been given in the following tables. This will help in the next revision of IS 10500.

Bacteriological Quality

Parameter	IS 10500-91	W.H.O. Guidelines
All water intended for drinking		E - Coli thermo-tolerant Coliform bacteria must not be detectable in any 100 ml. sample.
Treated water entering the distribution system		E - Coli or thermo-tolerant Coliform bacteria must not be detectable in any 100 ml. sample. Total coliform bacteria must not be detectable in any 100 ml. sample.
Treated water in the distribution system	No sample should contain E-Coli in 100 ml. Through out the year 95% samples should not contain any coliform organisms in 100 ml. No sample should contain more than 10 coliform organisms per 100 ml. Coliform organisms should not be detectable in 100 ml. of any 2 consecutive samples.	E-Coli or thermo tolerant Coliform bacteria must not be detectable in any sample. In 95% of samples taken throughout any 12 months period, total Coliforms must not be detectable in any 100 ml. sample.

TABLE 7 : Drinking water quality standards of select parameters⁸.

SR.NO	Characteristics	BIS Standards	WHO Standards
1	Colour	10 (Hazen Unit)	15 TCU
2	Odour	Unobjectionable	Unobjectionable
3	Taste	Agreeable	Agreeable
4	PH	6.5 – 8.5	-
5	* Total Hardness (as CaCO ₃)	300	-
6	* Calcium (as Ca)	75	-
7	* Magnesium (as Mg)	30	-
8	* Dissolved Solids	500	1000
9	* Nitrate (as NO ₃ ⁻)	45	50 (acute)
10	* Nitrite (as NO ₂ ⁻)	-	3 (acute) 0.2 (P) (Chronic)
11	* Sulphate (as SO ₄ ²⁻)	200	250
12	* Alkalinity	200	-
13	* Chlorides (as Cl)	250	250
14	* Lead (as Pb)	0.05	0.01
15	* Cadmium (as Cd)	0.01	0.003
16	* Copper (as Cu)	0.05	2 (P)
17	* Zinc	5	3
18	* Iron (as Fe)	0.3	0.3
19	* Manganese (as Mn)	0.01	0.5 (P)
20	MPN	10	ZERO

*: Mg / l (max)

P: Provisional value

RESULTS

SECTION - I

Physico-Chemical parameters

TABLE 8 : THE WARDS AND THE AREAS COVERED IN PRESENT STUDY

S.No.	Ward	Areas covered
1.	A	Crawford market, Colaba, Sassoon Dock, Dhobi Talao, Fort, Churchgate, Dalal Street, TIFR.
2.	B	Dongri, Sandhurst Road, Dockyard Road, Masjid
3.	C	Kalbadevi, Bhuleshwar, Marine Drive, Charni Road, Grant Road(E).
4.	D	Nana Chowk, Khetwadi, Mumbai Central (E), Mumbai Central (W).
5.	E	Byculla (E), Byculla (W), Mazgaon, Reay Road.
6.	F/N	Chinchpokli(E), Chinchpokli (W), Matunga, Naigaon, Lalbaug, Wadala, King's Circle, Matunga (W), Kalachowki,
7.	F/S	Parel, Sewri (E), Sewri (W).
8.	G/N	Dadar-Matunga, Dadar (E), Sion-Koliwada, Sion, Dharavi.
9.	G/S	Elphinstone Road, Lower Parel (E), Lower Parel (W), Worli.
10.	H/E	Vakola, Santacruz (E), Khar Road (E), Bandra (E).
11.	H/W	Khar Road (W), Bandra (W).
12.	K/E	Vile Parle (E), Andheri (E), Jogeshwari.
13.	K/W	Vile Parle (W), Andheri (W).
14.	L	Kurla (E), Kurla (W), Vidyavihar(E), Vidyavihar (W).
15.	M/E	Chembur (E).
16.	M/W	Chembur (W), Trombay.
17.	N	Ghatkopar (E), Ghatkopar (W), Vikhroli (E).
18.	P/N	Malad (E), Malad (W).
19.	P/S	Goregaon (E), Goregaon (W).
20.	R/N	Dahisar.
21.	R/S	Borivili (E), Borivili (W) ,Kandivili.
22.	S	Kanjurmarg, Bhandup, IIT Powai.
23.	T	Mulund.

➤ **PHYSICO-CHEMICAL PARAMETER ANALYSIS :**

One thousand four hundred and fifty seven drinking water samples from various wards were analyzed for assessing their Physico-chemical status. Table 9 gives an overview of the number of water samples collected for analysis from different wards from different storage and supply facilities .

TABLE 9 : THE OVERVIEW OF THE NUMBER OF WATER SAMPLES COLLECTED FROM DIFFERENT STORAGE AND SUPPLY FACILITIES

Ward	Total Number of Samples	Stored Samples	Over Head Tank	Under Ground Tank	At Supply Time	Bore well Samples	Tanker Samples
A	222	201	6	12	3	0	0
B	121	113	1	2	5	0	0
C	103	87	5	9	0	1	1
D	123	117	0	2	3	0	1
E	58	43	8	0	7	0	0
F/N	174	156	0	5	13	0	0
F/S	39	37	0	0	0	0	0
G/N	89	87	0	2	0	0	2
G/S	210	191	1	13	5	0	0
H/E	96	93	0	1	2	0	0
H/W	54	33	0	1	20	0	0
K/E	80	65	3	11	1	0	0
K/W	44	41	1	2	0	0	0
L	82	77	1	0	3	0	1
M/E	168	87	11	33	44	0	0
M/W	47	33	6	7	1	0	0
N	107	98	1	0	3	5	0
P/N	29	29	0	0	0	0	0
P/S	38	30	2	6	0	0	0
R/N	8	3	2	3	0	0	0
R/S	65	63	0	1	0	1	0
S	53	49	0	0	4	0	0
T	46	46	0	0	0	0	0

Most of the samples showed normal readings for the physical parameters

pH

The pH values of all the samples analyzed were within the range of 6.5 to 8.5 which was very well within limits of Bureau of Indian Standards (BIS). pH levels less than 7 may cause severe corrosion of metals in the distribution system. In the absence of a distribution system, the acceptable range of pH may be broader. At pH levels above 8.0, there is a progressive decrease in the efficiency of the chlorine disinfection process.

TEMPERATURE

All the samples showed more or less same temperature within the difference of 1°C.

COLOUR

The true color of the water is the colour of water from which the turbidity has been removed. Samples collected from Assisi Nagar, Chembur (E), Dockyard Road and Masjid showed not only the brownish turbidity but also the presence of small red worms and mosquito larvae. The residents of Vile Parle (E) and Sasson Dock complained about muddy water supply, however, during sampling, any colour or muddiness was not observed. During the S.V. Road, Borivili (W) sampling at Mhatre Chawl, residents complained of source water supply that was yellow in colour. However, no such sample was encountered during the sampling schedule. One probable reason for this might be that the water at the beginning of supply time was initially flushed off. Two source-water samples collected from New BMC Chawls, Khar Road (E) without the initial water being flushed off, were blackish in colour. After a 48-hour storage, the settled solids were black

and had a slimy appearance. This condition persisted during the re-sampling schedule. Most of these places it was noted that the drinking water pipelines were passing very close to sewage pipes or the surrounding was very unclean. It is possible that the dirty water or sewage water was contaminating the drinking water supply.

TASTE AND ODOUR

Water odour is mainly due to the presence of organic substances. **Masjid BIT chawls (Ward B) , Dockyard Road and Worli – Ward G (S)** residents complained about the bad odour in the water samples to our volunteers when they had gone for sample collection in these areas. The samples collected from New BMC Chawls, Khar Road (E) had a foul odour that aggravated upon storage.

“Taste” problem in the drinking water supplies represents the largest single class of consumer complaints. An unpleasant taste may result in reduced water consumption. Changes in the normal taste of public water supply may point to changes in the quality of raw water source or the deficiencies in the treatment process.

Chlorination may produce chlorine residues that are perceptible by the consumer, but lowering the chlorine dose to overcome taste problems must not compromise the microbiological safety of the water. Water should be free of ‘objectionable taste and odour’ for the majority of its consumers : the guideline value is “not offensive to most of the consumers”.