Water Quality Monitoring Planning

Dr. C. K. Jain
Scientist 'F' & Head
Environmental Hydrology Division
National Institute of Hydrology
Roorkee – 247 667
Email: ckj_1959@yahoo.co.in

Abstract

The quality of both surface and ground waters is governed by a set of complex interacting physical, chemical and biological processes with reference to various beneficial uses of water. Traditionally human health as influenced by consumptive use of water as well as the use involving body contact (bathing and swimming) has been the primary concern. Although, many other beneficial uses of water such as fisheries, agriculture, industry and recreation have also been acknowledged. In recent years, the concern for water quality has broadened in scope beyond humans and wildlife to the ecological integrity of surface water also. Anthropogenic activities directly impact upon the biological communities and disrupt the ecological processes, thereby causing all kinds of water quality problems. The management of water quality therefore requires an understanding of all the physico-chemical processes and the role of biota and the ecological processes as well as their rehabilitation. This lecture presents the concepts of water quality management for sustainable development keeping all these aspects in mind.

1. Introduction

Water is one of the basic necessities for the survival of human beings and prosperity of civilization. The ever increasing growth of population, industrialization, steady rise in irrigation activities, urbanization and high level of living standards exert tremendous pressure on the available water which is highly uneven in its spatial and temporal distribution both in quantity and quality. The water is put to different uses such as irrigation, industry, power generation, drinking, bathing, recreation, fisheries, wild life propagation, pollution abatement etc. For each of the uses the water is required in appropriate quantity and required quality. Now-a-days, there is an increasing awareness for the maintenance of water quality especially in urban areas. With the rapid increase in population and growth of industrialisation in the country, pollution of natural water by municipal and industrial wastes has increased tremendously.

The term 'water quality' is a widely used expression, which has an extremely broad spectrum of meanings. Each individual has vested interests in water for his particular use. The term water quality therefore, must be considered relative to the proposed use of water. From the user's point of view, the term 'water quality' is defined as physical, chemical and biological characteristics of water by which the user evaluates the acceptability of water. For example for the sake of man's health, we require that his water supply be pure, wholesome and potable.

In recent years the rivers are being used indiscriminately for disposal of municipal, industrial and agricultural wastes thereby polluting the river water beyond the permissible limits. Due to this, the river water is gradually becoming unfit even for irrigation purposes at some places. Thus it has become very essential to evaluate the environmental impacts of water resources to minimize the progressive deterioration in the quality of water. Therefore, a detailed study of water quality in all the vulnerable rivers is imperative for better management and use of water for different purposes.

2. Water Quality Monitoring Planning

Water quality problems stem basically from two factors, the natural hydrology of a river basin and the development and use of land and water resources by human beings. Depending on the interrelation of these two factors, a wide variety of quality problems can result. Each river basin, therefore, is unique and it must be subjected to individual and intensive water quality assessment to provide a proper basis for judicious management of the land and water resources.

For a proper planning of water quality monitoring programme, the following points should be considered:

- What are the objectives of the programme ?
- From where samples are to be taken ?
- Which determinants are of interest ?
- When and how often samples are to be taken ?
- What is to be done with the results ?

These questions will provide a framework for defining measurement programmes. Results obtained from such a programme should be regularly reviewed to decide if any changes (e.g. determinants or sampling frequency) in the monitoring programme are necessary.

2.1 Objectives of the Monitoring Programme

It is an obvious point that the objectives of a programme should be clearly and precisely formulated by the user. If it is not done, inappropriate analytical data may well be provided and/or the user is likely to call for needlessly large or unduly small numbers of results. Furthermore, if the objectives are not precisely expressed, it will be difficult or impossible to decide the extent to which they are achieved.

It is suggested that analytical information should be requested on a regular basis only when the user knows beforehand that the results will be used-in a precisely known fashion-to answer one or more defined questions on quality. Requests for analysis based on the thought that the results may be ultimately prove to be useful should be avoided, particularly when-as is increasingly the case - analytical sampling effort is limited. There is an almost infinite number of analysis that might be useful in most situations, but it is completely impracticable to attempt any such comprehensive coverage. Therefore, selection from all the possible objectives and determinants is essential for a proper planning of monitoring programme.

As a further means of optimising measurement programmes, the user should formulate his information needs as quantitatively as possible. As an extreme and perhaps rather artificial example of a badly defined requirement, consider the statement, 'to obtain information on the quality of river'. Such a statement is almost completely useless as a basis for the design of a monitoring programme for the following reasons:

i. The determinants are not specified so that analysis required are not known;
ii. The particular river and the locations on the river are not defined so that inappropriate sampling positions may be chosen;
iii. No indication is given on the time scale or sampling frequency so that too few or too many samples may be collected and analysed;
iv. As a result of all of the above lacks, there is no indication of the amount of data that will need to be processed and the nature of the data treatment so that appropriate data handling techniques cannot be defined.

Therefore, users of analytical results must seek to avoid uncertainties such as those in the above example by careful and quantitative definition of every aspect of their requirements. Thus, an objective such as the above would be better expressed by a statement of the form - 'to estimate each year the annual average concentration of ammonia (NH_3 + NH_4) at all river sites used for the production of potable water'. Appropriate statement of this type for other determinants of interest then provide a set of quantitative targets essential in optimising the choice of sampling, analytical and data handling techniques.

2.2 Objectives of GEMS/WATER

The fundamental objectives of the water quality monitoring system within the GEMS/WATER programme are to:

1. Assess the impacts of man's activities upon the quality of the water and its suitability for required uses.
2. Determine the quality of water, in its natural state, which might be available to meet future needs.
3. Keep under observation the source and pathways of specified hazardous substances.
4. Determine the trend of water quality at representative stations.

The first objective is met by the establishment of impact stations, the second by baseline stations, the third by either impact or baseline stations depending upon whether the hazardous substance is of artificial or natural origin, the fourth by trend stations.

Baseline stations are located in an area where no direct diffuse or point sources of pollutants are likely to be found. They are used to establish the natural background level of variables, to check if no synthetic compounds are found in remote areas (e.g., DDT) to assess the long term trends of surface water quality resulting from global atmospheric pollution. Impact stations are situated in water bodies where there is at least one major use of the water, or which are greatly affected by man's activities. Four type of impact stations can be identified according to different uses of water:

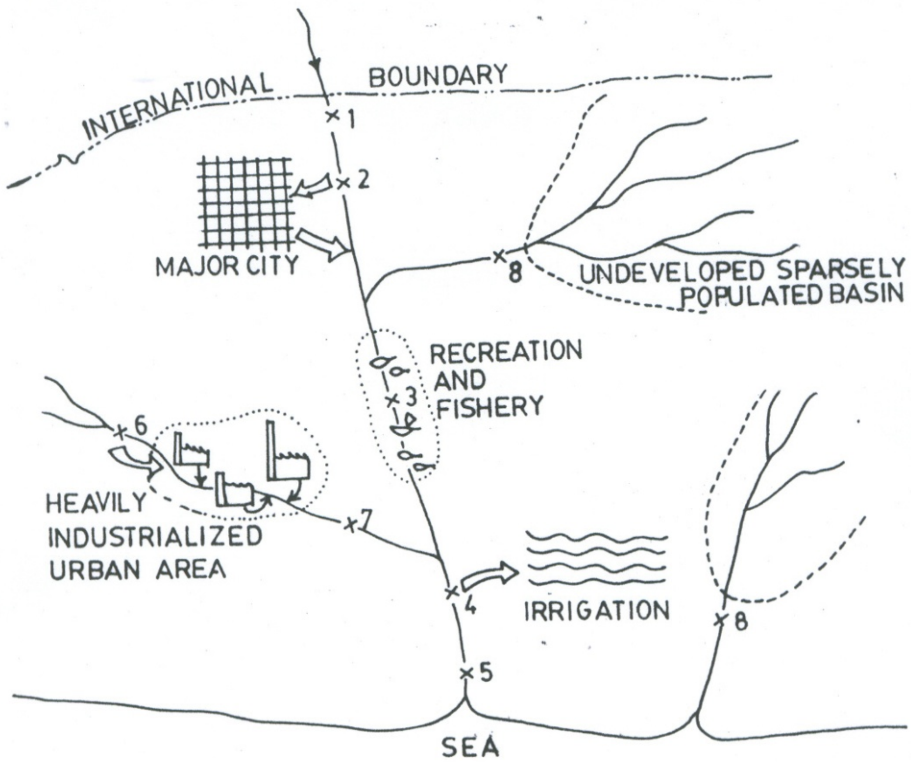
i. Drinking water - at the raw water intake before treatment for drinking water.
ii. Irrigation - at the water intake before distribution for irrigation.
iii. Aquatic life - river and lake stations representative of the general quality of the water body.
iv. Multiple impacts - several water uses at the station and/or of the water body.

Trend stations are set up specially to assess the trends of water quality. They must be representative of a large area with various types of human activities. These stations should be more frequently sampled in order to increase the statistical significance of the average concentrations and to validate the trends.

2.3 Sampling Locations and Points

Sampling location and point mean the general position within a water body and the exact position at a sampling location at which samples are obtained. The objectives of a programme sometimes immediately define the sampling locations. For example, when the concern is to measure the efficiency of a chemical plant for purifying water, sampling locations will be required before and after the plant. Similarly, when the effect of an effluent discharge on the water-quality of a receiving river is of interest, samples will be required from locations upstream and downstream of the discharge. For larger scale water bodies (e.g., a river basin, a large estuary, a large urban drinking water distribution system), however, the objectives may be defined in terms that provide essentially no indication of sampling locations. For example, objectives such as 'to measure river quality within a river basin' or 'to measure the quality of water in a distribution system' give no indication of which of the virtually number of possible sampling locations are of interest. Such broadly expressed objectives are completely inadequate as a basis for the detailed planning of efficient programmes of sampling, and should always be sharpened so that they do indicate the position of sampling locations. A commonly useful device for helping in this respect is to consider the intended use of the water since this will aid in indicating these positions in a water body where quality is of key importance.

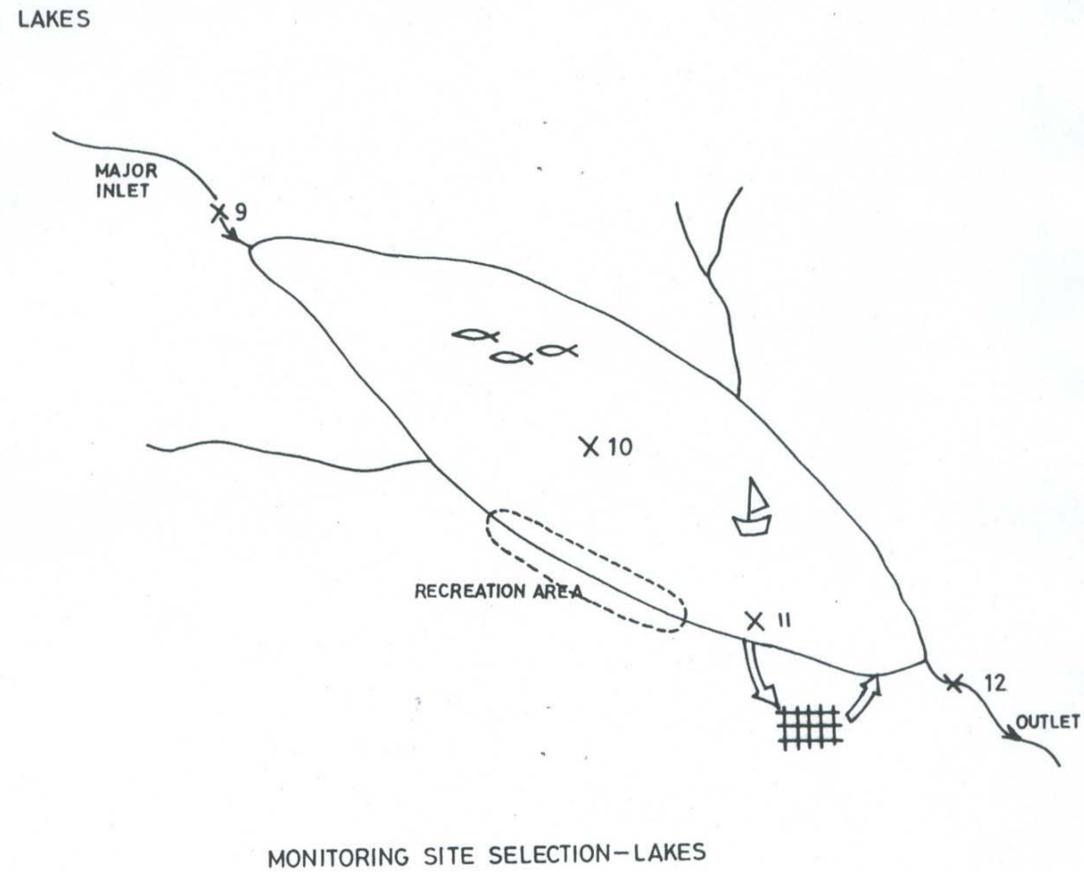
Fig. 1 illustrates the hypothetical case of river system along with the criteria for the choice of the different sampling sites. Fig. 2 and 3 illustrates similarly the location of sampling sites for lakes and ground water with corresponding criteria for the choice of different sampling sites.



MONITORING SITE SELECTION - RIVERS

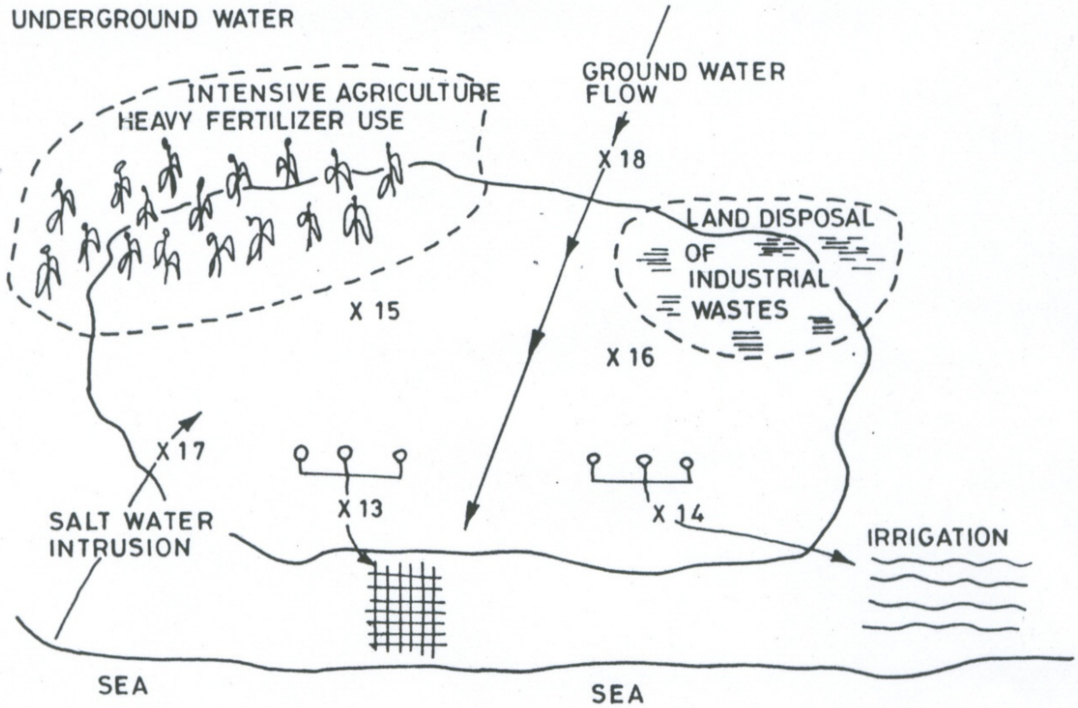
Station	Type	Criteria
1	Impact (or baseline)	Immediately downstream of an International boundary
2	Impact	Abstraction for public supply of large town
3	Impact	Important fishing, recreation and amenity zone
4	Impact	Abstraction for large scale agricultural area
5	Trend	Fresh water tidal limit of major river
6	Impact	Abstraction for large industrial activity
7	Impact	Downstream of industrial effluent discharge & important tributary influencing main river
8	Baseline	Station where water is in a natural state (no direct or indirect pollution, no water use)

Fig. 1. Monitoring Site Selection - Rivers



Station	Type	Criteria
9	Impact (or baseline)	Principal feeder tributary
10	Impact (or baseline)	General water quality of lake
11	Impact	Water supply of major city
12	Impact (or baseline)	Water leaving lake

Fig. 2. Monitoring Site Selection - Lakes



MONITORING SITE SELECTION – UNDERGROUND WATER

Station	Type	Criteria
13	Impact	Water supply to large town threatened by fertilizer residues and saline intrusion
14	Impact	Water for large scale irrigation threatened by leachate from waste tips
15 } 16 } 17 }	Impact	Water supply of major city
18	Baseline	No human activities in the ground water recharge area

Fig. 3. Monitoring Site selection – Ground Water

2.4 Determinants of Interest

The particular determinants appropriate to a programme are critically dependent on the type of water and the objectives of the study. Depending on the intended use of a receiving water, the parameters listed in Table 1 are of significance for water quality characterization. These serve as guidelines for analysis of wastewater quality for purpose of treatment and control. The parameters listed in Table 2 are frequently used for the identification of various types of pollution associated with industrial waste water.

Some of the most important and most frequently used tests in the analysis of water are the non-specific tests listed in Table 3. These tests often measure a property of a group of substances. For example alkalinity indicates the capacity of water to neutralize hydrogen ions. Many of these tests are used to determine the suitability of natural water for industrial or municipal use and to determine the type and degree of treatment required. Table 4 lists some of the more frequently measured parameters in pollution studies.

Table 1. Parameters for Water Quality Characterization

Water Use	**Quality Parameters**
Domestic water supply	Colour, odour, taste Organic content: Chlorine demand, COD, BOD, TOC, phenols Carcinogens and toxic compounds: Insecticides, pesticides, detergents Turbidity, salinity Alkalinity, pH Total hardness, Ca, Mg, Fe, Si, etc. Pathogenic organisms, total bacterial count (37^oC), E. Coli, plankton count.
Fish, shellfish, wildlife and recreation	Colour, odour Toxic compounds Turbidity, floating matter, sludge deposits, salinity Temperature Dissolved Oxygen, BOD Alkalinity, pH, Pathogenic organisms, plankton count nitrogen, phosphorous, etc. (inorganic nutrients which support algae blooms and other undesirable aquatic growth).
Agricultural irrigation	Salinity and Na-Ca content Alkalinity, pH Pesticides, growth regulators Persistent synthetic chemicals (e.g., polyethylene derivatives, asphalt sprays, etc.) Pathogenic organisms.
Watering of livestock	Salinity Toxic compounds Pathogenic organisms Plankton count.

Table 2. Significance of Parametric Measurements

Test(s)	Significance
Dissolved solids	Soluble salts may affect aquatic life or future use of water for domestic or agricultural purposes
Ammonia, nitrites,	Degree of stabilization (oxidation) or nitrates, and total organic nitrogenous matter, organic nitrogen
Metals	Toxic pollution
Cyanide	Toxic pollution
Phenols	Toxic pollution, odor, taste
Sulfides	Toxic pollution, odor
Sulphates	Corrosion of concrete, possible biochemical reduction to sulfides
Calcium and magnesium	Hardness
Synthetic detergents	Toxic pollution

Table 3. Nonspecific Water Quality Parameters

Physical	Chemical	Physiological
Filterable residues Salinity Density Electrical conductance	Hardness Alkalinity and acidity BOD COD Total Carbon Chlorine Demand	Taste Odor Color Suspended solids Turbidity

Table 4. Tests used for the Measurement of Pollution of Natural Waters

Nutrient Demand	Specific Nutrients	Nuisance	Toxicity
DO BOD COD Total Carbon	Nitrogen: Ammonia Nitrate Nitrite Organic nitrogen Phosphorous: Orthophosphate Polyphosphate Organic phosphorous	Sulfide Sulfite Oil and Grease Detergents Phenols	Cyanide Heavy Metals Pesticides

2.5 Frequency and Time of Sampling

The quality of water in various water bodies is rarely if ever constant in time but is subject to change. While there may be some relationship between the role of change of different variables others alter independently. In measuring the mean, maximum and minimum values of variables over a period of time the closeness of the monitored values to the true values will depend upon the variability of the variables and the number of samples taken. The larger the number of samples from which the mean is derived the narrower will be the limits of the probable difference between the observed and true means. These confidence limits are not directly proportional to the number of samples but to the square of the number. Therefore, in order to double the reliability of a mean value the number of samples must be increased to four fold.

Variations in water quality are caused by changes (increase or decrease) in the quantity of any of the inputs to a water body system. Such changes may be natural or man-made and either cyclic or random. Water quality variation may therefore be similarly cyclic or random.

The variability differs between rivers, lakes and underground waters. It is most pronounced in rivers and the ranges will be greater, the nearer the sampling point is to the source or sources of variability. As the distance from the source increases longitudinal mixing smooths out irregularities and fewer samples are needed to meet given confidence limits. However, as the distance between the source of variability and the sampling point increases not only will there be reduction in the range of variation but there will also be dilution and some variables will be reduced by self purification, deposition and adsorption. These effects must be considered if a sampling station used for quality control purposes is located some distance from the area of point of use.

In lakes the mass of water and good lateral mixing provides a inertia against any rapid changes resulting from modifications in inputs and outputs. Many lakes exhibit marked seasonal variations due to thermal stratification, overturn and biological activity. Depending upon the type of lake the sampling may be carried out with a seasonal bias related to the natural cycles of the lake.

Underground water has a lower variability than that of either rivers or lakes. The rate of quality changes depends upon the depth of sampling, water volume of the aquifer and the hydraulic conductivity. The time elapsing between changes in land use and in surface recharge water and their effect upon the underground water will depend upon the time of percolation. Variations are often, but not invariably, seasonal with a time lag according to the rate of percolation. Direct injection into boreholes or saline intrusion from subterranean sources may take effect more rapidly.

The time of sampling is also of main concern when the quality of the water shows more or less regular variations, e.g., diurnal variations in the concentration of dissolved oxygen in rivers and variations of quality on start-up and shut-down of industrial plant.

It is seldom if ever that the quality of water at only one instant of time is of interest. Normally, information is required for a time period during which quality may vary. The basic problem arises, therefore, of deciding the time at which to collect samples so that they will adequately represent the quality during the period of interest.

The best technical solution to this problem would often be to use an automatic, on-line instrument providing continuous analysis of the water of interest. This approach can be of great value in that, in principle, a continuous record of quality is obtained and the problems of selecting particular times for sampling do not arise.

3. Major Water Quality Issues

3.1 Water Scarcity

- Due to un-even distribution of rainfall in time and space and ever-increasing demand of water for agricultural, industrial and domestic activities, the water resources are over-exploited. This is resulting in shrinking or even drying up of many water bodies for considerable period in a year.

- Maintaining targeted water quality in such water bodies is very difficult. If objectives of Water Act, 1974 is to be fulfilled maintaining minimum level of water needs to be specified. For example, restriction on water abstraction from different water bodies (rivers, lakes or ground water). The Central Ground Water Authority (CGWA) formed under Environment (Protection) Act, 1986 has already taken such initiatives. The restrictions need to be extended to the rivers and lakes also.

- Targets for conservation: reducing demands by optimum use, minimisation of wastage, efforts to reduce the percolation and evaporation losses, conservation efforts in domestic uses, ground water recharging, rain water harvesting. afforestation, recycling and reuse.

- There are number of cases where salinity is increasing in both surface water and ground water. The increase in ground water salinity is mainly due to increased irrigation activities or seawater intrusion in coastal areas. The salinity in surface water is increasing mainly due to discharges of industrial waste water or agricultural return water.

- The salinity impairs the fitness of water for drinking or irrigation purposes. It may also affect the ecosystem in surface waters.

3.2 Oxygen Depletion

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- A large portion of wastewater is discharged into watercourses without any treatment mostly originated from domestic sources. Such wastewater contains high amount of organic matter. The industries also discharge effluents containing high organic matter, e.g., agro-based industries. This organic matter when oxidized in water through microbial activities, consumes dissolved oxygen. Since water has limited availability of oxygen, consumption exceeds the availability, oxygen depletion is resulted. Thus, the survival of aquatic life becomes difficult.

- In many water bodies massive input of organic matter sets off a progressive series of chemical and biological events in the downstream water. The stretch is characterised by high bacterial population, cloudy appearance, high BOD and strong disagreeable odour - all indicating general depletion of oxygen. Masses of gaseous sludge rising from the bottom are often noticed floating near the surface of the water. During monsoon the sludge deposited in such stretches is flushed, which stays in suspension, causing rise in oxygen uptake in the downstream. Due to such sudden oxygen depletion, heavy fish mortality occurs every year during first flushing after onset of monsoon.

3.3 Pollution Due to Urbanization

- Urbanisation has encouraged the migration of people from villages to the urban areas. This has given rise to a number of environmental problems such as water supply, waste water generation and its collection, treatment and disposal. In urban areas, water is tapped for domestic and industrial use from rivers, streams, wells and lakes. Approximately 80% of the water supplied for domestic use passes out as wastewater. In most of the cases, wastewater is let out untreated and it either percolates into the ground in turn contaminates the ground water or is discharged into the natural drainage system causing pollution in downstream areas.

3.4 Non-point Source Pollution

- The non-point sources of water pollution have been recognized as being of great importance than point sources. This is due in part to the continuing efforts to reduce pollution from point sources over the past few decades, as well as recognition that non-point sources, such as storm water, may contain harmful contaminants. Pesticides and nutrients, particularly, are of major concern because of high toxicity and eutrophication problems. This has increased the need to identify and quantify major sources of nutrients and pesticides deposited within the river system.

- In rural areas most people use open field for defecation, with a few using pit--latrines or septic-tanks. Much of the bathing and washing (clothes, utensils etc.) is in or near the water-body reducing abstraction and transport of water but causing in-situ diffuse pollution.

3.5 Eutrophication

- The discharge of domestic wastewater, agricultural return water or runoff water and many industrial effluents contribute nutrients like phosphates and nitrates. These nutrients promote excess growth of algae in water bodies. This is not desirable for balanced aquatic ecosystem.

3.6 Salinity

- Salinity is increasing in many water bodies especially ground water due to leaching of salts build-up in agricultural areas under intense irrigation.

- A number of industrial activities discharge wastewater with high dissolved solids, cause increase in salinity of water.

- Due to discharge of toxic effluents from many industries and increased use of chemicals in agriculture and their subsequent contribution to the water bodies, many water bodies in the country are polluted due to presence of toxic substances.

- Presence of toxic substance impairs the water quality by making it unfit for human consumption, aquatic life, and irrigation.

3.7 Natural Contaminants

- By far the greatest water quality problem in developing country is the prevalence of water borne diseases. Yet, in addition to the human induced pollution problems, water supply also has specific natural quality problems, which are mainly related to local geology. Some of the specific problems of natural origin includes fluoride, arsenic etc.

3.8 Pathogenic Pollution

- Water borne diseases are the most important water quality issues in India. This is mainly due to inadequate arrangements for transport and treatment of wastewaters. A major portion of the wastewater generated from human settlements is not properly transported and treated before discharging into natural waters. This results in contamination of both surface and ground waters. Moreover, contribution of pathogens through diffuse sources is also quite significant. Thus, most of the surface water bodies and many ground water sources are contaminated.

- A large population of the country still uses water directly for drinking or contact use without any treatment; thus being exposed to water borne diseases. This is the single major cause for mortality due to water pollution.

3.9 Ecological Health

- A large number of areas in our aquatic environment support rare species and ecologically very sensitive. They need special protection.

- Since, the Water Act, 1974 provides for maintenance and restoration of wholesomeness of aquatic resources, which is directly related to ecological health of the water bodies, it is important that ecological health of the water bodies is given first priority in the water quality goal.

4. Ground Water Quality

In recent years, an increasing threat to ground water pollution due to human activity has become of great importance. The adverse effects on ground water quality are the results of man's activity at ground surface, unintentionally by agriculture, domestic and industrial effluents, unexpectedly by sub-surface or surface disposal of sewage and industrial wastes. A major problem in urbanised areas is the collection and disposal of domestic wastewater. Because a large volume of sewage is generated in a small area, the waste cannot be adequately disposed off by conventional septic tanks and cesspools. Therefore, special disposal sites may be required to collect and dispose such wastes in densely populated areas.

The quality of ground water is the resultant of all the processes and reactions that have acted on the water from the moment it condensed in the atmosphere to the time it is discharged by a well. Therefore, the quality of ground water varies from place to place, with the depth of water table, and from season to season and is primarily governed by the extent and composition of dissolved solids present in it. The wide range of contamination sources is one of the many factors contributing to the complexity of groundwater assessment. It is important to know the geochemistry of the chemical-soil-groundwater interactions in order to assess the fate and impact of pollutant discharged on to the ground. Pollutants move through several different hydrologic zones as they migrate through the soil to the water table. The serious implications of this problem necessitate an integrated approach in explicit terms to undertake ground water pollution monitoring and abatement programmes.

The supply of ground water is not unlimited, nor it is always available in good quality. In many cases, the abstraction of excessive quantities of ground water has resulted in the drying up of wells, salt-water intrusion and drying up of rivers that receives their flows in dry seasons from ground water. Ground water quality is being increasing threatened by agricultural, urban and industrial wastes, which leach or are injected into underlying aquifers. Once pollution has entered the sub-surface environment, it may remain concealed for many years, becoming dispersed over wide areas and rendering groundwater supplies unsuitable for human uses.

Ground water in several areas, where sewage is being discharged without proper treatment, has been adversely affected by contaminants associated with sewage. Due to indiscriminate use of fertilisers very high concentrations of potassium and nitrate have been found in ground water at several places in the states of Punjab, Haryana and Uttar Pradesh. Excessive concentrations of nitrate in ground water, which may originate from fertilisers or sewage or both, have been reported to the extent of several hundreds mg/L in various parts of the country. Ground water pollution from some of industrial sources has reached alarming levels. High levels of hexavelant chromium at Ludhiana and Faridabad, lead near Khetri in Rajasthan, nickel in Coimbatore, Cadmium in Kanpur and parts of Delhi are some of manifestations of heavy metal pollution. Arsenic concentrations in ground water have been found in excessive of permissible limit of 0.05 mg/L in West Bengal. Population in these areas is suffering from 'Arsenic Dermatosis' by drinking arsenic rich ground water.

The problem of ground water pollution in several parts of the country has become so acute that unless urgent steps for detailed identification and abatement are taken, extensive ground water resources may be damaged. Essentially all activities carried out on land have the potential to contaminate the ground water, whether associated with urban, industrial or agricultural activities. Large scale, concentrated sources of pollution such as industrial discharges, landfills and subsurface injection of chemicals and hazardous wastes, are an obvious source of ground water pollution. These concentrated sources can be easily detected and regulated but the more difficult problem is associated with diffuse sources of pollution like leaching of agro-chemicals and animal wastes subsurface discharges from latrines and septic tanks and infiltration of polluted urban run-off and sewage where sewerage does not exists or defunct. Diffuse sources can affect entire aquifers, which is difficult to control and treat. The only solution to diffuse sources of pollution is to integrate land use with water management. Table 5 presents land-use activities and their potential threat to ground water quality.

4.1 Common Ground Water Contaminants

- Nitrates: Dissolved nitrate is the most common contaminant in ground water. High level can cause blue baby disease (Methamoglobinarnia) in children, may form carcinogens and can accelerate eutrophication in surface waters. Sources of nitrates include sewage, fertilizers, air pollution, landfills and industries.

- Pathogens: Bacteria and viruses that cause water borne diseases such as typhoid, cholera, dysentery, polio and hepatitis. Sources include sewage, landfills, septic tanks and livestocks.

- Trace metals: Include lead, mercury, cadmium, cupper, chromium and nickel. These metals can be toxic and carcinogenic. Sources include industrial and mine discharges, fly ash from thermal power plants either due to fall out or disposal in ash ponds.

- Organic compounds: Include volatile and semi-volatile organic compounds like petroleum derivatives, PCBs, pesticides. Sources include agricultural activities, street drainages, sewage landfills, industrial discharges, spills and vehicular emissions fall out.

Table 5. Land-Use Activities and their Potential Threat to Ground Water Quality

Land use	**Activities potential to ground water pollution**
Residential	Unsewered sanitation Land and stream discharge of sewage Sewage oxidation ponds Sewer leakage, solid waste disposal, landfill Road and urban run-off, aerial fall out
Industrial and Commercial	Process water, effluent lagoon Land and stream discharge of effluent Tank and pipeline leakage and accidental spills Well disposal of effluent Aerial fall out Landfill disposal and solid wastes and hazardous wastes Poor housekeeping Spillage and leakages during handling of material
Mining	Mine drainage discharge Process water, sludge lagoons Solid mine tailings Oilfield spillage at group gathering stations
Rural	Cultivation with agrochemicals Irrigation with wastewater Soil salinization Livestock rearing
Coastal areas	Salt water intrusion

5. Legal Considerations

The basic objective of the Water (Prevention and Control Pollution) Act, 1974 is to maintain and restore the wholesomeness of the national aquatic resources. Due to large variation in type, size, shape, quality and quantity of water available of our aquatic resources, each one has got a very specific waste load receiving capacity. This implies the need for prescribing different effluent standards based on assimilative capacity of recent systems. Notwithstanding its merits, it is difficult to administer compliance of much varying standards specific types of effluents. To reduce administrative difficulties of relating effluent quality to ambient water quality the concept of Minimum National Standards (MINAS) was evolved by the Central Pollution Control Board whereby minimum effluent limits are prescribed for each category of discharge, regardless of receiving water requirements. Where water quality standards cannot be reached by imposition of a standard level of treatment alone, then and only then will the conditions of the receiving waters dictate more stringent controls (State Boards can make the

MINAS more stringent). The conventional methods of treatment cannot cope with these specific situations and the polluters are required to go for introduction of new methods for specific requirements. The number of such situations in our country is gradually rising due to water scarcity in many water bodies and some times due to the nature of effluents.

6. Approach to Water Quality Management

The Water (Prevention and Control of Pollution) Act, 1974 reflects the national concern for water quality management. The basic objective of the Act is to maintain and restore the wholesomeness of water through prevention and control of pollution. The Act does not define the level of wholesomeness to be maintained or restored in different water bodies of the country. For defining these levels for different water bodies the Central Pollution Control Board (CPCB) had initially taken use of water as a base for identification of water quality objectives for different water bodies. Hence, it has classified the national aquatic resources according to their uses. CPCB has also identified primary water quality criteria for different uses of water as a yardstick for the preparation of different pollution control programs. The use-based classification system is given in Table 6.

Table 6. Use Based Classification of Surface Waters in India

Designated best use	Quality Class	Primary quality criteria
Drinking water source without conventional treatment, but with chlorination	A	6.5 to 8.5 (I); 6 or more (2); 2 or less (3); 50. 5%-200. and 20%-50 (4); NIL (5 - 8)
Outdoor bathing (organized)	B	6.5 to 8.5 (I); 5 or more (2); 3 or less (3); 500, 5%-2000, and 20%-500 (4); NIL (5 - 8)
Drinking water source with conventional treatment	C	6.5 to 8.5 (I); 4 or more (2); 3 or less (3); 5000, 5%-20000, and 20%-5000 (4); NIL (5 - 8)
Propagation of wildlife and fisheries	D	6.5 to 8.5 (I); 4 or more (2); NIL (3 - 4); 1.2 (5); NIL (6 - 8)
Irrigation, industrial cooling, and controlled waste disposal	E	60 to 8.5 (I); NIL (2 - 5); 2250 (6); 26 (7); 2 (8)

(l) pH, (2) Dissolved Oxygen, mg/l, (3) BOD, (20^{o}C) mg/l, (4) Total Coliform (MPN/1OO ml), (5) Free Ammonia, mg/l, (6) Electrical Conductivity, µmho/cm, (7) Sodium Adsorption Ratio, (8) Boron, mg/l.

The 'designated best use' yardstick as explained above is based only on limited number of parameters called primary criteria. While implementing such criteria there are many practical difficulties, which need scientific support. The criteria should be such that they can support not only the designated uses but also the ecological sustainability of the water body (wholesomeness), which is the prime objective of the Water Act, 1974. Hence, the CPCB with the help of an expert group has revised the approach.

6.1 The Revised Approach

While human interests cannot be ignored or downgraded in importance, it is now widely accepted that the long term interests of human beings themselves lie in maintaining environment and ecosystems in an overall healthy condition. A system totally oriented to the objective of protecting direct beneficial uses by man and of classifying water-quality on that basis may not be adequate. In many cases, (such as in case of small water-bodies, or those with no significant current water-use), the objective may have to be the protection of certain basic environmental quality for sustaining ecosystem. Even where beneficial uses, whether current or potential, can be clearly defined and a 'designated best-use', the first priority in water-quality assessment and management would go to maintaining and restoring the desirable level of general environmental quality or 'wholesomeness'. With this approach, it is not that protection of designated best use is being abandoned, but that, the over-all health of ecology is given its rightful place, ahead of any direct current beneficial uses by man. Such ecological considerations shall ensure the biological integrity of a water-body including both structural as well as functional integrity.

For effective management of water quality it is necessary to involve local administrative bodies at the district, block, municipal and village panchayat levels, NGOs and the citizens themselves in conducting at least a crude, rapid and overall assessment of water quality.

While water quality requirements for specific large-scale organised uses may continue to be prescribed and even strengthened, the stake-holders could share responsibility for water quality monitoring and management in such cases. It would lead to a 2-pronged approach, viz., defining water-quality requirements and classification with the objective of (a) maintaining and restoring wholesomeness of water for the health of ecosystem and environment in general (Basic water quality requirement) and (b) protecting designated organised uses of water by man and expecting the stake holders to share responsibility in monitoring and management of such quality by associating with them local administrations, NGO's and citizens in the monitoring and management of desired quality to the extent possible.

All water bodies where the existing water quality is below acceptable level should be identified on priority basis for taking remedial measures to restore their quality to the acceptable level within a stipulated period. In case of water bodies where the water is of acceptable quality, but below the desirable quality, limits of the relevant parameters should be identified and quality restoration programme should be implemented within a reasonable period.

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