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MONITORING OF GROUNDWATER POLLUTION FROM SEWAGE WASTE IN BAHADRABAD, HARDWAR (U.P.)

NATIONAL INSTITUTE OF HYDROLOGY
JAL VIGYAN BHAVAN
ROORKEE - 247 667, (UP) INDIA

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PREFACE

In recent years, an increasing threat of groundwater pollution due to human activities has become of great importance for many countries. The adverse effects on groundwater quality are the result of man's activity at ground surface, unintentionally by agriculture, domestic and industry, unexpectedly by sub-surface or surface disposal of sewage and industrial waste water and by solid dumps.

In view of aggravation of groundwater pollution problems in the country, it was envisaged to study the impact of land disposal of sewage waste on groundwater quality of Bahadrabad area in district Hardwar.

The report has been prepared by Shri Sudhir Kumar and Dr C K Jain, Scientist of Man's Influence Division.

Satish Chandra
(SATISH CHANDRA)

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ABSTRACT

Many and diverse men's activities produce innumerable waste materials and by products. Disposal of these waste materials is becoming a major problem world over. A wide variety of solid wastes from industries, residences and municipalities is disposed off on the land, whereas, liquid waste is disposed either over or below land surface. The disposal of wastes, whether on surface or subsurface pose a serious threat to groundwater quality.

Municipal sewage water may contaminate the groundwater through (i) leakage from collecting sewers, (ii) leakage from the treatment plant during processing, and (iii) land disposal of the treatment plant effluent. In addition, it can also contaminat the groundwater indirectly through sewage disposal to surface water bodies which recharge aquifers, and land disposal of sewage as irrigation water.

In the present report, an attempt has been made to assess the effect of municipal sewage waste disposal from Bharat Heavy Electrical Limited, Hardwar on quality of groundwater in the Bahadrabad area. Sewage waste water is being collected in storage tanks and then spread over an area of about 15 sq. km. as irrigation water.

Water samples from nine sites including two from sewage waste, two from shallow dug wells, four from hand pumps and one from deep tube-well have been collected in premonsoon and postmonsoon seasons. The samples were analyzed for routine physical and chemical parameters. The results of the analysis indicate that the waste disposal has started contaminating the shallow groundwater, though the magnitude of contamination is low. Further, the analysis shows that both the shallow and deep groundwater of the area is safe for drinking purposes.

1.0 INTRODUCTION

1.1 General

Ground water is a renewable natural resource with a relatively short and shallow circulation, with close dependence on precipitation and surface water and on the influence of man whose activities qualitatively and quantitatively menace and pollute it with increasing frequency. Man in his endeavor to increase agricultural production and to improve his living conditions produce innumerable waste materials and by-products. These waste materials has affected the natural environment with far reaching consequences. Disposal of industrial and municipal waste, extensive use of fertilizers and confinement of farm animals often adversely effect groundwater quality. Contamination may impair the use of groundwater or may create hazards to public health through poisoning or the spread of disease.

The main sources of contamination related to waste disposal practices are:

- Industrial waste - water impoundments
- Land fills and dumps
- Septic tanks and cesspools
- Collection, treatment and disposal of municipal waste water
- Land spreading of sludges
- Brine disposal from petroleum exploration and development
- Disposal of mine wastes
- Disposal of animal feed lot wastes

A wide variety of wastes from industries, residences and municipalities is disposed off on the land. This practice ranges from simple dumping of refuse on a readily available piece of land to controlled disposal of processed waste on sites which are designed to minimize the potential for contamination of local water resources.

Municipal waste water follows one of the following direct routes to contaminate groundwater; leakage from collecting sewers, leakage from treatment plan during processing, and land disposal of the treatment-plan effluent. In addition, there are two indirect routes; effluent disposal to surface water bodies which recharge aquifers, and land disposal of sludge which is subject to leaching. Although the volume of waste water entering the groundwater system from these various sources may be substantial, there have been few documented cases of hazardous levels of constituents of sewage or storm water affecting groundwater supplies.

Untreated sewage is principally composed of domestic wastes. In areas where manufacturing is also served by the community system, the waste product of industry can add important potential contaminants. Storm runoff from streets, parking lots, and roofs contributes salts, inorganic chemicals and organic matter which have deposited on exposed surfaces.

Ground water contamination from land spreading of sludge is most likely to be in the form of chemical contamination. Some constituents are soluble and are likely to be leached more readily than others. These include sodium, potassium, sulfate, chloride and nitrate ions. Other constituents are held more strongly in the sludge matrix or are attenuated more strongly in soil. These include calcium , magnesium etc. Constituents which are more strongly held in sludges or move relatively slowly into or through the soil profile pose less of a threat to groundwater, but may affect the quality of crops to a greater extent.

The rate and extent to which chemical constituents of sludge are leached depend upon the amount of precipitation and the relationship between precipitation and evapotranspiration. Where precipitation occurs in excess of evapotranspiration, sludge constituents can be carried to groundwater by recharge.

1.2 Scope of the Present Work

In modern society, waste disposal is a major problem. If the waste is disposed in the rivers, as is the normal practice, it pollutes the surface water resources, and if it is burnt, it causes air pollution. Due to pollution attenuation properties of the soil, the land disposal is considered as one of the best ways of waste disposal. But soil also have some finite capacity to degrade or absorb/adsorb the pollutants. If this limit is crossed then groundwater starts getting polluted.

In district Hardwar (earlier a part of district Saharanpur) sewage waste is being disposed on land near Bahadrabad, for about last 20 years. In the present study, it has been proposed to study the impact of this land disposal of sewage waste on groundwater of the area. Water samples from sewage waste and shallow groundwater (dug wells and hand pumps) and deep groundwater (tube wells) for premonsoon and postmonsoon seasons have been analyzed to evaluate the impact.

2.0 GENERAL CRITERIA FOR SELECTION OF WASTE DISPOSAL SITE

The waste disposal site should be selected based on some scientific criteria, so that the groundwater can be saved from contamination.

The site selection criteria can be divided into four main categories, namely geology, soil, hydrology, and climate (Wood, 1984).

2.1 Geology

The first parameter to be considered is the geology of a potential site for the waste disposal facility. Geology of the area can be described as the interdependence of the structural, stratigraphic, and physiographic characteristics of rocks. For the purpose of selection of site, it can be divided into two sub parameters of local topography and the quality of host rock.

2.1.1. Local Topography

Natural and physical features define the local topography. The lay of the land can be considered in terms of its nearness to water bodies, variation in elevation, slope, intervening terrain and rock outcrops.

Nearness to surface water bodies

A surface water body such as a stream, canal or a lake acts as a intersection between the groundwater and the surface. If some contaminant leaks from the site and travel to a nearby stream, the plume is more likely to flow downstream then to spread beyond it. Distance from site to stream directly influences the contamination travel time, the longer the travel distance, the longer the time needed for a contaminant to reach the natural boundary. Stream density can influence the content of groundwater contamination. For example, when streams are thinly scattered, the distance between them naturally increases. Therefore, contaminants from the site will have a longer travel time in the ground, where they may be sorbed and react with the soils, leaving few pollutants to reach the stream. On the other hand, closely spaced steams decrease the ground contamination zone at the expense of stream contamination.

Variation in Elevation

The elevation of a particular site is not important by itself but it becomes significant in relation to the surrounding area. Sites with high elevation relative to surrounding areas often have a high potential for groundwater movement away from the site. Since groundwater flows from areas of high to low potential, relative elevation of the sites determine the distance that the contaminants will eventually travel before reaching a stable location, where relatively low potential occurs.

Slope

Slope refers to any ground whose surface forms an angle with the plane of horizon, whether a natural or an artificial incline such as a hillside to terrace. Since water flows from a place of high to low potential, slope influences both surface and groundwater flow movement. Therefore, as ground surface slope increase, a more rapid decrease in elevation head occurs, causing an increase in velocity and discharge.

A disposal site at the top of a hill receives little or no runoff except from direct rainfall. In contract, a site in an area a the bottom of a hill will collect runoff from the surrounding region in addition to its direct rainfall. A high elevation site may have the advantage of remoteness from the groundwater table, but has disadvantage of contaminating a larger soil zone. Thus, trade off must be made between sites with high and low slopes.

2.1.2 Quality of host rock

The quality of host rock may be measured by its structural integrity and regularity of deposits. Bedrock geology determines the structural framework that surfaces as land forms.

Structural integrity

Structural integrity of host rock includes fractures and joints, inconsistencies and weathering.

The contaminated water may move very easily and with high speed through the host rock with fractures and joints. So very less time is required to reach the contaminated water to the aquifer and hence very little or no attenuation of contaminants take place. So the host rock with high fracture or joint density should be avoided, while selecting the waste disposal site.

Geological inconsistencies or abnormalities, such as intrusion of igneous rock, may influence the flow of water and contaminants. Similarly, the presence of aquicludes and clay beds in the alluvium can alter water movement because of its relative impermeability.

Weathering disintegrates the rock through physical and chemical process. Net effect of weathering is the increase in porosity and permeability. This change in porosity and permeability of host rock can also affect the movement of contaminants.

2.1.3 Regularity of deposits.

The regularity of a deposit of host rock may be measured by its aerial extent, thickness and depth from surface.

Aerial extent

Speed and direction of movement of contaminants from a pollutant source depend on the medium through which they pass. It is easier to predict migration in a homogeneous isotopic medium, which has a uniform structure and properties that are the same in all directions at a particular point, so that a contaminant will migrate equally in all directions. However, few deposits are totally homogeneous and/or isotopic. An area is desirable whose deposits are regular and large enough for a site, particularly when structural integrity of the rock is sound.

Thickness

The thickness travelled by a pollutant through a medium affects the flow period. Therefore, the thicker a deposit, the longer a flow period through the deposit. It is easier to estimate the contaminant flow period for a thick homogeneous deposit then for one composed of numerous thin layers. Flow through a sand layer is quicker than through a clay layer. But when clay layer overlies the sand layer, the down ward filtration is slowed down (Wick effect). This slowing down is due to capillary forceps present in the clay layer.

2.2 Soil

The second general category to be considered in selecting a land disposal sites is the soil of the region. Soil is defined as the mantle of weathering between atmosphere and unweathered rock (Blatt et al. 1980). Transport capacity and the sorption capacity are the two most important characteristics of soil, which affect the movement of contaminants.

2.2.1 Transport capacity

Transport capacity refers to a soil's ability to allow movement of water carrying contaminants. Thus, the greater the soil transport capacity, the greater the migration of contaminants, which is undesirable.

The texture class of a soil influences its porosity and thus its permeability. Soil texture class is based on the percentage of sand, silt and clay. As texture of soil materials become finer, the groundwater velocity tends to decreased from higher to lower for the same groundwater potential. Coarse textured material encourages contaminant migration.

The transport capacity of soil also depends upon the porosity and permeability of the soil. To the grains of soil are considered as small spheres, then the least dense packing arrangement of spheres has a porosity of 47.6 percent while that of the most dense is 26.0 percent. Soils generally tends to have dense pecking and moreover the grains are not spheres. So the porosity of soils is further decreased.

Hydraulic conductivity measures the ease by which the fluid flow through a porous medium. The hydraulic conductivity for sand is about 10^{-3} cm/sec, while that for marine clay is 10^{-8} cm/sec. In other words, a fluid which flows 10^{3} ft/year through sand will flow 0.01 ft/year through clay, under the same pressure gradient. Hence a contaminant can travel quickly and cover great distances in a geological formation containing glacial out wash and deltaic sands that are well sorted sand and gravel beds then in one made up of clay.

Therefore, a site should be chosen such that the porosity and permeability of the soil is low and it can act as a natural defence by retarding the movement of contaminants.

2.2.2 Sorption Capacity

Sorption capacity depends on predominant minerals and pH of soil. Sorption includes both adsorption and absorption of contaminants.

The most important soil particles which interact with contaminants are the clay minerals. Their cation exchange capacity (CEC) is extremely important in attenuating heavy metals. The CEC can be defined as the capacity of the soil to exchange cations. A soil with high CEC may act as a back up system for retarding unplanned movement of heavy minerals. For example, a soil with an average CEC greater than 30 meq/100 gm could be considered acceptable, 20 to 30 meq/100 gm neutral and less than 20 meq/100 gm as unacceptable.

The hydrogen ion concentration (pH) of soil influences the dominant removal mechanism for metal cations. The dominant removal mechanism for metal cations when $pH < 5$ is exchange or adsorption, and when $5 < pH < 6$, it is precipitation (EPA, 1978).

2.3 Hydrology

Hydrology is the science dealing with the properties,distribution, and circulation of water. Proximity to groundwater supplies and to surface water supplies should be considered for selection of site. Both of these supplies influence contaminant migration and have the potential to become polluted.

Proximity of groundwater supplies

Proximity of a waste disposal site to groundwater supplies can be evaluated using the distance from the site to the groundwater table, hydraulic gradient, presence of different aquifers and closeness to wells.

When distance from the surface to the water table is short, contaminant travel time is also short, allowing for little attenuation before pollutants disperse laterally in thesaturated zone.

Hydraulic gradient influences the direction in which water will flow. A hydraulic gradient sloping away from local groundwater supplies is desired. The steeper the hydraulic gradient, the lower the attenuation time and the faster the water movement.

In a multi aquifer system, the nature of inter connection between the aquifers is also an important factor for the selection of the site. If the aquifers are interconnected then all the aquifer system can get contaminated.

Proximity to surface water supplies

Proximity to surface water supplies, like proximity to groundwater supplies, involves considerations of quantity, quality, and use. The analogous parameters, such as distance from waste disposal site, hydraulic gradient, and stream at density, influence contaminant flow from a site to surface water supplies. The difference is that once an aquifer has been contaminated, it is polluted for a long time, whereas a polluted surface may be diluted and flushed out quite quickly.

2.4 Climate

Climate is considered a driving force in contaminant migration. For potential sites within the small area, climate is unlikely to vary significantly.

Site flooding can weaken the structure of waste disposal site, causing it to fail and leak wastes. Therefore, it is essential that the site is not built on a flood plain or area subject to local flooding, unless designed to withstand flood impacts.

3.0 GENERAL CHARACTERISTICS OF MUNICIPAL WASTE WATER AND METHODS OF LAND TREATMENT

3.1 Characteristics of Contaminants

Municipal waste water treatment plants handle wastes which vary in composition corresponding to certain patterns of every day life. Typical hourly variation in flow and domestic sewage is shown in fig. 1.

Although waste water is primarily liquid, the composition can probably best be studied by first considering the total solids content.The sources of domestic solids in waste water include toilets, sinks, baths, laundries, garbage grinders and water softness. In addition to domestic sewage, municipal waste water contains storm water and commercial and industrial discharges. The contributors of total solids in waste water is expressed as grams/capita/day (gpcd). Compositions of strong, medium and weak domestic sewage are presented in Table 1.

The resulting water quality after land spreading of waste water depends on the initial waste-water characteristics, site topography, hydrologic and geologic conditions, type of vegetation and application method.

Survival of pathogens in the water depends on soil moisture, soil temperature and type of organisms. Pathogens in general do not enter healthy, unbroken vegetables but may be harbored in broken, bruised, or unhealthy plants and vegetables.

Chemical compounds found in waste water such as nitrate, mineral salts, and toxic trace organics may reach the groundwater as a result of land spreading. Nitrate is of concern because it is reported to be a cause of methenoglobinemia in infants. High salt content can be harmful of people with cardiac and circulatory diseases.

3.2 Land Treatment

There are three general methods of applying waste water to land namely irrigation, overland flow, and infiltration percolation.

Reclaimed sanitary waste water is generally used to irrigate certain field crops such as cotton, sugar beets, and vegetables. It cannot be used for field crops that are normally consumed in a raw state.

Land application of waste water by infiltration percolation is often refereed to as groundwater recharge because the major portion of the water applied percolates to the water table. Depending upon its final quality, the recharged water may

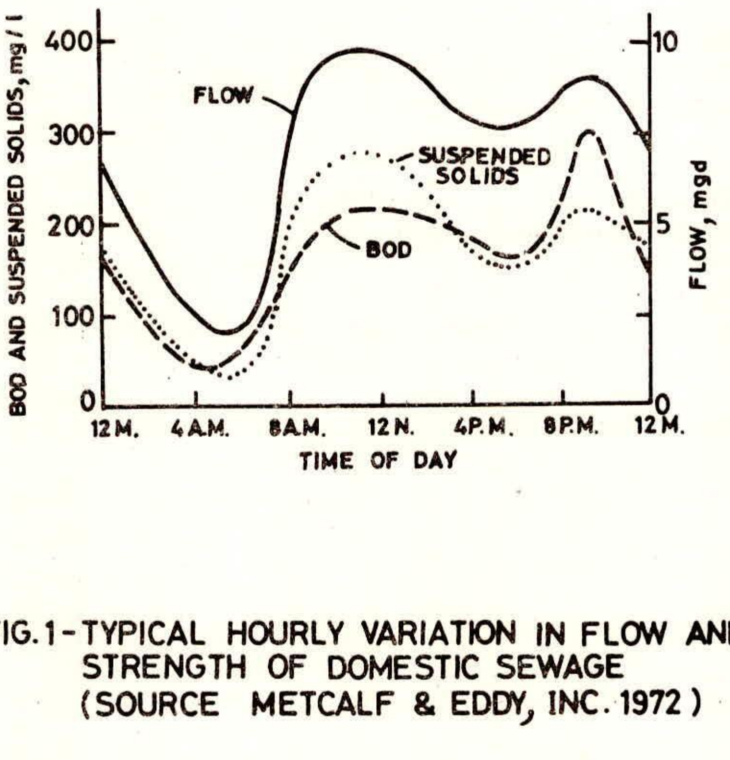

FIG. 1 - TYPICAL HOURLY VARIATION IN FLOW AND STRENGTH OF DOMESTIC SEWAGE (SOURCE METCALF & EDDY, INC. 1972)

Table 1: Estimate of the Components of Total Solids in Waste Water

Component	Dry Weight (gpcd)
Water supplies and groundwater, assumed to have little hardness	12.7
Feces (solids, 23 percent)	20.5
Urine (solids, 3.7 percent)	43.3
Toilet (including paper)	20.0
Sinks, baths, laundries, and other sources of domestic wash waters	86.5
Ground garbage	30.0
Water softeners	- a)
Total for domestic sewage from separate sewerage systems, excluding contribution from water softeners:	213.0
Industrial wastes	200.0 b)
Total for industrial and domestic wastes from separate sewerage system	413.0
Storm water	25.0 c)
Total for industrial and domestic wastes from combined sewerage system	438.0

a Variable
b Will vary with the type and size of industries
c Will vary with the season

Source: Metcalf and Eddy, Inc. 1972.

be recovered and used for irrigation recreation, municipal or industrial supply.

The physical design of a land treatment system is governed by the type of application involved and each system has specific characteristics which make it applicable to certain situations.

Flows to land spreading and basin recharge system vary primarily depending on the type of system employed. The actual application rates employed are a function of soil type, character of waste water and degree of pretreatment, and the desired waste removal efficiency.

Land spread of waste water can pose a significant threat to groundwater quality. A summary of the effectiveness of removal of the more common constituents apper in Table 2.

Table 2: Contamination Likely From Land Disposal of Domestic Waste Water.

Parameter	Irrigation method	Infiltration-percolation method
Nitrogen	Nutrients that are not used by plants or fixed in the soil can leach to groundwater	Significant qunatities passed to groundwater at most sites
Phosphorus	Leaching of excess phosphorus is rare occurrence. Organic and clay soils absorb practically all of the phosphorus	Removal may be limited because granular soils are used
Organics	Usually broken down by micro-organisms and used by plants. Can appear in groundwater when application rate is highest or when in open soil, such as sand or gravel, with a high percolation rate.	Evidence is that little organic matter reaches groundwater
Trace Elements	Toxic compounds can be changed by the chemical reaction of cation exchange and can be rendered non toxic by bacteria. Chemical precipitates formed can be leached out	Retention may be limited due to granular nature of soil
Total Dissolved solids	Leaching can occur and build up is possible	Build up is possible
Enteric Organisms	Usually are removed or die out and do not reach groundwater especially if water table is kept low	Spread of bacteria and viruses by insects or percolating water is of concern but unlikely under soil conditions

Source : Pound, E E and F W Crites, 1973.

4.0 DESCRIPTION OF THE AREA UNDER STUDY

The area under study is a part of Gangetic plains lying in the Hardwar district of Uttar Pradesh (U.P). The area lies between latitudes N 29°55' to 29°57' and longitudes 78°2' E to 78°5' E. The water disposal site is bound by Upper Ganga Canal in the south, Siwalik piedmont in the north and Ranipur Rao in the east. The sewage waste from the Bharat Heavy Electricals Limited (BHEL), the major industrial establishment in the area, is dumped on the Bengal Engineering Group (BEG) farm land and is used as the irrigation water.

4.1 Physiography and Climate

Physiographically the area is generally flat with a gentle slope (1-2%) towards south. The area is devoid of relief features of any prominence.

Moderate type of submonsoonic climate prevails in the area with average rainfall of about 1500 mm. Most of the precipitation occurs within a short period of four months. The temperature ranges from 8°C in the winters to 40°C in the summers.

4.2 Geology and Geohydrology

Geologically the area is a part of Upper Gangetic plains which is mainly composed of Pliestocene and Sub-recent alluvium. The alluvium contains sand, silt and clay and gravels.

Based on physiography and geohydrology the Gangetic plains can be divided into four sub-zones i.e. (i) Bhabar zone, (ii) Tarai zone, (iii) Central alluvial plains and (iv) Marginal alluvial plains.

The disposal site under study is in the Bhabar zone of the Gangetic plains. The Bhabar zone consists of unsorted gravels, of various sizes and sand with interrelations of clay. The depth of water level is generally 30 m or more, below ground level. The deep water table conditions are mainly due to the non availability of the confining layers at shallow depth, but in the present area the groundwater level is shallow (ranging from 3-10 m) as the area is traversed by Upper Ganga Canal. The seepage of the water from canal has raised the water table in the area under study. The granular material of this sub-zone are highly permeable, by virtue of that the rainwater is readily absorbed and form a recharge zone.

The discharge in this zone varies from 98 to 227 m^3/hr. for draw down between 2.08 to 9.68 m.

4.3 Collection and Disposal of Sewage Waste

A major problem in urbanized area is the collection and disposal of domestic waste water. Because a large volume of sewage is generated in a small area, the waste cannot be adequately disposed of by conventional septic tanks and cesspools. Therefore, special disposal sites are used to collect and dispose of such wastes in densely populated areas.

The municipal corporation of Hardwar district has constructed a sanitary sewer system to collected the sewage at a central point. The sewage is being collected in lined large diameter wells away from the township. When the level of sewage becomes sufficiently high then it is pumped out by electric pumps and is spread over BEG farms through unlined channels. The waste is used for irrigation of these farms.

5.0 METHODOLOGY

5.1 Sampling

Sampling is one of the most important and foremost step in collection of representative water sample for groundwater (or any water) quality studies. Moreover, the integrity of the sample must be maintained from the time of collection to the time of analysis.

Many factors are involved in the proper selection of sampling sites, e.g. objectives of the study, accessibility, chemical sources locations and manpower and facilities available to conduct the study. Further more, the hydrologist must be aware of the locations of point and non point source of chemical and physical constituents, such as industrial complexes, sewage out falls, agricultural wastes etc.

In the present study nine sites for raw sewage and groundwater sample were chosen (Fig. 2). Sampling was carried out in the months of June (Pre-monsoon) and November (Post-monsoon) 1988.

The samples were collected by dip (or grab) sampling method. For complete sampling at a point, the samples were collected in the following manner:

i) Two bottles of 500 ml for field analysis:

One sample filtered for determining nitrate, nitrite and ammonia and second sample for direct measurement of pH, conductivity and temperature.

ii) One bottle of 500 ml for lab. analysis of turbidity, alkalinity , hardness, chloride, fluoride.

iii) One bottle of 500 ml preserved by adding 5 ml nitric acid per liter to prevent adsorption to the walls of bottle for determination of other cations which may change before the sample reach the laboratory.

5.2 Water Quality Parameters

The quality of water depends on a large number of individual hydrological, physical, chemical and biological factors. Some parameters are of special importance and deserve frequent attention and observation, other gives a rough picture of water body and its quality status.

During the present study the chemical properties and the constituents of water analyzed are, pH, specific conductance (EC), colour, odour, Hardness, alkalinity (Carbonates and bicarbonates), temperature and major cations and anions.

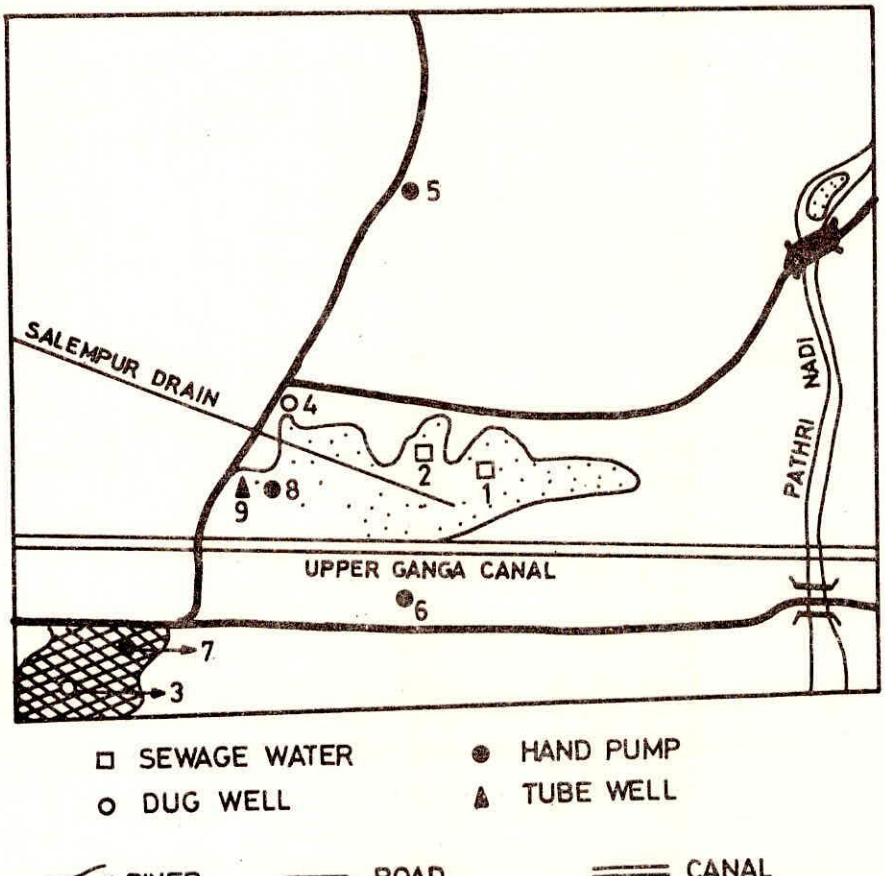

FIG. 2 - LOCATION MAP OF SAMPLING POINTS

5.2.1 Physical parameters

Temperature

The temperature of water is one of the most important characteristics which determine the trends and tendencies of changes in its quality. The shifting of various dynamic equilibria such as concentration of carbonates, sulfides, or degree of alkalinity or electric conductivity are affected by temperature changes.

pH

pH value represents the concentration of hydrogen ions (H^+) in water and is a measure of acidity and alkalinity of water. A value of pH below 7.0 indicates acidic character while pH greater than7.0 alkaline character of water.

Electric conductivity

Electric conductivity is a measurement of water's capacity for conveying electrical current and is directly related to the concentrations of ionized substance in the water. Solution of most inorganic acids, bases and salts are relatively good conductors. Conductivity measurements are commonly used to determine the purity of demineralised water and total dissolved solids in boiler, cooling tower water, irrigation and domestic supply.

Colour

Colour in water may result from the presence of natural metallic ions, humus and peat material or industrial wastes . For drinking purpose the water should be colourless.

Odour and Taste

Disagreeable tastes and odours in water are associated with the presence of a great variety of living micro-organisms or decaying vegetation or organic compounds. For drinking purposes the water should be odourless.

5.2.2 Major Anions

Carbonates and Bicarbonates

The presence of carbonates and bicarbonates is the most common cause of alkalinity in natural waters. Bicarbonates represent the major form since they are formed in considerable amounts from the action of carbonates upon the basic materials in the soil.

Sulfate

Sulfate appears in natural waters in a wide range of concentrations. Sodium and magnesium sulfate exert cathartic action and hence its concentration above 250 mg/L in potable water is objectionable. Sulfate cause a problem of scaling in industrial water supplies and problem of odour.

Chloride

Chloride is one of the major inorganic anion in water. It is present in all potable water supplies and in sewage, usually as a metallic salt. When sodium is present in drinking water, chloride concentrations in excess of 250 mg/L give a salty taste. High chloride concentrations in water are not known to have toxic effects on man, though large amounts may act corrosively on metal pipes and be harmful to plant life.

5.2.3 Major cations

Sodium

Sodium, the sixth most common element, is present in nearly all natural waters. The levels may very from less than 1 mg/L to more than 500 mg/L. Ratio of sodium to total cations is important in agriculture and human pathology. Soil permeability can be harmed by a high sodium ratio.

Potassium

Potassium is less common cation in the groundwater. Its concentration in most drinking waters seldom reaches 20 mg/L. However, occasional brines contain more than 100 mg/L potassium.

Calcium

Calcium is one of the principle cations in groundwater. In the sedimentary rocks, calcium occurs as carbonates, and in alluvium it occurs in limestone. Calcium carbonate imparts the property of hardness to water together with sulfate, carbonates and bicarbonates.

Magnesium

After calcium, magnesium is the most important alkaline earth metal present in the groundwater. It is one of the important contributors to the hardness of water. The magnesium concentration in water may vary from zero to several hundred ppm, depending on the source of water.

5.2.4 Other Parameters

Hardness

The hardness of water was originally defined in terms of its ability to precipitate soap. Calcium and magnesium ions are the principle causes although iron, aluminum, manganese and hydrogen ions are capable of producing the same effect. Temporary hardness is caused by the presence of bicarbonates of calcium and magnesium, whereas permanent hardness is mostly due to sulfates.

Nitrogen

In water, the forms of nitrogen of greatest interest are nitrate, nitrite, ammonia and organic nitrogen. All these forms of nitrogen are biochemically inconvertible and are components of the nitrogen cycle.

Total oxidized nitrogen is the sum of nitrate and nitrite nitrogen. Nitrate generally occurs in trace quantities in surface water but many attain high levels in groundwater. High levels of nitrate indicate the introduction of biological waste or contamination due to leaching from heavily fertilized fields.

Fluoride

Fluoride occurs naturally in groundwater and normally 1.0 mg/L level is maintained in public drinking water supplies for the prevention of dental disorders. Excessive amount of fluoride cause an objectionable discoloration of teeth enamel called fluorosis.

Iron

Iron is present in most surface and sub surface waters. In polluted surface water, the concentration of iron varies from several micrograms to hundreds of micrograms per liter. In subsurface water it may be in the magnitude of gm/L.

5.3 Methods of Analysis and Equipment Used

The laboratory of the Institute is capable of analyzing the basic parameters for water and waste water. However, for the measurements of some parameters such as pH, conductance and temperature, the portable water testing kit was used. The list of equipment used and methods of analyses are presented in Table 3. Testing of each equipment and calibrations have been carried as per standard methods for the examination of water and waste water.

Table 3: Analysis Methods and Equipment Used in the Study

S.No.	Parameter	Analysis method	Equipment used
1.	Temperature	Thermometric	Portable kit (Naina Model NPC 358 D)
2.	pH	Electrometric	"
3.	Conductance	Wheatstone bridge	"
4.	Turbidity	Photometric	Turbidimeter (Hach Model 16800)
5.	Alkalinity	Titrimetric	Digital titrator (Hach)
6.	Hardness	Titrimetric	Digital titrator (Hach)
7.	Ammonia-nitrogen	Nesslerization	Spectrophotometer (Hach DREL/5 System)
8.	Nitrate-nitrogen	Cadmium-reduction	"
9.	Nitrite-nitrogen	Diazotization	"
10.	Chloride	Mercuric-nitrate	Digital titrator (Hach)
11.	Sulfate	Turbidimetric	Spectrophotometer (Hach DREL/5 System)
12.	Phosphate	Ascorbic acid	"
13.	Fluoride	SPADNS method	"
14.	Iron	1,10 phenanthroline	"
15.	Sodium	Flame emission	Flame photometer (Toshniwal - RL 01.02)
16.	Potassium	Flame emission	"
17.	Calcium	Titrimetric	Digital titrator (Hach)
18.	Magnesium	Titrimetric	Digital titrator (Hach)

6.0 RESULTS AND DISCUSSION

6.1 Effect of Sewage Waste Disposal on Groundwater

The quality of groundwater as determined by the physical and chemical constituents is of great importance in determining its use. The quality may change due to its reaction with aquifer material or interaction with poor quality infiltrating water. Near the waste disposal site the leachate, high in dissolved solids, percolates down and deteriorates the groundwater quality. Presence of some minerals and bacteria or virus, beyond a certain limit may make the water injurious for irrigation, drinking or industrial purposes.

In the present study, the groundwater quality of the nearby area of the waste disposal site was monitored in two seasons, i.e. premonsoon and postmonsoon . The physico-chemical analysis of the raw municipal waste, shallow and deep groundwater was carried out. The results of the analysis are presented in table 4.

The result of chemical analysis (Table 4) indicates that the sewage waste has started affecting the quality of groundwater. The water samples from dug wells generally have high values of electrical conductivity, alkalinity, hardness, anions and cations (except iron) as compared to hand pump water (which are relatively deeper than the dug wells). The quality of water of tube wells is further better than that of hand pumps.

The increase in iron content in dug wells and hand pump water may be due to the leaching of iron from the soil. The low iron content and better quality of groundwater in tube wells may be due to the fact that the tube wells are deep and tap the confined aquifer where sewage water has no effect.

6.2 Suitability of Water for Irrigation Purpose

Irrigation water quality refers to its suitability for agricultural use. A good quality water has the potential to cause maximum yield under good soil and water management practices. However, the quality of irrigation water depends primarily on dissolved substances.

Water used for irrigation always contains measurable quantities of dissolved substances which, as a general collective term, are called salts. They include relatively small but important amount of dissolved solids. The nature and quality of dissolved salts depend upon the source of water and its course before use and determine the quality of irrigation water.

With good quality water there should be very infrequent or no problem affecting productivity. However, with poor quality water, various solid and cropping problem can be expected to

Table 4. Chemical Analysis of Groundwater and Sewage Water Samples from Bahadrabad Area

(a) Pre-monsoon 1988

Sample No. (1)	Colour (2)	Turbidity, NTU (3)	Cond., umhos (4)	pH (5)	Alkalinity (mg/L) (6)	Hardness (mg/L) (7)	Sulfate (mg/L (8)	Chloride (mg/L) (9)	Fluoride (mg/L) (10)	NO_3-N (mg/L) (11)	NO_2-N (mg/L) (12)	NH_3-N (mg/L) (13)	K (mg/L) (14)	Na (mg/L) (15)	Ca (mg/L) (16)	Mg (mg/L) (17)	Fe (mg/L) (18)
1 (SW)	4	26	570	7.4	295	118	10.8	12.6	0.75	1.1	0.15	9.25	0.8	37.0	36.0	6.80	0.12
2 (SW)	6	60	519	7.1	265	100	7.0	19.0	0.68	1.2	0.15	7.50	0.9	42.0	32.0	4.87	0.05
3 (DW)	-	8	422	7.4	185	181	6.0	13.5	0.55	2.0	0.12	0.65	0.9	31.0	20.0	9.80	0.09
4 (DW)	-	10	484	7.7	186	80	2.0	7.4	0.52	1.2	0.04	0.60	0.3	14.5	18.0	8.54	0.12
5 (HP)	-	6	320	7.3	147	85	9.0	6.0	0.50	2.2	0.02	-	-	8.3	24.4	5.85	0.35
6 (HP)	-	3	287	7.4	145	78	13.0	2.0	0.45	1.4	0.02	-	-	4.3	26.0	3.17	0.50
7 (HP)	-	9	271	6.9	160	84	18.0	10.0	0.35	2.1	0.09	-	0.1	7.4	25.6	3.90	0.30
8 (HP)	-	9	350	7.1	197	71	16.0	4.0	0.54	1.3	0.02	-	-	4.6	24.0	2.68	0.38
9 (TW)	-	4	241	7.2	145	66	6.0	5.0	0.48	1.5	0.02	-	0.1	2.7	22.0	2.68	0.16

(b) Post-monsoon 1988

1 (SW)	2	22	552	7.3	275	112	6.0	11.0	0.72	1.3	0.19	10.10	0.6	31.0	24.0	6.70	0.11
2 (SW)	8	47	527	7.3	256	92	5.0	11.0	0.64	1.2	0.17	8.20	0.7	37.0	27.0	4.10	0.14
3 (DW)	2	10	442	7.6	202	87	7.0	10.4	0.57	1.8	0.11	0.70	0.7	33.0	22.7	8.20	0.08
4 (DW)	-	11	594	7.8	207	72	3.0	8.0	0.40	1.2	0.04	0.70	0.1	12.1	13.0	6.30	0.11
5 (HP)	-	6	428	7.4	231	73	7.0	3.0	0.53	2.3	0.04	0.12	-	6.1	19.3	4.30	0.21
6 (HP)	-	7	296	7.2	131	67	11.0	2.0	0.45	1.5	0.02	-	-	3.1	18.0	3.00	0.37
7 (HP)	-	8	353	7.1	155	61	13.0	7.0	0.31	2.0	0.08	0.12	0.1	5.7	21.4	3.70	0.22
8 (HP)	-	5	357	7.3	179	61	12.0	3.0	0.41	1.3	0.02	0.12	-	3.2	21.0	1.80	0.31
9 (TW)	-	4	251	7.4	127	49	4.0	3.0	0.52	1.4	0.02	0.10	0.1	2.1	17.5	1.70	0.18

develop.

Salinity problem related to water quality occurs if the total quantity of salts in the irrigation water is high enough for the salts to accumulate in the crop root zone to the extent that yields are affected. If excessive quantities of soluble salts accumulate in the root zone,the crop will have difficultly in extracting enough water uptake by the plant and usually results in slow or reduced growth.

In order to see the suitability of water under study for irrigation purposes, sodium absorption ratio (SAR) have been calculated by using the following formula and results are given in table 5.

The ionic symbols indicate concentrations of the ions in milliequivalents per liter. Calculation of SAR for a given water provides a useful index of the sodium hazard of that water for soils and crops. The greater the SAR of a water, the greater is the sodium hazard.

Table 5: Sodium Absorption Ratio of Water Samples

Sample No.	Premonsoon (meq/liter)			SAR	Postmonsoon (meq/liter)			SAR
	Na	Ca	Mg		Na	Ca	Mg	
1. (SW)	1.61	1.80	0.56	1.48	1.35	1.20	0.55	1.44
2. (SW)	1.83	1.60	0.40	1.83	1.61	1.35	0.37	1.75
3. (DW)	1.35	1.00	0.80	1.42	1.43	1.14	0.67	1.50
4. (DW)	0.63	0.90	0.70	0.70	0.53	0.65	0.52	0.60
5. (HP)	0.36	1.22	0.48	0.39	0.27	0.96	0.35	0.33
6. (HP)	0.19	1.30	0.26	0.21	0.14	0.90	0.25	0.18
7. (HP)	0.32	1.28	0.32	0.36	0.25	1.07	0.30	0.31
8. (HP)	0.20	1.20	0.22	0.24	0.14	1.05	0.15	0.18
9. (TW)	0.12	1.10	0.22	0.15	0.09	0.87	0.14	0.13

SW- surface water; DW- dug well; HP- hand pump; TW- tube-well

The U.S. Salinity Laboratory, Department of Agriculture, USA recommended the following classification on the basis of SAR values:

SAR	Water Class
< 10	Excellent
10-18	Good
18-26	Fair
> 26	Poor

As evident from table 5, the values of SAR in the water samples of the area varies from 0.21 to 1.83 in premonsoon period and from 0.18 to 1.75 in the postmonsoon period which indicates that the water is excellent for irrigation purposes.

7.0 CONCLUSIONS AND RECOMMENDATIONS

7.1 Conclusions

From the results and discussion described in the previous pages, following conclusions have been drawn.

i) The quality of sewage (used as irrigation water) as well as groundwater of the area under study is good for irrigation purposes.

ii) The sewage disposal on land has started polluting the groundwater of the area, although the effect is not much pronounced.

iii) The groundwater of the area is suitable for drinking purposes as per BIS standards.

iv) The iron from sub soil is leached by percolating water thereby increasing the iron content in groundwater

v) Deep aquifers are unaffected by sewage disposal on land till now.

vi) There is not much variation in quality of groundwater in pre and post monsoon periods.

7.2 Recommendations

Based on the preliminary study conducted on the effect of sewage waste disposal on groundwater quality, the following recommendations are made:

i) Detailed and intensive study be conducted on the soils of the sewage disposal site to find out the level of soil pollution which in turn affects the groundwater quality.

ii) Groundwater flow direction in the area should be determined to know the direction of flow of pollution plume.

iii) Quality of groundwater should be monitored for long period to know the affect of sewage waste disposal on land in the area.

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DIRECTOR	SATISH CHANDRA
DIVISIONAL HEAD	K K S BHATIA
STUDY GROUP	SUDHIR KUMAR C K JAIN
LABORATORY STAFF	RAKESH GOYAL TILAK RAJ SAPRA TEJ PAL SINGH