CASE STUDY

CS(AR) - 187

STATUS OF GROUNDWATER QUALITY IN PATNA TOWN

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PREFACE

Groundwater meets 38% of India's water requirement. It is, among other things, used as drinking water, for irrigation and for industrial purposes. Stress on groundwater both in terms of quality and quantity are growing rapidly due to various activities of mankind on the surface.

In recent years pollution of aquifers and thereby groundwater have become an important issue. Groundwater quality variation problems can be understood only by regular monitoring of water quality parameters.

Patna suffers from unsanitary conditions due to unplanned sewage disposal on the surface. It is feared that the subsurface and the groundwater have been influenced by them.

With the above problem in mind, 'Study of Groundwater Quality of Patna' was kept in the work program of 1994-95 and the Regional Centre, Patna took up the study to analyze different parameters of water quality.

The study was carried out by Sri Biswajit Chakravorty, Sc'C' and Sri Ramakar Jha, Sc'B' under the guidance of Dr K.K.S Bhatia, Sc'F'. The assistance for collection and analysis of water samples was provided by Sri R.K Jaiswal, SRA, Sri Atm Prakash, RA, Sri Santosh M.B and Sri Sivdas A.K, Technician.

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ABSTRACT

Drinking water sources are becoming scarce every day. In recent years the surface water has been deteriorated due to high level of pollution. Hence groundwater is the most important resource for drinking water supply. However due to the rapid industrialization and other human activities, there are threats to the quality of groundwater.

The quality of groundwater varies from place to place depending on human activity and industrial pollution, with the depth of water table, and from season to season. It is primarily governed by the extent and composition of dissolved solids in it. Groundwater quality variation problem can be understood only by the regular monitoring of water quality parameters for use as drinking water and for irrigation purpose.

Patna, in general suffers from unsanitary conditions with several types of sewage disposal systems including primitive ones. It was feared that some of the abstraction sight might have been influenced by them.

In the present study, thirty two tubewell out of sixty seven major deep tubewells have been selected covering length and breadth of Patna town for groundwater quality study. Groundwater samples from all these 32 tubewells were collected and general drinking water quality parameters (e.g. Temperature, pH,

Conductivity, Chloride, Alkalinity, Hardness, Sulphate, Iron, Sodium) were analyzed for possibility of contaminations. The results indicate that the concentration of most of the parameters in thirty two locations are within the permissible limit excepting the hardness and the concentration of iron. Concentration of Iron in groundwater of Anisabad, Rajapur, Lalit Bhawan, Gardanibagh No. 32 and Chajjubagh are more than 3.0 mg/l.

1.0 INTRODUCTION

From the very beginning, man realized the importance of water for his daily life. For this reason, water is called as life and it has been known as the nectar. Water is available in various forms on the earth. Areawise, seven tenth of the surface of the globe is water. For obvious reasons the quantity available on the earth in various forms cannot be explored for utilization. Even quantity of fresh water available is quite enough to meet our future requirements. As such no shortage would be observed in near future, if full quantity of fresh water available is without any danger of contamination. Unless scientific and adequate strategy are taken to mitigate the problem of water pollution, time will come when all activities may stuck up due to scarcity of water.

Generation of waste is a part of human activities from time immemorial. During last two decades it became increasingly evident that pollution was impairing different uses of water and in certain cases even destroying possible utilization of water sources.

Although avoidance of contamination from all the sources would be the most satisfactory solution, such an option is not practicable. However, future planning must address the problem of minimizing the creation of such sources by improved industrial technology for waste reuse, better agricultural management and better engineered containment of contaminants, including appropriate citing of waste facilities away from susceptible groundwater source.

Groundwater is generally free of suspended solids and objectionable colours. In some instances, however, the water may be associated with underground beds of peat and decay of vegetation which contribute substantial amounts of colour.

Dissolved minerals present in groundwater contribute to hardness (Calcium and Magnesium) and alkalinity (Bicarbonate, Carbonate and hydroxide). This is due to the presence of more amounts of carbon dioxide in the groundwater.

The minerals present in water, determine its usefulness for various purpose. Presence of some ions, beyond a certain limit, may make water unfit for irrigation, drinking or industrial purpose. For example, high levels of nitrate (more than 45 mg/l) may cause methenoglobinemia or blue baby disease. Hence, it becomes necessary to monitor the groundwater quality in an area to assess its suitability for various uses.

Drinking water quality guidelines define the perceived acceptable limits with regards to the physical, chemical, bacteriological and radiological content of potable water. IS 10500-1983 stipulates the Indian standards for drinking water.

1.1 Movement of contaminants in the subsurface

Groundwatermoves in the aquifer very slowly (typically less than 0.6m/day). Therefore, many years may elapse between start of pollution from its source and its reflection in a well. For the same reason, many years may be required to rehabilitate contaminated aquifers after the source of pollution has been eliminated. This long delay can force abandonment of wells and may require costly development of alternate water supplies. Prevention of contamination thus is the best way for protecting ground water water quality.

Slow movement of groundwater, however, is a favourable factor when the contaminants are degradable. In such a case long underground detention time may result in complete removal of the undesired substances. On the other hand, slow movement causes long contact with the subsurface minerals, most of which are soluble in water and may cause natural degradation of subsurface water.

The wide range of contamination sources is one of the many factors contributing to the complexity of ground water quality assessment. It is important to know the geochemistry in order to assess the fate and impact of chemicals discharged into the ground. Chemicals will pass through several different hydrogeologic zones i.e unsaturated and saturated zones, as they migrate through the soil to the water table.

1.1.1 Unsaturated zone

The unsaturated zone serves two functions : as reactor and as storage reservoir but, it is almost impossible to retrieve a pollutant from the unsaturated zone.

The uppermost region of the unsaturated zone is the site of important process leading to pollutant attenuation. Some chemicals are removed in this zone by adsorption or by decomposition through oxidation and microbial activity or by consumption by vegetation.

1.1.2 Saturated zone

Once dissolved contaminants reach the water table, they enter the ground water flow system. The relative unavailability of dissolved oxygen in the saturated zone limits the potential for oxidation of chemicals.

1.2 Status of groundwater pollution in India

In India, ground water poliution of three categories viz. point, line and the diffuse, are taking place. Wastes from municipal sources such as sewage effluents and sludge cause point, line and diffuse pollution whereas industrial effluent cause point pollution mostly and when discharged on land may also cause line and diffuse pollution. Agricultural activities such as irrigation return flow, excessive use of fertilizers, pesticide and herbicide applications are conducive to diffusive pollution of groundwater.

1.2.1 Municipal Wastes

Municipal sewer of most of the cities and towns are discharged into the nearest available water course without proper treatment. In case water course is not available, sewage effluents are discharged on waste land or these sewage effluents are passed through unlined channels to nearby fields where farmers use it for irrigation purposes. In either case, sewage effluents find their way into subsurface system which eventually results in ground water pollution.

Municipal wastes are being increasingly dumped in sanitary land fills near the big cities. Often these land fills are selected without taking into consideration of the hydrogeological conditions of the area resulting to leachate percolating into the saturated zone.

1.2.2 Industrial Sources

Effluents discharged by most of the industries has reached alarming level in several parts of India. These effluents are passed without proper treatment into unlined channels or depressions resulting to percolation into the groundwater system. Some of the cases where ground water has been severally effected due to industrial pollution include :

(i) High levels of cyanide to the extent of 2.0 mg/l have been found in ground water in several areas of Ludhiana town in the Punjab.

(ii) High concentrations of chromium have been found in groundwater from Ludhiana (Punjab), Faridabad (Haryana), Kanpur (U.P), Varanasi (U.P.).

(iii) Groundwater in Pali (Rajasthan) and Jetpur (Gujarat) has become highly coloured due to seepage of effluents from textile dye industries.

(iv) Groundwater near Jalandhar (Punjab) near a distillery is pumping coloured water due to percolation of effluent into the saturated zone.

(v) High levels of nickel and zinc have been found in ground water near Khetri mines (Rajasthan) and in parts of Udaipur (Rajasthan) respectively.

(vi) Cadmium concentration at some places in Kanpur and Delhi have been observed to be in high concentration.

(vii) Groundwater pollution in Warangal (A.P.) have been reported to be due to discharge of untreated tannery and textile wastes (Naram, 1981).

(viii) Tanneries located along the palar river in Tamil Nadu discharge their organic and inorganic effluents resulting to pollution of groundwater (Krishnaswamy, 1981).

(ix) Neutral to slightly alkaline nature of groundwater have been found in parts of upper catchment of Betwa River basin in Central India (Das and Kidwai, 1981).

(x) The waste discharge from the big and small industries of Kota (Rajasthan) is resulting in increasing pollution of Chambal river which is further manifested in the deteriorating quality of the well waters on either flank of the river.

1.2.3 Agricultural Pollution

Fertilizers are applied to almost all crops in varying proportions depending on their type. The use of nitrogen, phophate and potassium fertilizers have increased many folds during past years.

Studies conducted by agencies have revealed that there are high levels of nitrate in groundwater to the extent of several hundred mg/l in parts of southern Punjab, southern Haryana, Rajasthan, U.P., Maharastra, A.P. and several other states. In southern and south-western Haryana, nitrate level exceeding 50 mg/l at shallow depths have been observed at several places (Kakar, 1981). High levels of potassium and phosphate have also been reported in groundwater from several places in Punjab, Haryana and Uttar Pradesh.

1.2.4 Natural sources

There are water quality problems due to natural sources in several areas of the country. In parts of Rajasthan, southern Punjab, Haryana, U.P., Gujarat, A.P., Tamil Nadu and Karnataka, high concentrations of fluoride in ground water have been reported and there are cases of mottling of teeth, dental and skeletal fluoris at many places. In certain exceptional cases like Sagalia in Gujarat, the fluoride concentration has been found to be 19 mg/l (Raghava Rao, 1977). High concentrations of iron in ground water have been reported from several areas, particularly those in high rainfall areas of West Bengal, North Eastern States and Kerala. In Assam, iron concentrations in ground water to the extent of 20 mg/l has been reported.

1.3 Purpose of investigation

Patna, in general suffers from insanitary conditions with several types of sewage disposal systems including primitive ones. It is feared that some of the abstraction sight might have been influenced by them.

The present study is aimed at (i) see the regional variation in the quality of groundwater (ii) to delineate the poor quality zones for drinking and irrigation purpose.

To achieve these aims, thirty two tubewell out of sixty seven major tubewells have been selected covering length and breadth of Patna. Water samples from all these thirty two tubewells were collected and analyzed.

2.0 DESCRIPTION OF THE STUDY AREA

The area of Patna town falls within the latitude 25°32'N to 25°38'N and longitude 85°02'E to 85°18'E with a mean height above sea level of about 53 meters along the southern bank of Ganga Figure-2.1). The town has a linear development along the river Ganga and stretches about 21 km east-west; a width of about 3.5 km north-south. The city is bounded by Ganga in the north, Punpun in the south,and Son in the west with Ashok Rajpath as the central spine. The average ground level of south Patna is about 47 meters above mean sea level.

The entire area forms a part of Ganga valley and has a monotonously flat relief. The area possess good groundwater potential having considerable granular zone below a zone of clay formation at the top. The land is flat with a gentle slope towards the south and east with minor undulations. A portion in the north of Ashok Rajpath, however, slopes towards the river Ganga. The high flood level of Ganga in 1967 and 1975 was higher than the average ground level of the town.

The soil of Patna is predominantly alluvial and loamy with colour varying from light brown to deep brown. The underlying sand falls into two distinct categories, white to grey and reddish brown in colour, associated with former channels of the

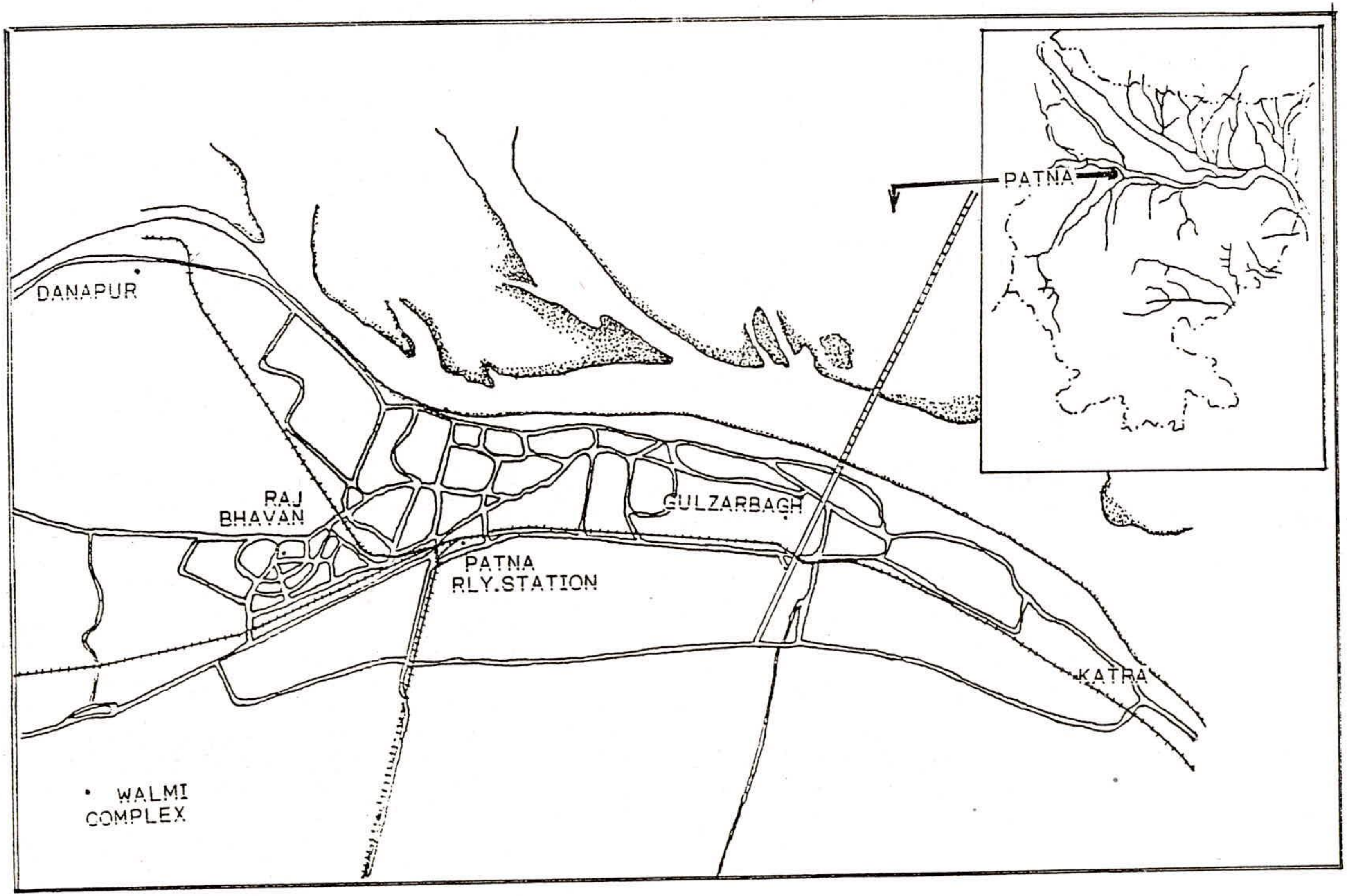


FIG. 2.1 INDEX MAP OF PATNA

river Ganga and Son respectively. As reported by the department of Agriculture, Government of Bihar, the average pH of the soil of Patna is between 6.3 to 8.2. The nutritional status of Patna soil is of the medium type. The permeability of the soil is neither too high nor too low, hence the rate of percolation of water through the soil is of medium nature. These characteristics coupled with ambient temperatures (10°C to 42°C) cause depletion of organic matter present in the soil to a great extent.

2.2 Population

There is a phenomenal rise in population during the decennial period ending 1991. Patna urban agglomeration has crossed one million population in 1991. The rise in population of the capital continued unabated causing great pressure on land within the municipal areas. Many new colonies have come up towards eastern, western and southern part of Patna during the last decade

Increasing population, expanding urbanization and rapid industrialization during recent years have threatened the environment with consequences of severe pollution in the Patna township. Patna township experienced severe hepatitis out-break in 1981 caused by sewage contamination which may be either from the source or from the system of public water supply.

2.3 Water supply

Almost the entire population of Patna depends on ground water for drinking. Of the total population, about 65% uses ground water delivered by community systems and 35% uses that through private sources (tubewell, hand pump and dug wells).

Ideally, groundwater is characterized by cleanliness, bacterial purity and constant temperature and chemical quality and should require very little treatment prior to its use. Utilization of groundwater resources and increase of surface pollution have caused contamination and general deterioration of groundwater quality mainly in and around Patna City.

The basic composition of groundwater reflects its contact with soils, minerals and rocks. For years, septic tank, seepage fields, land fill leachate, irrigation leachates are the primary cause of groundwater pollution. Contamination of Patna's groundwater resources has recently become an issue of public concern.

2.4 Ground water condition

In Patna water supply is being maintained through groundwater till date. The per capita availability of fresh water ranges from 30-40 gallons per day (Water Board 1982). Presently about sixty seven pumps ranging from 30-125 HP capacity are engaged in extracting water from deep aquifers yielding approximately 5,640,000 gallons/hr (Table- 2.1). Apart from this in far flung corner of the town mostly in the southern part of Agamkuan, and old Patna city, Anishabad, Digha and South of by pass road, people are still using water from the dug well.

The alluvial tract of the area has ideal hydrogeological conditions for the groundwater development. The Fence diagram based on borehole data of Danapur and Raj Bhawan is shown in Figure-2.2.

The movement of the groundwater in the Patna township is controlled by configuration and nature of aquifer which is directed roughly towards north-east. As revealed from the fence diagram (Figure-2.2) one principal aquifer exists 60 m below ground level in the area. This aquifer (Son sand) is quite thick and it contains fresh groundwater which is extensively exploited through Government and Private tubewells.

2.5 Shallow aquifers

Ground water within the shallow aquifer of the area occurs under unconfined condition. This aquifer is composed mainly of silty clay and fine sand. The thickness of this sequence is variable within the depth range of 10 to 60 m (Figure-

Table 2.1 : MAJOR TUBEWELLS IN PATNA

Sl. No.	Location	HP of Pump	Year of Starting	Capacity (gal/hr)
1	SEKHPURA	75	1962	50,000
2	RAJBANSINAGAR	100	1976	100,000
3	LALIT BHAWAN	100	1982	100,000
4	BAILEY ROAD	125	1966	100,000
5	SRI KRISHNA PURI	100	1976	100,000
6	DIGHA NO-1	60	1955	60,000
7	DIGHA NO-2	75	1973	100,000
8	RAJAPUR	120	1977	100,000
9	ADALATGANJ	60	1973	60,000
10	HIGHCOURT	100	1955	100,000
11	NEW MARKET	100	1973	100,000
12	MITHAPUR	35	1979	30,000
13	JAKKANPUR	100	1965	100,000
14	GARDANIBAGH ROAD NO-13	100	1955	80,000
15	GARDANIBAGH ROAD NO-32	100	1980	80,000
16	ANISHABAD-II	120	1988	100,000
17	HARDING ROAD	75	1980	60,000
18	CHANDMARI ROAD	75	1977	60,000
19	CHARAYA TAND ROAD NO-1	50	1955	50,000
20	CHARAYA TAND ROAD NO-2	60	1987	60,000
21	CHAJJU BAGH	60	1973	60,000
22	PIRMUHANI	100	1955	100,000
23	KADAMKUAN NO-1	100	1955	100,000
24	KADAMKUAN NO-2	100	1978	100,000
25	CONGRESS MAIDAN	60	1973	60,000
26	MACHUA TOLI	100	1976	100,000
27	BANKIPUR NO-1	100	1965	100,000
28	BANKIPUR NO-2	75	1977	60,000
29	MUSALLHAPUR	100	1974	100,000
30	SCIENCE COLLEGE	75	1982	60,000
31	BHAWARPOKHAR	35	1984	30,000
32	GOLAKPUR	50	1961	50,000
33	CHAUDHARY TOLA	75	1983	60,000
34	ALAM GANJ	120	1965	100,000
35	SERSHAH ROAD	60	1973	30,000
36	MANGAL TALAB NO-2	125	1966	100,000
37	KHAJKALA NO-1	100	1955	80,000
38	KHAJKALA NO-2	125	1965	100,000
39	PATNA CITY HOSPITAL	100	1981	100,000
40	KAIMASHIKOH	100	1981	100,000
41	KATRA	125	1964	100,000
42	GULJARBAGH	100	1986	100,000
43	RAJENDRA NAGAR ROAD NO-11	100	1988	100,000
44	NAWAB BAHADUR ROAD	120	1989	100,000
45	DARIAPUR	100	1989	100,000
46	CHITRAGUPTA NAGAR	60	1989	60,000

Contd.

Table 2.1 : **MAJOR TUBEWELLS IN PATNA**

Sl. No.	Location	HP of Pump	Year of Starting	Capacity (gal/hr)
47	HARDING PARK NO-2	120	1986	100,000
48	KRISHNA NAGAR	60	1987	50,000
49	M.L.A FLAT NO-2	120	1988	100,000
50	JAKKANPUR NO-2	100	1989	100,000
51	MANDIRI	120	1990	100,000
52	GHAGHA GHAT	120	1989	100,000
53	RAJENDRA NAGAR ROAD NO-1	120	1991	100,000
54	KANKARBAGH NO-1	125	1991	100,000
55	KANKARBAGH NO-2	125	1991	100,000
56	KANKARBAGH NO-3	60	1991	60,000
57	KHOJPURA	120	1991	100,000
58	AJUMAN ISLAMIA HALL	120	1991	100,000
59	KHAJKALA NO-3	120	1992	100,000
60	MANGAL TALAB NO-3	120	1992	100,000
61	IMBHACITY NO-2	120	1991	100,000
62	MALSALAMI	120	1991	100,000
63	SANDALPUR	60	1989	60,000
64	KUMHARAR	120	1990	100,000
65	GARDANIBAGH	100	1993	100,000
66	CHANDARPUR TOLA	100	1993	100,000
67	ASHOK NAGAR	30	1994	30,000

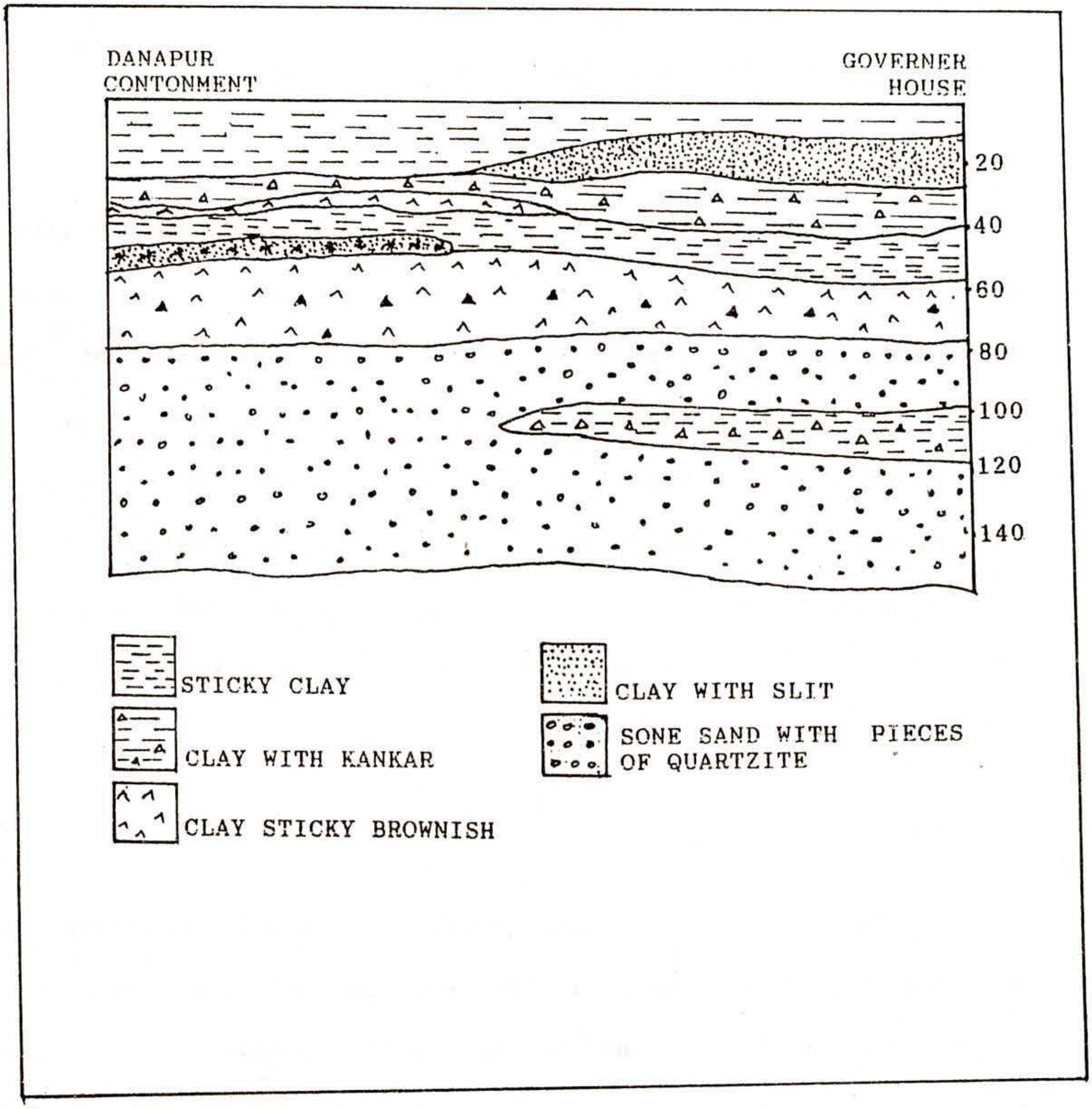


FIG. 2.2 LITHOLOGY OF PATNA BASED ON BOREHOLE DATA

2.2) having very low permeability. Most of the dug wells and hand pumps are receiving water from this zone. Maximum saturation of this zone is observed after the monsoon.

Depth to water level for Patna area shows that shallow water level occurs in the area adjoining Sewerage line or around the land used for disposal of sewage. The eastern part of the Patna town covering Kankarbagh, Gandhinagar, Kumharar, Musalahpur, South of Guljarbagh and Pahari areas are badly affected with this problem, on the other hand the area of western Patna are not showing such alarming problem. The depth to water level in southern and western part is ranging from 6 to 10 m in general but it is more than 10m on the bank of river Ganga.

2.6 Deeper aquifer

Ground water is deep aquifer occurs under confined to semi-confined conditions. In the major part of the area, the piezometric surface of the confined aquifer occurs below ground level.

Sub-surface lithological details of bore holes (Figure-2.2) shows that Son sand (Coarse grained sand & Gravel) beyond 60m b.g.l. The transmissivity of the aquifer zone is very high that is nearly 7000 m^2/day at Rajbhawan area and 13000 to 18000 m^2/day in Danapur cantonment area.

It seems that the deeper aquifer at Patna area is not affected because of the overlying impermeable clay beds acting as retarding medium for solute percolation. On the perusal of Litho-logs its has been found that around 85% of material is sticky stratified in the first 60 m depth. If there is any contamination growing up that must be down to the depth of 40 m or at the most extend up to the 60 m depth. The low rate of infiltration in clay zone has helped to restrict contamination in deeper zone.

2.7 Physiography and Drainage

Patna is developed along the southern bank of Ganga river. This upland area is a natural levee formed by Ganga river. South of this levee area, low lying water-logged area occurs in a large part viz. South of Patna Sahib, Bankaghat, Pahari and along Patna bypass road. These areas remains water-logged during monsoon period as well as in lean period due to the flow of domestic effluents through unlined open channel. This low lying area of southern Patna town is like a saucer shaped flood plain occupied by the colonies of southern Patna (Ashok Nagar, Kankarbagh, Hanuman Nagar, Gandhinagar etc.) and western Patna (Anishabad, Phulwari, Rukanpura etc.). The upland area along Ganga river is about 2-4 m. higher than the low lying flood plains of southern Patna town.

The saucer shaped depression has a gentle slope towards the south-east direction with minor undulations and thus all the natural streams follows the same gradient and finally meet in Punpun in extreme south east. During the monsoon period the entire storm water does not drain out fully through natural streams and finally a large quantum of water is retained in low lying area. A new scheme has been launched in Kankarbagh area where sewage and storm waters collected into the manhole and are pumped at Jogipur to an open channel which is connected to a tributary of Punpun river.

At Jogipur pumping station, the system was initially designed for only 144 cusecs of discharge but todays the sewage effluent is 2-3 times more than the designed capacity and hence the present pumping is inadequate.

2.8 Climate

The climate of Patna town is characterized by a cold season, hot summer and average monsoon season. The winter season starts in early November and lasts till about the middle of March. The summer season continues till mid-June and thereafter monsoon season commences and remains generally upto the end of September. October is a transitional month. The maximum and minimum temperature is about 45°C and 10°C respectively. The average annual rainfall in the district is 992 mm.

Light westerly to south westerly winds prevails in the winter and early summer seasons. In May the easterly and less frequently north eastern winds begin and these predominate in the monsoon months.

3.0 SOURCES OF GROUNDWATER POLLUTION IN PATNA

There are many potential sources of ground water contamination including septic tank systems, solid waste disposal sites, land disposal of sewage, industrial wastes and sludges, irrigation and other agricultural practices. Table-3.1 shows principal sources of groundwater contamination and their relative importance in different areas of Patna.

Table 3.1: Principal sources of groundwater contamination and their areawise relative importance.

Source	Patna Saheb	Bankipur	Kankarbagh, Chandamari	South bypass	Anishabad, Phulwari	Khagaul, Danapur
1. Septic tank Cesspools.	I	I	I	III	I	II
2. Land fills.	III	II	I	IV	III	III
3. Land disposal of water and sewage.	III	III	I	IV	II	II
4. Surface impoundments.	IV	IV	I	I	I	II
5. Agricultural activity / fertilizers.	IV	IV	IV	I	II	II

I = High. II = Moderate. III = Low. IV = not significant.

3.1 Septic tank and Cesspool

The term septic system is commonly used to describe a sub-surface, non-aerated sewage disposal system that uses soil filtration and adsorption for attenuating the effluent. Out of 11 lakh population of Patna town, about 60% population disposes their sewage by individual on site system. Septic tank represent the highest total volume of waste water-discharged directly to the sub-surface and being the most frequently recorded sources of contamination of groundwater. Severe hepatitis outbreak in 1981 at Patna by sewage contamination of either the source or the system of public water supply has been experienced (Ghose and Sharma 1989). Problems of ground water contamination by septic system occurs in a high-density residential area.

The amount of discharge from septic tank system is commonly 200 litres/cap-day. Septic tank effluents contain 40 to 80 mg N/liter, 11 to 31 mg P/liter, and 20 to 450 mg/liter of BOD. (Sikora 1976).

3.2 Sewage and waste water disposal

Sewage system was first introduced in Patna during the Year 1936-39 when sewer lines were laid to cater the needs of the central part of Patna. In recent year new residential complexes have come up in the western and the southern fringe. The Patna

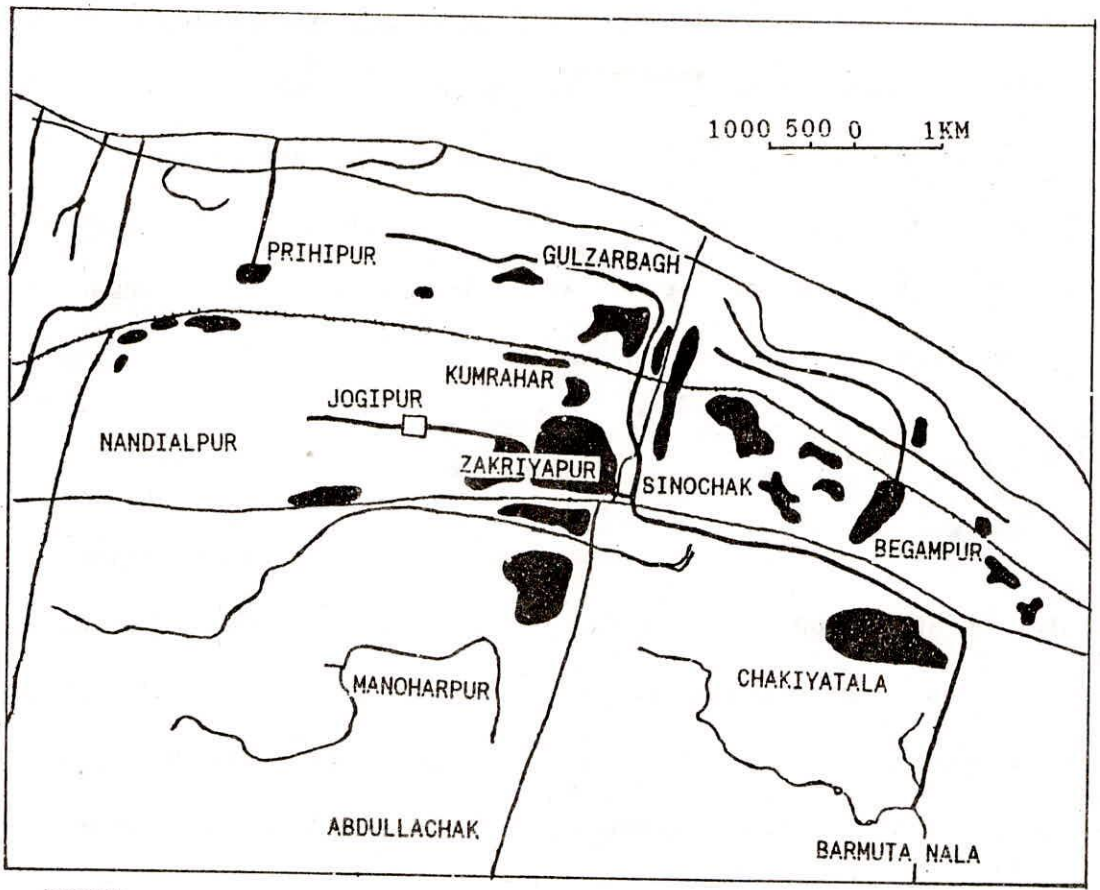
Improvement Trust had constructed sewage treatment plant at Saidpur, Beur and the Jogipur. At present Saidpur and Beur treatment plant is in operation.

A schematic diagram of Sewage line of Patna town is shown in Figure-3.1.

The domestic effluents and industrial effluents of Patna town is channelised through manhole as well as through open channel to Ganga river. The total volume of effluents is estimated at 4,30,000 m^3/day. A sewage pumping station has been constructed at Jogipur (Kankarbagh) where pumped domestic effluent is discharged to unlined open channel leading to Punpun river via Pahari village. Owing to this the water levels in dug wells in adjoining areas have come up nearer to the surface. The areas affected by this problems are Ashok Nagar, Jogipur, Gandhinagar, Kumharar. Agam Kunwan, Pahari village and south of old Patna city.

Some of the area namely Chandmari, Anishbad, Rukanpura, Purandarpur, Musalahur and Bahadurpur are directly discharging their domestic effluent to pounds or open fields.

The surface storage of domestic and industrial effluent are also contaminating locally to the aquifer of the area through



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SEWARAGE LINE
LAND DISPOSAL OF SEWAGE
AND STORM WATER

FIG. 3.1 SEWAGE LINE OF PATNA

sub-soil infiltration. Mobile pollutants such as nitrates are of greatest concern since evidence indicates that several other common pollutants (BOD, Pathogenic micro-organisms and Phosphates) remain near the area of application. Bacteria and viruses die off quite rapidly as waste water passes through the soil material.

3.3 Land fills

The solid waste contributed by the large population of Patna is about 300 to 500 metric tonnes per day as calculated on the basis of per capita per day domestic and industrial refuse available. It has been estimated that per capita per day refuse contribution varies approximately from 300 to 1450 gm. (Ghose and Sharma 1989).

Out of the total refuse, a major portion of it is transported to two trenching grounds namely Sahadra in the west and Paharpur in the south. Besides many places in the town, the refuse collected is dumped in low lying areas to fill up the land but dumping is haphazard and sanitary filling practices are not followed.

Precipitation that infiltrates through the waste forms leachate which can move downward from the land fill into the water table and cause groundwater contamination. If the waste is buried below the water table, the moving ground water can dissolve compound from the waste and become contaminated. Land fill leachates can contain very high concentrations of both the inorganic and organic compounds.

3.4 Other sources

Some other sources like Petrol pumps and vehicle service stations are also contributing contamination through leaking tanks and percolating organic liquids.

4.0 WATER QUALITY AND GROUNDWATER CONTAMINATION

Water naturally contains a number of different dissolved inorganic constituents. The major cations are calcium, magnesium, sodium and potassium. The major anions are chloride, sulphate, carbonate and bicarbonate. These major constituents constitute the bulk of the mineral matter contributing the total dissolved solids. In additional there may be minor constituents present, including iron, manganese, fluoride, nitrate, strontium and boron. Trace elements such as arsenic, lead cadmium, and chromium may be present in amounts of only a few micrograms per liter, but they are very important from a water quality stand point.

4.1 Water quality standards

Water quality standards are regulations that set specific limitations on the quality of water that may be applied to a specific use.

Standard fixed by Indian Standard Institute (1983) and other organizations are given in Annexure-I.

4.1.1 Electrical conductivity

Conductivity is a measurement of water's capacity to convey electrical current and is related to the concentration of ionized substance in the water. Electrical Conductivity is directly proportional to the amount of dissolved salts.

4.1.2 Hydrogen ion concentration (pH)

The pH value is a measure of activity of concentration of the hydrogen ions present in water. A low pH solution has a high hydrogen ion concentration and is therefore acidic while high pH solution are low in hydrogen ion concentration and are therefore alkaline. The pH value of natural water is an important index of acidity or alkalinity and is the resulting value of acidic/basic interaction of a number of its mineral and organic components. The parameter pH require immediate determination otherwise it may give some erratic values.

4.1.3 Chloride

Chloride, in the form of chloride ion, is one of the major inorganic anions in water and waste water. Chlorides are present in all potable water supplies and in sewage, usually as metallic salt. When sodium is present in drinking water, chloride concentration in excess of 250 mg/l give a salty taste. If the chloride is present as a calcium or magnesium salt, the taste detection level may be as high as 1000 mg/l.

The high concentration of chloride at shallow depth has been reported with decreasing trend downward (Figure-4.1). It is probably due to contaminants produced by sewage, septic tank and land fills. It is believed that the chloride content present in such pollution waste has leached and reached to the ground water making higher concentration at shallow depth. The deep tubewell (150 m depth) water samples are in the range of 7.1 to 11 mg/l.

4.1.4 Alkalinity

Alkalinity refers to the capability of water to neutralize acids. The presence of carbonates, bicarbonates and hydroxides are the most common cause of alkalinity in natural water. Alkalinity values provide guidance in applying proper dose of chemicals. Water charged with carbon dioxide dissolves the carbonate minerals, as it passes through soil, to give bicarbonates.

A high value of total alkalinity has been reported at shallow depth with a decreasing trend with increasing depth (Figure-4.1).

4.1.5 Sulphate

A wide range of sulphate content in the groundwater is made possible through oxidation, reduction, precipitation, solution and concentration processes as water traverses through

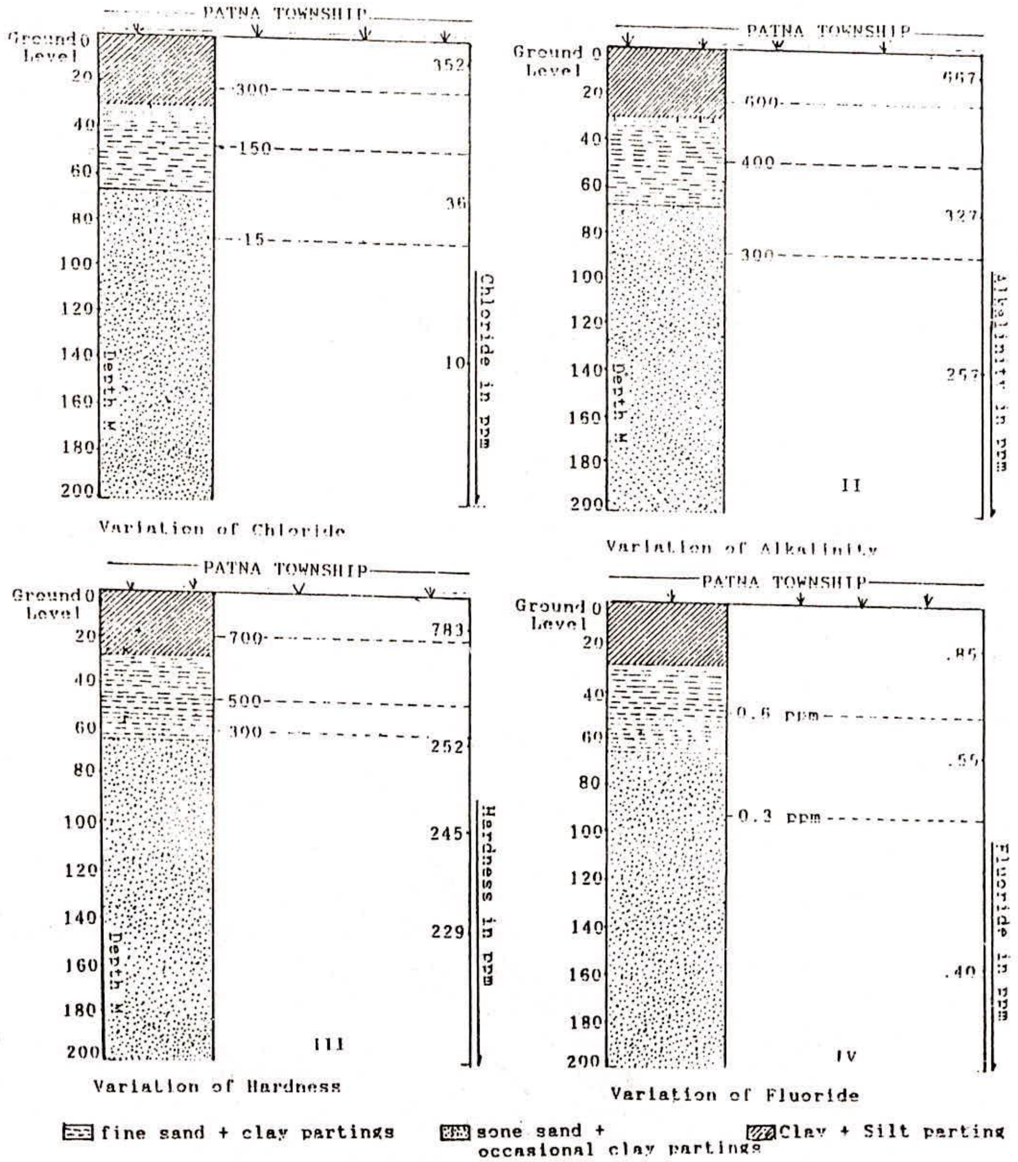


FIG. 4.1 VARIATION OF CONCENRATION OF SOME PARAMETERS WITH DEPTH (CGWB-1994)

sediments or rocks. The solute produced by land fill, septic tank and sewage is also a factor of Sulphate concentration is ground water.

On the perusal of data, it has been reported that the water of dug wells at Patna city and Bakhtiayarpur area having more concentration of Sulphur (7 to 168 mg/l) than in other parts of the district due to infiltration of solute of wide spread pollutant like land-fill, septic tank, sewage water and fertilizer application. The sub-surface clayey soil may have also contributed in the enrichment of sulphate content in ground water. However, this concentration too, is far below the maximum desirable limit (150 mg/l).

4.1.6 Hardness

The hardness of water was originally defined in terms of its ability to precipitate soap. Presence of calcium and magnesium ions are the main cause producing hardness.

The total hardness represents the total concentration of calcium and magnesium expressed as their calcium carbonate equivalent. Temporary hardness is caused by the presence of bicarbonates of calcium and magnesium. Permanent hardness is mostly due to sulphates.

A schematic diagram of variation of hardness with depth reported is shown in Figure-4.1.

4.1.7 Fluoride

High fluoride concentration in water lead to Fluorosis. Prolonged consumption of water containing fluoride in concentration greater than maximum allowable dose (1.5 ppm, WHO, 1984) may produce a disease known as skeletal fluorosis. The common natural sources of fluoride are fluorospar, fluorapatite, hornblende, tremolite and some micas. Apart from natural sources considerable amount of fluoride may be contributed due to activities of man. Fluoride commonly used in steel, Aluminum, tile-industries, burning of coal, application of insecticide in soils eventually results in leaching by percolating water increase the fluoride level of groundwater.

Fluoride concentration in dug well water of Patna city area ranges from 0.6 to 1.1 mg/l in hand pump water 0.3 to 0.8 mg/l and in tubewell water 0.3 to 0.5 mg/l (Sharma 1989). This is clearly showing that the concentration is decreasing as depth increases (Figure-4.1). However, the fluoride concentration in Patna city and around is well within the maximum desirable limit (I.S.I 1983).

4.1.8 Calcium

The absence of Calcium from drinking water may cause ricket in the body while excess concentration causes gout and rheumatism.

In hydrogeological studies, the equilibrium of Calcium carbonate in contact with natural water, either surface or ground water, is one of the most important geochemical reaction. The CO_2 of the atmosphere reacts with H_2O to form H_2CO_3, a weak acid and the resulting solution will have a pH of about 5.7. CO_2 in soil from the organic decomposition is another source being even more important in groundwater studies.

The desirable limit of calcium ion is 75 mg/l for drinking water.

4.1.9 Magnesium

Magnesium is one of the constituents responsible for hardness of water along with calcium concentration. The lower concentration of magnesium is not harmful but higher concentration is laxative.

The desirable limit of magnesium concentration is 30 mg/l for drinking water. In general, the ground water in Patna exists within the standard limit and is suitable for human consumption.

4.1.10 Sodium

Certain clay minerals can increase the content of sodium in ground water by base exchange reactions. The higher sodium concentration in drinking water is harmful especially to those suffering from cardiac, renal and diseases pertaining to circulatory system of human body.

The tubewells tapping deep aquifer shows Na concentration around 28 mg/l. The low value in deep water may be due to absence of clay content as well as heavy influx of ground water within the aquifer zone.

4.1.11 Potassium

Potassium ions in underground waters are rarer than the sodium ions, despite the high solubilities of potash salts. This is because (a) potassium decomposes insoluble secondary mineral, (b) large amount of potassium assimilated by plants, and (c) it is readily absorbed by clay.

The concentration of potassium in dug well varies from less than 1 mg/l to 12 mg/l, in general.

This exceptionally higher values may be due to application of fertilizers in the fields.

4.1.12 Iodine

The iodine in extremely small concentration (eg 4 mg) is present in the adult human body, yet it needs to be maintained not only during childhood, rather throughout life by consuming iodide containing food and water to keep thyroid gland active. Deficiency of iodine (less than 5-10 microgram/l) produces a disease known as Goiter. Endemic goiter is a disease characterized by a tumor-like enlargement of thyroid gland.

The iodine concentration in shallow well varies from 8.0 to 15.5 microgram/l and as such there is no alarming situation in and around Patna town.

4.1.13 Nitrate

Nitrate is the most common contaminants identified in ground water. Nitrate is itself non-toxic, but when reaches the human body through water and food, it is reduced to nitrite by the specific bacteria present in the mouth and the human gut (Lakshmanan, et al., 1986). Nitrite being a powerful oxidising agent, quiickly acts upon the iron of red blood cell and converts the former from Fe^{++} (soluble) into Fe^{+++} (insoluble) form. Thus, oxygen carrying business by hemoglobin in human system is greatly hindered (Sharma, 1983). The continuous nitrite formation for prolonged period which often happens to occur in the individual or community where majority of people have acdic bowels on account of the consumption of nitrified, soft and corrosive water.

High level of nitrate present a health problem and can cause methenoglobinemia (blue baby disease) and cancer. Nitrate affects young babied less than three months old by depriving them of Oxygen.

The primary source of NO_3^- in groundwater is leaching from soils. The presence of Nitrate in groundwater is an index of pollution hazard. As per I.S.I nitrate concentration up to 45 mg/l. is the maximum permissible limit for drinking water.

The samples of tubewell water (deep water) are generally showing nil concentration except in one sample of Rajbhawan Patna which shows less than one mg/lit. nitrate.

4.1.14 Iron

The iron compounds found in groundwater are commonly represented either in ferrous (Fe^{++}) or ferric (Fe^{+++}) forms. Ferrous compounds are unstable in water, excess of oxygen having been gained, they oxidize into ferric hydroxide present in ground water as colloids. Water containing iron compound is unpleasant to the taste.

4.2 Bacteriological contamination of groundwater

Although analysis of bacteriological parameters has not been carried out in the chemical laboratory, the data is available from the PHED, Patna, where the bacteriological analysis has been carried out for shallow and deep ground water (Ghose and Sharma in 1989).

The MPN count for shallow ground water is 2.4×10^5/100 ml, but in the tap water (deep ground water) it has been reported as nil. The same water has also been studied under sterilized condition which shows nil MPN count for both shallow as well as for deep groundwater.

5.0 RESULT AND DISCUSSION

5.1 Suitability of groundwater for drinking

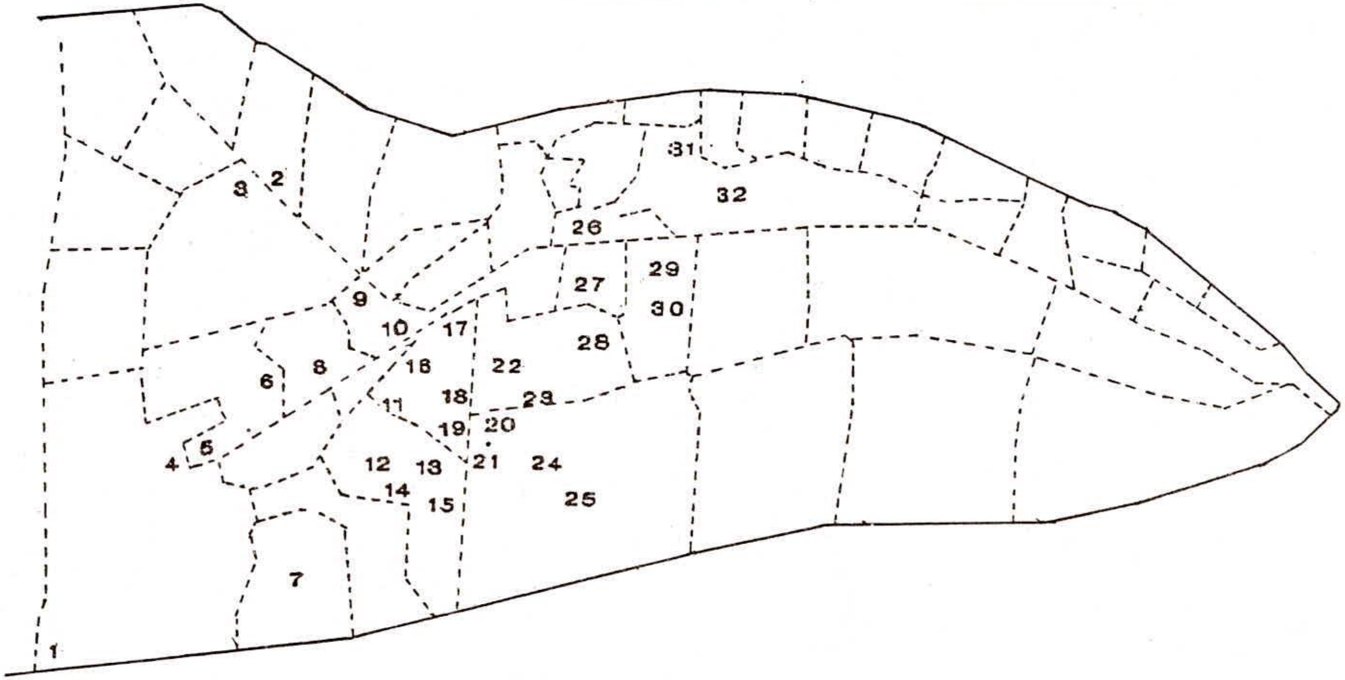
The quality of groundwater as determined by the physical and chemical constituents is of great importance in determining its use. The quality may change due to its reaction with aquifer material or interaction with poor quality of infiltrating water.

Out of sixty seven tubewells (Table- 2.1) water samples from thirty two tubewells spread over central and west part of Patna (Figure-5.1) have been analyzed for pre-monsoon and post-monsoon season.

The result of the chemical analysis is given in Table-5.1 to Table-5.4.

The maximum concentration of various parameters found in different location is shown below :

	Parameters	Concentration	Location
1.	E.C	1.750 millimho	Khajpura.
2.	Chloride	52 mg/l	Bankipur
3.	Total Alkalinity	282 mg/l	Khajpura.
4.	Total Hardness	348 mg/l	Anisabad.
5.	Calcium (Ca^{++})	30.48 mg/l	Adalatganj and Chirayyatar 1.
6.	Magnesium (Mg^{++})	77.78 mg/l	Anisabad.
7.	Sulphate	40.00 mg/l	Khajpura
8.	Iron	3.50 mg/l	Anisabad, Rajapur, Lalit Bhawan, Gardanibagh No. 32 and Chajjubagh.
9.	Sodium	169 mg/l	Anisabad



1. WALMI	11. BAILEY ROAD	23. NEW MARKET
2. DIGHA No.1	12. JAKKANPUR No.1	24. CHIRAYYATAR 1
3. DIGHA No.2	13. JAKKANPUR No.2	25. CHIRAYYATAR 2
4. SHEIKHPURA	14. GARDANIBAGH No. 13	26. BANKIPUR
5. KHAJPURA	15. GARDANIBAGH No. 32	27. CONGRESS MAIDAN
6. RAJVANSHINAGAR	16. CHAJJUBAGH	28. PIRMOHANI
7. ANISABAD	17. HIGHCOURT	29. KADAMKUAN No. 1
8. S K PURI	18. M L A FLAT	30. KADAMKUAN No. 2
9. RAJAPUR	19. ADALATGANJ	31. SCIENCE COLLEGE
10. LALIT BHAWAN	20. MEETHAPUR	32. GOLAKPUR
	21. CHANDMARI ROAD	
	22. HARDING ROAD	

FIG. 5.1 LOCATION OF GROUNDWATER SAMPLING POINTS

Table: 5.1 Result of chemical analysis of Groundwater of Patna

Sl. No.	LOCATION	Temperature °C		pH 6.5-8.5		Conductivity millimho		Chloride (as Cl),mg/l 250 mg/l max	
		PRE	POST	PRE	POST	PRE	POST	PRE	POST
1.	WALMI	21.9	22.8	7.24	6.85	1.008	1.150	15.0	12.0
2.	DIGHA No.1	24.8	23.9	7.65	6.95	1.210	1.160	12.0	12.0
3.	DIGHA No.2	24.9	23.9	7.71	7.21	1.210	1.160	9.0	10.0
4.	SHEIKHPURA	22.1	22.0	6.65	6.75	1.320	1.418	31.0	28.0
5.	KHAJPURA	23.5	23.3	7.26	6.87	1.460	1.750	45.0	44.0
6.	RAJVANSHINAGAR	23.7	23.0	7.90	7.32	1.280	1.230	28.0	18.0
7.	ANISABAD	26.3	24.2	7.21	7.11	1.165	1.510	40.0	40.0
8.	S K PURI	24.8	24.5	7.55	7.24	1.190	1.150	24.0	16.0
9.	RAJAPUR	24.5	23.9	7.79	7.50	1.160	1.120	11.0	14.0
10.	LALIT BHAWAN	23.8	23.7	7.92	7.66	1.220	1.300	28.0	21.0
11.	BAILEY ROAD	22.2	22.3	7.52	7.50	1.180	1.210	19.0	18.0
12.	JAKKANPUR No.1	22.4	21.6	7.21	7.25	1.070	1.270	16.0	14.0
13.	JAKKANPUR No.2	23.9	21.9	7.10	7.10	1.076	1.270	15.0	12.0
14.	GARDANIBAGH No. 13	25.1	23.3	7.10	7.10	1.109	1.370	19.0	18.0
15.	GARDANIBAGH No. 32	24.0	23.6	7.05	7.10	1.144	1.480	32.0	38.0
16.	CHAJJUBAGH	24.9	23.3	7.99	7.56	1.280	1.350	29.0	24.0
17.	HIGHCOURT	24.0	22.7	7.90	7.60	1.010	0.940	22.0	20.0
18.	M L A FLAT	23.9	21.1	7.93	7.61	1.170	1.280	19.0	16.0
19.	ADALATGANJ	24.9	23.2	7.91	7.90	1.170	1.170	10.0	17.0
20.	MEETHAPUR	21.5	21.1	7.09	7.10	1.215	1.700	30.0	27.0
21.	CHANDMARI ROAD	22.4	22.5	7.20	6.95	1.058	1.210	18.0	16.0
22.	HARDING ROAD	26.0	23.6	7.15	7.05	1.101	1.120	18.0	14.0
23.	NEW MARKET	22.2	21.5	7.05	7.05	1.075	1.220	13.0	15.0
24.	CHIRAYYATAR 1	22.7	21.5	6.93	6.95	1.070	1.270	21.0	22.0
25.	CHIRAYYATAR 2	24.6	22.7	7.06	7.05	1.088	1.300	23.0	18.0
26.	BANKIPUR	26.8	24.5	7.37	7.15	1.343	1.230	52.0	39.0
27.	CONGRESS MAIDAN	27.0	24.9	7.33	7.35	1.537	1.340	36.0	39.0
28.	PIRMOHANI	27.0	25.0	7.68	7.45	1.423	1.370	22.0	26.0
29.	KADAMKUAN No. 1	26.6	25.0	7.35	7.35	1.545	1.590	35.0	28.0
30.	KADAMKUAN No. 2	26.9	25.3	7.22	7.30	1.636	1.570	45.0	40.0
31.	SCIENCE COLLEGE	25.6	24.3	7.32	7.05	1.435	1.400	18.0	13.0
32.	GOLAKPUR	26.6	24.8	7.31	7.10	1.415	1.380	18.0	16.0

For most waters the concentration of dissolved solids in milligrams per liter is equal to 0.55 to 0.7 times the conductivity in microsiemens per centimeter at 25°C. The exact value of the coefficient depends on the types of salts in the water.

Table: 5.2 **Result of chemical analysis of Groundwater of Patna**

Sl. No.	LOCATION	Carbonate Alkalinity (mg/l as $CaCO_3$)		Bicarbonate Alkalinity (mg/l as $CaCO_3$)		Total Alkalinity (mg/l as $CaCO_3$)	
		PRE	POST	PRE	POST	PRE	POST
1.	WALMI	16	30	186	184	202	214
2.	DIGHA No.1	40	40	174	192	214	232
3.	DIGHA No.2	44	40	220	216	264	256
4.	SHEIKHPURA	32	42	234	198	266	240
5.	KHAJPURA	44	40	238	236	282	276
6.	RAJVANSHINAGAR	112	94	162	166	274	260
7.	ANISABAD	16	22	232	228	240	250
8.	S K PURI	20	20	220	246	240	266
9.	RAJAPUR	32	30	198	190	230	220
10.	LALIT BHAWAN	60	56	180	184	240	240
11.	BAILEY ROAD	40	40	216	220	256	260
12.	JAKKANPUR No.1	24	32	216	200	240	232
13.	JAKKANPUR No.2	16	20	228	220	244	240
14.	GARDANIBAGH No. 13	12	18	230	222	242	240
15.	GARDANIBAGH No. 32	20	20	222	220	242	240
16.	CHAJJUBAGH	12	20	232	212	244	232
17.	HIGHCOURT	40	40	200	200	240	240
18.	M L A FLAT	16	20	238	254	254	274
19.	ADALATGANJ	16	20	222	190	238	210
20.	MEETHAPUR	12	20	230	200	242	220
21.	CHANDMARI ROAD	16	20	158	190	174	210
22.	HARDING ROAD	12	18	218	242	230	260
23.	NEW MARKET	16	26	234	194	250	220
24.	CHIRAYYATAR 1	12	20	222	232	234	252
25.	CHIRAYYATAR 2	20	20	218	232	238	252
26.	BANKIPUR	20	20	226	200	246	220
27.	CONGRESS MAIDAN	24	20	236	252	260	272
28.	PIRMOHANI	28	26	226	216	254	242
29.	KADAMKUAN No. 1	12	18	264	242	276	260
30.	KADAMKUAN No. 2	20	20	248	240	268	260
31.	SCIENCE COLLEGE	16	20	230	220	246	240
32.	GOLAKPUR	16	20	244	230	260	250

Table: 5.3 Result of chemical analysis of Groundwater of Patna

Sl No.	LOCATION	Calcium Hardness (as $CaCO_3$), mg/l 200 mg/l max.		Total Hardness (as $CaCO_3$), mg/l 300 mg/l max.		Magnesium Hardness (as $CaCO_3$), mg/l 100 mg/l max.		Ca^{++} 75 mg/l.		Mg^{++} 30mg/l	
		PRE	POST	PRE	POST	PRE	POST	PRE	POST	PRE	POST
1.	WALMI	36	32	240	260	204	228	14.43	12.83	49.58	55.42
2.	DIGHA No.1	32	28	252	244	220	216	12.83	11.22	53.47	52.50
3.	DIGHA No.2	32	28	240	244	208	216	12.83	11.22	50.55	52.50
4.	SHEIKHPURA	60	60	272	280	212	220	24.06	24.05	51.52	53.47
5.	KHAJPURA	28	24	308	336	280	312	11.22	9.62	68.05	75.83
6.	RAJVANSHINAGAR	44	28	248	268	204	240	17.64	11.22	49.58	58.33
7.	ANISABAD	32	28	304	348	272	320	12.83	11.22	66.11	77.78
8.	S K PURI	48	36	272	280	224	244	19.25	14.43	54.44	59.30
9.	RAJAPUR	32	24	232	248	200	224	12.83	9.62	48.61	54.44
10.	LALIT BHAWAN	44	36	244	252	200	216	17.64	14.43	48.61	52.50
11.	BAILEY ROAD	44	36	248	256	204	220	17.64	14.43	49.58	53.47
12.	JAKKANPUR No.1	56	44	272	272	216	228	22.46	17.64	52.50	55.42
13.	JAKKANPUR No.2	32	28	224	264	192	236	12.83	11.22	46.67	57.36
14.	GARDANIBAGH No. 13	68	52	292	296	224	244	27.27	20.84	54.44	59.30
15.	GARDANIBAGH No. 32	44	43	256	280	212	232	17.64	19.24	51.52	56.39
16.	CHAJJUBAGH	40	40	252	280	212	240	16.04	16.03	51.52	58.33
17.	HIGHCOURT	32	36	240	272	208	236	12.83	14.43	50.55	57.36
18.	M L A FLAT	48	40	248	256	200	216	19.25	16.03	48.61	52.50
19.	ADALATGANJ	64	76	244	248	180	172	25.65	30.43	43.75	41.80
20.	MEETHAPUR	44	40	224	232	180	192	17.64	16.03	43.75	46.67
21.	CHANDMARI ROAD	40	36	276	284	236	248	16.03	14.43	57.36	60.28
22.	HARDING ROAD	52	40	252	232	200	192	20.84	16.03	48.61	46.67
23.	NEW MARKET	36	28	228	232	192	204	14.43	11.22	46.67	49.58
24.	CHIRAYYATAR 1	76	64	280	264	204	200	30.43	25.65	49.58	48.61
25.	CHIRAYYATAR 2	44	36	224	272	180	236	17.63	14.43	43.75	57.36
26.	BANKIPUR	40	36	220	276	180	240	16.03	14.43	43.75	58.33
27.	CONGRESS MAIDAN	40	36	280	272	240	236	16.03	14.43	58.33	57.36
28.	PIRMOHANI	48	36	288	296	240	260	19.24	14.43	58.33	63.19
29.	KADAMKUAN No. 1	20	24	260	304	240	280	11.22	9.62	58.33	68.05
30.	KADAMKUAN No. 2	36	40	292	312	256	272	14.43	16.03	62.22	66.11
31.	SCIENCE COLLEGE	28	24	288	312	260	288	11.22	9.62	63.19	70.00
32.	GOLAKPUR	36	36	236	260	200	224	14.43	14.43	48.61	54.44

Table: 5.4 **Result of chemical analysis of Groundwater of Patna**

Sl No.	LOCATION	Sulphate (as SO_4,mg/l) 150 mg/l max.		Iron (as Fe,mg/l) 0.3 mg/l max		Sodium (as Na),mg/l	
		PRE	POST	PRE	POST	PRE	POST
1.	WALMI	20.0	25.0	0.80*	0.90*	108	137
2.	DIGHA No.1	27.0	26.0	0.00	0.10	77	91
3.	DIGHA No.2	6.0	-	2.45*	2.50*	87	101
4.	SHEIKHPURA	39.0	32.5	1.10*	1.00*	117	101
5.	KHAJPURA	30.0	29.0	0.95*	0.80*	134	156
6.	RAJVANSHINAGAR	5.0	-	0.00	0.00	91	67
7.	ANISABAD	35.5	26.0	3.15*	3.50*	169	141
8.	S K PURI	7.0	-	2.20*	2.10*	87	92
9.	RAJAPUR	3.5	-	3.30*	3.50*	65	57
10.	LALIT BHAWAN	10.0	10.5	3.20*	3.50*	83	121
11.	BAILEY ROAD	12.0	10.5	0.45*	0.60*	91	101
12.	JAKKANPUR No.1	10.0	-	0.00	0.00	136	153
13.	JAKKANPUR No.2	18.0	-	0.00	0.00	147	118
14.	GARDANIBAGH No.13	20.0	-	0.30	0.20	154	167
15.	GARDANIBAGH No.32	15.0	10.5	3.30*	3.50*	165	142
16.	CHAJJUBAGH	10.0	-	2.90*	3.50*	88	76
17.	HIGHCOURT	18.0	-	1.00*	1.00*	88	92
18.	M L A FLAT	10.0	10.5	0.75*	0.60*	98	76
19.	ADALATGANJ	10.0	-	0.00	0.00	130	157
20.	MEETHAPUR	13.5	10.5	0.00	0.00	160	147
21.	CHANDMARI ROAD	16.0	20.0	0.00	0.00	143	165
22.	HARDING ROAD	12.0	-	0.35*	0.40*	145	159
23.	NEW MARKET	25.0	26.0	1.05*	0.90*	157	132
24.	CHIRAYYATAR 1	13.0	10.5	0.80*	0.70*	154	147
25.	CHIRAYYATAR 2	12.0	10.5	0.00	0.00	151	131
26.	BANKIPUR	6.0	5.5	0.00	0.00	128	147
27.	CONGRESS MAIDAN	5.0	-	0.00	0.00	147	142
28.	PIRMOHANI	30.0	26.0	0.00	0.00	137	151
29.	KADAMKUAN No. 1	35.0	38.5	0.00	0.00	150	165
30.	KADAMKUAN No. 2	29.0	32.5	0.00	0.00	145	132
31.	SCIENCE COLLEGE	15.0	20.0	0.00	0.00	144	165
32.	GOLAKPUR	25.0	27.0	0.00	0.00	154	147

* = Value more than desirable limit.

The result indicates that the concentration of most of the parameters in thirty two locations are within the permissible limit (IS: 105000-1983) excepting the hardness and the concentration of iron. Concentration of iron in groundwater of Anisabad, Rajapur, Lalit Bhawan, Gardanibagh No. 32 and Chajjubagh are more than 3.0 mg/l (Table-5.4).

The concentration of other parameters in shallow aquifer is high (as reported by CGWB) compared to the deep (tubewell) aquifer. This might be due to non-percolation of contaminants through almost impervious sticky clay horizon as apparent from the litholog (Figure-2.2).

Patna is fortunate in this regard that despite considerable load on the surface, deep tubewell water below 60m depth is quite safe. Only the shallow zone is vulnerable to contamination.

5.2 Suitability of groundwater for irrigation

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 dissolve substances.

In order to see the suitability of water for irrigation purpose, sodium absorption ratio (SAR) have been calculated (Table-5.5) by using the following formula:

$$SAR = \frac{M_{Na}}{\sqrt{(M_{Ca} + M_{Mg})}}$$

Where, M_i is the concentration of 'i' in mmoles/l.

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

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

As evident from Table-5.5, the values of SAR in the water sample of Patna area varies from 1.57 to 4.65 and is thus excellent for irrigation purposes. The maximum SAR of 4.65 has been found at Meethapur.

Table: 5.5 Sodium Absorption Ratio of Groundwater samples of Patna.

Sl. No.	LOCATION	Na^+ mmoles/l		Ca^{++} mmoles/l		Mg^{++} mmoles/l		S A R	
		PRE	POST	PRE	POST	PRE	POST	PRE	POST
1.	WALMI	4.70	5.96	0.36	0.32	2.04	2.28	3.03	3.70
2.	DIGHA No.1	3.35	3.96	0.32	0.28	2.20	2.16	2.11	2.55
3.	DIGHA No.2	3.78	4.39	0.32	0.28	2.08	2.16	2.44	2.81
4.	SHEIKHPURA	5.09	4.39	0.60	0.60	2.12	2.20	3.09	2.62
5.	KHAJPURA	5.83	6.77	0.28	0.24	2.80	3.12	3.32	3.69
6.	RAJVANSHINAGAR	3.96	2.91	0.44	0.28	2.04	2.40	2.52	1.78
7.	ANISABAD	7.35	6.13	0.32	0.28	2.72	3.20	4.22	3.29
8.	S K PURI	3.78	4.00	0.48	0.36	2.24	2.44	2.29	2.39
9.	RAJAPUR	2.83	2.48	0.32	0.24	2.00	2.24	1.86	1.57
10.	LALIT BHAWAN	3.61	5.26	0.44	0.36	2.00	2.16	2.31	3.31
11.	BAILEY ROAD	3.96	4.39	0.44	0.36	2.04	2.20	2.51	2.74
12.	JAKKANPUR No.1	5.92	6.66	0.56	0.44	2.16	2.28	3.59	4.00
13.	JAKKANPUR No.2	6.39	5.13	0.32	0.28	2.00	2.36	4.20	3.16
14.	GARDANIBAGH No. 13	6.70	7.26	0.68	0.52	2.24	2.44	3.92	4.22
15.	GARDANIBAGH No. 32	7.18	6.18	0.44	0.48	2.12	2.32	4.49	3.69
16.	CHAJJUBAGH	3.83	3.31	0.40	0.40	2.12	2.40	2.41	1.98
17.	HIGHCOURT	3.83	4.00	0.32	0.36	2.08	2.36	2.47	2.43
18.	M L A FLAT	4.26	3.30	0.48	0.40	2.00	2.16	2.71	2.06
19.	ADALATGANJ	5.66	6.83	0.64	0.76	1.80	1.72	3.62	4.34
20.	MEETHAPUR	6.96	6.39	0.44	0.40	1.80	1.92	4.65	4.20
21.	CHANDMARI ROAD	6.22	7.18	0.40	0.36	2.36	2.48	3.74	4.26
22.	HARDING ROAD	6.31	6.92	0.52	0.40	2.00	1.92	3.98	4.54
23.	NEW MARKET	6.83	5.74	0.36	0.28	1.92	2.04	4.52	3.77
24.	CHIRAYYATAR 1	6.70	6.39	0.76	0.64	2.04	2.00	4.00	3.93
25.	CHIRAYYATAR 2	6.57	5.70	0.44	0.36	1.80	2.36	4.39	3.46
26.	BANKIPUR	5.57	6.39	0.40	0.36	1.80	2.40	3.76	3.85
27.	CONGRESS MAIDAN	6.39	6.18	0.40	0.36	2.40	2.36	3.82	3.75
28.	PIRMOHANI	5.96	6.57	0.48	0.36	2.40	2.60	3.35	3.82
29.	KADAMKUAN No. 1	6.52	7.18	0.28	0.24	2.40	2.80	3.98	4.12
30.	KADAMKUAN No. 2	6.31	5.74	0.36	0.40	2.56	2.72	3.69	3.25
31.	SCIENCE COLLEGE	6.26	7.18	0.28	0.24	2.60	2.88	3.69	4.07
32.	GOLAKPUR	6.70	6.39	0.36	0.36	2.00	2.24	4.36	3.96

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

From the result of the chemical analysis following conclusions can be drawn.

1. The groundwater quality in Patna town is in general good for drinking purpose.

2. The iron content of some of the places mainly in the central part of Patna town is more than the desirable limit.

3. Deep aquifer is more or less unaffected by the surface pollution till now.

4. The groundwater quality is good for irrigation purpose as well.

6.2 Recommendations

1. Detailed and intensive study needs to 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.

2. It is also required to analyze the water quality of dug and shallow wells since they are the most vulnerable to pollution.

3. Quality of groundwater should be monitored for long period to know the effect of sewage waste disposal on land in Patna.

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APPENDIX - I

INDIAN STANDARDS FOR DRINKING WATER

Sl. No.	Characteristics	Desirable Limit
1.	Colour, Hazen units, Max	10
2.	Odour	Unobjectionable
3.	Taste	Agreeable
4.	Turbidity, NTU, Max	10
5.	Dissolved solids, mg/L, Max	500
6.	pH value	5.6 to 8.5
7.	Total hardness (as $CaCO_3$), mg/L Max.	300
8.	Calcium (as Ca), mg/L, Max	75
9.	Magnesium (as Mg), mg/L, Max	30
10.	Copper (as Cu), mg/L, Max	0.50
11.	Iron (as Fe), Mg/L, Max	0.3
12.	Magancese (as Mn), Mg/L, Max	0.1
13.	Chlorides (as Cl), mg/L, Max	250
14.	Sulphate (as SO_4), mg/L, Max	150
15.	Nitrate (as NO_3), mg/L, Max	45
16.	Fluoride (as F), mg/L	0.6 to 1.2
17.	Phenolic compounds (as C_6H_5OH) mg/L, Max	0.001
18.	Mercury (as Hg), Mg/L, Max	0.001
19.	Cadmium (as Cd), mg/L, Max	0.01
20.	Selenium (as Se), mg/L, Max	0.01
21.	Arsenic (as As), mg/L, Max	0.05
22.	Cyanide (as CN), mg/L, Max	0.05
23.	Lead (as Pb), mg/L, Max	0.1
24.	Zinc (as Zn), mg/L, Max	5
25.	Anionic detergents (as MBAS), mg/L, Max	0.2
26.	Chromium (as Cr^{6+}), mg/L, Max	0.05
27.	Polynuclear aromatic hydrocarbons (as PAH), ug/L, Ma;	-
28.	Mineral oil, mg/L, Max	0.01
29.	Residual, free chlorine, mg/L, Min	0.2
30.	Pesticides	Absent
31.	Radioactive materials :	
	(a) Alpha emitters, u c/mL, Max	10^{-8}
	(b) Beta emitters, u c/mL, Max	10^{-7}

* IS : 10500 - 1983

WATER QUALITY STANDARDS

ISI STANDARDS FOR SURFACE WATER QUALITY FOR VARIOUS USES

		TOLERANCE LIMIT				
Sl. No.	Characteristic	Class A	Class B	Class C	Class D	Class E
1	2	3	4	5	6	7
1.	pH value	6.5 - 8.5	6,5 - 8.5	6.5 - 8.5	6.5 - 8.5	6.5 - 8.5
2.	Dissolved oxygen, mg/l, (min).	6	5	4	4	-
3.	BOD (5- days at 20°C mg/l, (min)	2	3	3	-	-
4.	Total coliform organism, MPN/100 ml,Max	50	500	5000	-	-
5.	Colour,Hazen units,Max.	10	300	300	-	-
6.	Odour	10	300	300	-	-
7.	Taste	Tasteless	-	-	-	-
8.	Total dissolved solids, mg/L, max.	500	-	1500	-	2100
9.	Total hardness (as $CaCO_3$,mg/L), max.	300	-	-	-	-
10.	Calcium hardness (as $CaCO_3$),mg/L , max.	200	-	-	-	-
11.	Magnesium hardness (as $CaCO_3$),mg/L, max.	100	-	-	-	-
12.	Copper (as Cu),mg/L,max.	1.5	-	1.5	-	-
13.	Iron (as Fe),mg/l, max.	0.3	-	0.5	-	-
14.	Manganese (as Mn),mg/L,max.	0.5	-	-	-	-
15.	Cholrides (as Cl),mg/L,max.	250	-	600	-	600
16.	Sulphates (as SO_4),mg/L,max.	400	-	400	-	1000
17.	Nitrates (as NO_3), mh/L,max	20	-	50	-	-
18.	Fluorides (as F),mg/L,max.	1.5	1.5	1.5	-	-
19.	Phenolic compounds (as C_6H_5 OH),mg/L, max.	0.002	0.005	0.005	-	-
20	Mercury (as Hg),mg/L,max	0.001	-	-	-	-
21.	Cadmimum (as Cd),mg/L,max	0.01	-	0.01	-	-
22.	Salenium (as Se),mg/L,max	0.01	-	0.05	-	-
23.	Arsenic (as As),mg/L,max	0.05	0.2	0.2	-	-
24.	Cyanide (as CN),mg/L,max	0.05	0.05	0.05	-	-
25.	Lead (as Pb), mg/L, max	0.1	-	0.1	-	-
26.	Zinc (as Zn)). mg/L,max	15	-	15	-	-

1	2	3	4	5	6	7
27.	Chromium (as Cr^{6+}),mg/L,max	0.05	-	0.05	-	-
28.	Anionic detergents (as MBAS) mg/L,max	0.2	1	1	-	
29.	Polynuclear aromatic hydrocarbons,(as PAH)	0.2	-	-	-	-
30.	Mineral oil, mg/L,max	0.01	-	0.1	0.1	-
31.	Barium (as Ba),mg/L,max	1	-	-	-	-
32.	Silver (as Ag),mg/L,max	0.05	-	-	-	-
33.	Pesticides	Absent	-	Absent	-	-
34.	Alpha emitters,uc/Ml,max	10^{-9}	10^{-9}	10^{-7}	-	
35.	Beta emitters,uc/ml,max	10^{-8}	10^{-8}	10^{-8}	10^{-8}	10^{-8}
36.	Free ammonia (as N),mg/L,max	-	-	-	1.2	-
37.	Electrical conductance at 25°C,mhos,max	-	-		1000×10^{-6}	2250×10^{-6}
38.	Free carbon diovide (as CO),mg/l, max	-	-	-	61	-
39.	Sodium absorption ratio	-	-	-	-	26
40.	Boron (as B), mg/L, max	-	-	-	-	-
41	Percemt sodium, max.	-	-	-	-	-

Source : IS : 2296 : 1982

Classes of water

Class A : Surface Waters for Use as Drinking Water Sources without Conventional Treatment but after Disinfection

Class B : Surface Waters for Outdoor Bathing

Class C : Surface Waters for Use as Drinking Water Source With Conventional Treatment Followed by Disinfection.

Class D : Surface Waters Used for Fish Culture and Wild Life Propagation

Class E : Surface Waters for Irrigation, Industrial Cooling or Control Waste Disposal.

WATER QUALITY CRITERIA FOR THE VARIOUS DESIGNATED BEST USES

(AS PER CBCB, NEW DELHI)

Water Quality Criteria	Designated Best use	Parameters affecting		Quality Criteria
1	2	3		4
A.	Drinking Water Source, without conventional treatment but after disinfection	1.	Coliform MNP	<50/100
		2.	Turbidity	<10 units
		3.	Colour	<10 units
		4.	BOD	<2 mg/L
		5.	DO	<6 mg/L
		6.	Toxicants (including pesticides)	No acute toxicity to be present,
		7.	Plate Count	<50/100 ml
		8.	Floating Matter.	Absent
		9.	Taste or Odour	Not perceptible
B.	Bathing, Swimming & Recreation	1.	Coliform MNP	<500/100 ml
		2.	Turbidity	<25 units.
		3.	Colour	<10 units
		4.	BOD	<3 Mg/L
		5.	DO	<5 Mg/L
		6.	Toxicants (including pesticides)	No acute toxicity to be present
		7.	Floating Matter	Not noticeable
		8.	Taste or Odour	Not perceptible
C.	Drinking Water Source after conventional treatment	1.	Coliform MNP	<5000/100 ml
		2.	Colour	<25 ml.
		3.	BOD	<3 mg/L
		4.	DO	>4 mg/L
		5.	Toxicants	No acute toxicity to be present
D.	Propagation of Wild Life Fisheries	1.	Coliform MNP	<5000/100 ml
		2.	BOD	<6 mg/L
		3.	DO	>4 mg/L
		4.	Toxicants	No acute toxicity to be present
E.	Irrigation, Industrial Cooling and Controlled waste disposal	1.	TDS	<1000 mg/L
		2.	(Ca+Mg)	<100 mg/L
		3.	Sodium Ratio	<0.5
		4.	Chlorides	<250 mg/L
		5.	Boron	<2 mg/L

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