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Case study on assessment of ground water quality of Varanasi (Uttar Pradesh)

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ABSTRACT

The studies were undertaken for the Assessment of Ground Water Quality of Varanasi City (U.P.). A total of 25 numbers samples for each seasons were collected. These were for Physical, Chemical & Biological constituents for the pre monsoon & post monsoon season. The pH at all the locations is almost neutral ranging between 7.5-7.7 which is well within the standard limit. The Total Dissolved Solids (TDS) are ranging between 396 to 1682 mg/L and the Conductivity ranges between 116 to 1700 mmhos/cm, which confirms the correlation between the two that the conductivity increases on increase of TDS. The values of Fluoride are ranging between 0.59 to 0.97 mg/L which are within the specified limits at all the locations and Hardness is ranging between 316 to 840 mg/L which are not within the specified limits at all the locations. The values of Alkalinity are ranging between 284 to 532 mg/L which are higher than the desirable limit but within the permissible limit, also the heavy metals in this area are not very high ranging between ND to 0.31 mg/L indicating the presence of some heavy metals, both could be due to the industries in this region. The values of Iron are ranging between 0.35 to 1.21 mg/L, which are exceeding the desirable limit at all the places, whereas at Ram Nagar it is 1.21 mg/L which is exceeding the permissible limit as well. The total and fecal coliforms are also negligible ranging between < 2.0 MPN/100 mL at all the locations indicating thereby that there is no bacteriological contamination .

KEYWORDS

Groundwater | Water quality | Varanasi | Impact assessment

CITATION

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Introduction

Ground Water Pollution is usually traced back to four main origins industrial, domestic, agricultural and over exploitation. The last category mainly accounts for seawater intrusion. Studies carried out in India reveal that one of the most important causes of ground water pollution is unplanned urban development without adequate attention to sewage and waste disposal. Industrialisation without provision of proper treatment and disposal of wastes and effluent is another source of ground water pollution. Excessive application of fertilizers for agricultural development coupled with over-irrigation intrusion due to excessive pumping of fresh water in coastal aquifers are also responsible for ground water pollution. In case of industrial units, effluent in most of the cases are discharged into pits, open ground, or open unlined drains near the factories, thus allowing it to move to low lying depressions resulting ground water pollution. The industries, which are burgeoning at terrifying fast rate, daily, produce about 55000 million M^3 of wastewater per day, out of which 68.5 million M^3 is discharged into river streams. Thus the magnitude of damage caused to our water resources can be estimated from the fact that about 70% of rivers and streams in India contain polluted water.

The incidence of ground water pollution is highest in urban areas where large volumes of waste are concentrated and discharged into relatively small areas. The ground water contamination, however, is detected only some time after the subsurface contamination begins. Thirteen states in India have been identified as endemic to fluorosis due to abundance in natural occurring fluoride bearing minerals. These are Nalgonda, Rangaraddy district in A.P., Banskatha, Kutch, Amroli in Gujarat, Hissar, Kaithal, Gurgaon in Haryana, Augul Bolengir, Phulbani in Orissa, Bhatinda, Sangrur in Punjab, Ajmer, Bikaner, Pali, Nagur, Sirohi in Rajasthan, Chengalpatti, Madurai in Tamilnadu, Unnao in U.P., Karnataka, Madhya Pradesh, Maharastra, Bihar, Delhi. There are nearly half million people in India suffering from ailment due to

S. No.	State	Total Replenishable Ground Water Resource (MCM/Yr)	Provision For Domestic Industrial And other uses (MCM/Yr)	Available Ground water for irrigation resource in net terms (MCM/Yr)	Net Draft (1993) (MCM/Yr)	Balance Ground water Resources for Future use (MCM/Yr)	Level Of ground Water de-velop-ment'(%)	Utilisable irrigation potential for land develop-Ment (Mha)
1	Punjab	18654.90	1865.50	16789.50	15757.70	1031.80	93.85	2.91715
2	Uttar Pradesh	83820.85	12573.13	71247.72	26835.28	44412.44	37.66	16.79896

Source: Ground Water Statistics 1996, Central Ground Water Board, MCM: Million Cubic Meters

Table 1: Ground Water Resources Of Panjab & Uttar Pradesh

excess of fluoride in drinking water. The available ground water resources of Punjab & UP are given below. In some villages of Rajasthan and in Gujarat level of the fluoride goes up to 11.0 mg/lit. Arsenic in ground water has been reported in a range (0.05-3.2) mg/l in shallow aquifers from 61 block in 8 districts of West Bengal namely Malda, Mushirbad, Nadia, North and South 24 Parganas, Bardharnan, Howrah and Hugli.

Objective of Studies

The present case studies were carried out for Ludhiana metro cities for assessment of ground water quality with the following objectives:

1. Assessment of Ground water quality during pre monsoon period located at

(a) Industrial zone;

(b) Municipal solid waste dumping site and

(c) Residential zone

2. Assessment of Ground water quality during post monsoon period located

(a) Industrial zone;

(b) Municipal solid waste dumping site and (c). Residential zone.

Description of Study Area

Description of the Study Area of Varanasi

Varanasi district forms part of central Ganga plain and is situated in the south west part of U.P. State. Physiographically the district can be divided into two physical regions, *i.e.*, the northern alluvial plain and the southern plateau area. The northern alluvial plain is drained by the Ganga and its tributaries namely the Gomti and the Varuna rivers. The southern plateau comprising of extensive hillocks and mesas of Vindhyan sandstone and shales, is deeply dissected by the Karamnasa river and its effluents.

The eternal and ancient city of Varanasi is a religious place on the bank of the Holiest Indian river Ganga. It is a magnificent city with myriad attractions both as an exalted place of pilgrimage and micro centre of faith. It is one of the most important places of pilgrimages for Hindu and Buddhists in the world. It is a unique city where the past and the present, eternity and continuity live side by side. The city rises through the High northern bank on the outside curve of Ganga to form a magnificent panorama of buildings in many varieties of Indian architecture. The unique relationship between the city and sacred river is the essence of 'Varanasi - the land of Sacred Light'. Glorified by myth and legend and sanctified by religion, it has always attracted a large number of pilgrims and being worshipped from times immemorial. The district Varanasi is located in south west portion of Uttar Pradesh and having the geographical coordinates as 82º 15' to 83º 30' East longitude and 24º 35' to 25º 30' North latitude. The district of Varanasi is surrounded by Jaunpur and Ghazipur districts in the north, Mirzapur district in the south, Bhadohi district in the west and Sahabad district of Bihar State in the eastern side. The geographical area of the district is 4035 Sq. Km. Administratively the district is divided into four tehsils, namely - Varanasi, Sakaldiha, Chandauli and Chakia which have been further sub-divided into twenty two development blocks. Varanasi is the largest Tehsil of the district occupying 35.9% of area and smallest is Chandauli which is having 15.5% share in the total area of the district. The district is having 2969 villages and 17 towns, as per 1991 census. Geographically, it can be divided into two parts, first portion comes under Gangetic plain and another is Naugarh's hilly terrain. The holy river Ganga divides the district into almost two equal parts and other rivers flowing through the districts area Gomti, Karamnasa, Chandra Prabha and Varuna. Karamnasa practically separates the district from the surrounding Bihar state. The district is well connected by National and State Highways and also by a network of railways. The National Highway nos. 2 and 7 pass through the district in the east-west and north-south directions, respectively. The Varanasi city is located in the North Eastern part of the Nation and is one of the biggest cities of Uttar Pradesh and is the district headquarters (Figure – 2.1). The geographical coordinates of the city are 25º 0' to 25º 16' North latitude and 82º 5' to 83º 1' East longitude. It is bounded on north by Jaunpur and Ghazipur, on south east by Mughal Sarai, on east by Bihar State, on west by Bhadohi and on south by

S. No.	INFORMATION	DATA
01.	Population	~ 14 lacs as per 2001 Census
02.	Area	78.5 sq.kms
03.	Altitude	80 meters above sea level
04.	Temperature Summer	22.6 to 41.5 °C
05.	Temperature Winter	9.5 to 23.4 °C
06.	Rainfall	1113.4 mm
07.	Language	Hindi, Urdu & English

Mirzapur. The area of the city is 78.5 Sq. Km. The Varanasi Nagar Nigam has divided the area of the city in 90 wards for administrative and management purposes. Apart from being a place of pilgrimage and tourist centre, Varanasi is a fast growing commercial, industrial and trading centre of Uttar Pradesh and Central India. It is well connected with all metro cities and other major cities of the country by Railways, National Highways and Airlines Varanasi Jal Sansthan provides the existing water supply in the city. With the development of many new residential areas and increase in population .

The general information about Varanasi is as given below

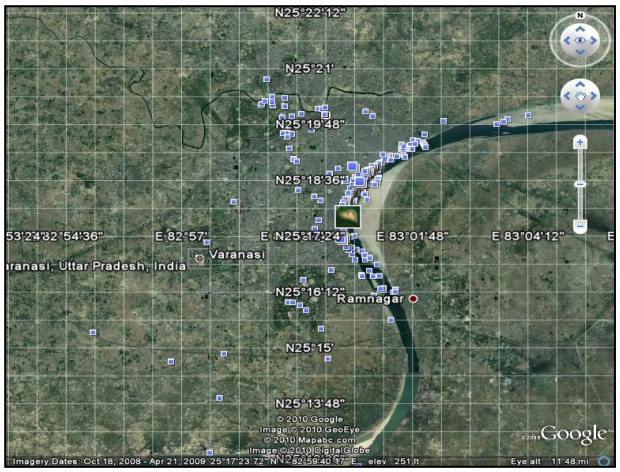
the water demand has increased. The surface water supply is not adequate to meet this increased demand. The drinking water supply is drawn from surface and ground water. The city is divided into two parts, viz., cis-Varuna area and the trans-Varuna area. The cis-Varuna area has a mixed supply of water, that is, from both surface and ground water, whereas in trans-Varuna area the water supply is exclusively from ground water. The source of surface water is river Ganga. Deep tube wells, hand pumps and private bore wells are the main sources for extraction of ground water in the city to cater to the water demand of the population. The depth of ground water varies from 3.02.to 15.25 m in various parts of the city. Apart from municipal sources of water supply, a large number of consumers also have shallow hand pumps for augmenting their water requirements.

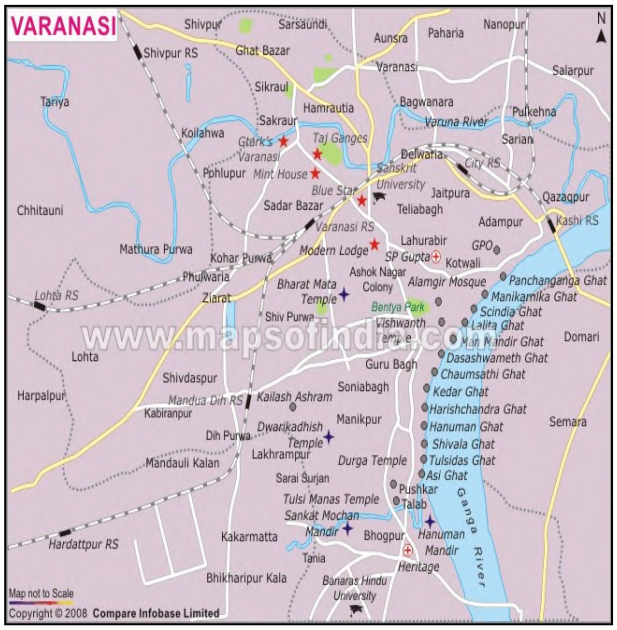
Physiography

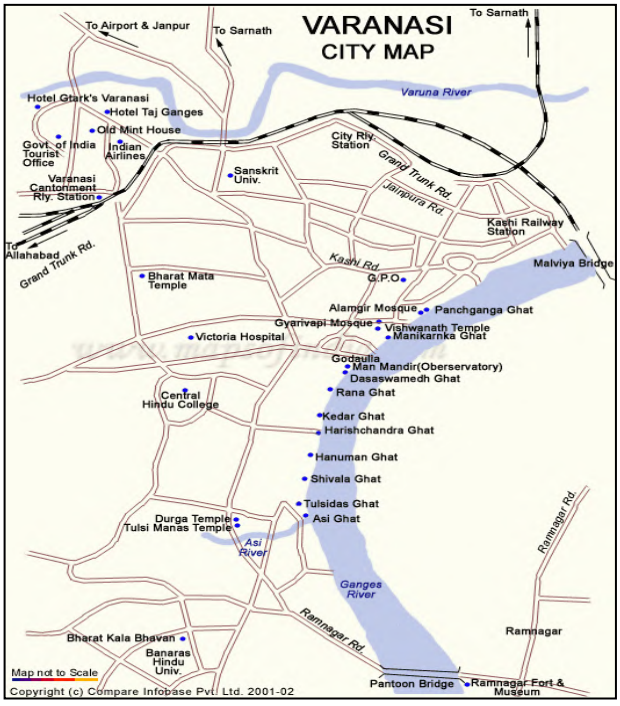
The district is picturesquely placed on both sides of the Ganga river. The northern part of it is alluvial plain while the southern part is having hilly tracts of projecting mountainous ranges of Vindhyas. The district is made up of two natural divisions, namely the plain under the Ganga and its tributaries and the plateau area of Naugarh development block of Chakia tehsil which has mountainous ridges overcast with dense forests and deep valleys drenched with rushing streams. The river system consists of two important rivers - the mighty Ganga, highly revered by Hindus since ages and its main tributary Gomti. Varuna, Asi Banganga, Chandra Prabha and Karamnasa are other important tributaries of the Ganga that drain the area. The surface of Chandauli tehsil is comparatively low which causes water logging problem during rainy season. The soil of the hilly-tract is hard and of red colour. In some places pieces of alkaline land is also found but a major part of Chandauli tehsil has black soil.The total area under forest in the district is 77404 hectares and almost ninety-nine percent of it is found in Naugarh development block of Chakia tehsil. The forest land of Varanasi is bounded by Chandauli in North, Bihar State in East, Mirzapur in South and Narayanpur-Ahraura, Robert ganj-Chopan highways in West. Geographically it is a hilly area and located in between Kymore and Vindhyan hills.

The forests are dense and mainly of the tropical dry mixed deciduous type having varying growth depending upon the nature of the soil and moisture. There are forests on ridges, flat hill tops, foot

of the hills but the trees found in this region are generally of poor quality. Salai, Piar, Mahua, Tendu apart from usual type of species of trees are found here. Dry Sal and green vegetation generally occur on the plateau region while *Bosewellia* type of jungle is found on the flat tops of the hill. *Dhak* jungle is also found in plain area of the district.







Banarsi langra a mango delicacy and yellowish betel leaves (Banarsi Pan) grown in the district are famous throughout the country.

The forest area mostly belonged to erstwhile Banaras princely State which is presently under the charge of U.P. Forest Department.

Physiographically Varanasi district may be divided into two physical regions – (1) the northern alluvial plain and (2) the southern hilly regions (plateau).

The plain is devoid of rock and made up entirely of alluvium of two types, the newer alluvium being the base of the flood plain of the Ganga and the older is that of the level upland (locally known as uparwar). The two are separated by clearly defined banks of varying heights which mark the extreme flood limit of the river. Apart from this difference, there are local variations depending upon the slope and height. The northern alluvial plain is generally a flat land with east or north-eastward slopes on a regional scale and forms a part of the central Ganga plain.

The southern hilly region, being a part of Vindhyan plateau is not uniform. It rises abruptly on the southern boundary of the alluvial tract with an escarpment, the average elevation being between 305 metre and 366 metre above mean sea level. The undulating table land extends between parallel ranges of hills and valleys. It is intersected every where by low ridges which are drained by torrential rains. The ridges are scarped and precipitous with long and tortuous gorges. The river Chandra Prabha escapes through these gorges by a single leap and the river Karamnasa by succession of cascades. A number of isolated hills stand out above the scarp. The general direction of the hills, which are not high, is east-west but there are numerous cross ranges which are rugged.

The area occupied by alluvium can be delineated all along Ganga and Gomti, draining all the blocks of the district, except Chakia block. Further the younger alluvium is confined dominantly within the flood plain of these rivers. The flood plain can

– (1) Younger flood plain (2) Older food plain.

1. *Younger Food Plain :* The river channel and its adjacent areas forming terraces which are subjected to periodic floods, consist of sand, silt and silty sand with minor clays and form the flood plain of the rivers. This is a narrow zone along the river channel and subjected to flooding regularly during rainy season.

2. *Older Flood Plain :* Older flood plain of the river Ganga and Varuna can be delineated extending to few kilometers and is locally termed as khadar.

The older flood plain is more conspicuous and wide in the eastern bank as compared to western side.

The soils in the district are classified into two broad groups, alluvial and residual, representing the different stages of soil development resulting from a sub humid to a humid climate and the physical and chemical weathering of the soils. The alluvial group, comprising the greater and the more important portion of the district - the tehsils of Chandauli and Varanasi, possesses soils developed from the alluviums of the Ganga, while the residual group comprising an area of less importance - tehsil Chakia, primarily possesses residual soils developed insitu from the Vindhyan rocks. The groups are inherently and genetically different in nature. Agriculturally also, they behave differently, the alluvial soils being very productive and the soils of the Vindhyan System supporting only sparse cultivation.

Climate

The Varanasi district falls in the subtropical region and its climate is classified as tropical to subtropical type, characterized by hot summer and severe winter. The district experiences three distinct seasons namely, summer, rainy and winter. Winter usually commences from middle of November and extends till end of February whereas summer starts from April and extends upto the middle of June. March is a transitional period. The rainy season starts normally by the third week of June and continues till September or early part of October.

The climate of Varanasi district is more or less dry. May and June are the hottest months of the year. Dust storms and hot waves are common during summers. The maximum temperature in winter is recorded to be 23.4 ºC and the minimum is 9.5 ºC. Winter starts from mid of November. The most chilling months are December and January. At times, when the area is under the grip of cold wave due to sweeping cold winds of northern Himalayas, the temperature drops to as low as freezing point in the plains. In general, the climatic conditions are beneficial to health. The maximum temperature in the summer is recorded as 41.5 ºC and the minimum is reported to be 22.6 ºC. The average normal maximum temperature has been observed as 41.5ºC during June and minimum 9.5ºC during January. The relative humidity varies from month to month being maximum of 82% during the month of August, in the period of south west monsoon and minimum of 28% during the month of April. It therefore varies from 28% in dry season to 82% during the rainy season. The mean monthly relative humidity is 55.75%. The district receives greater part of the annual rainfall through south west monsoon between July and September. The average normal rainfall of the city is varied from min 3.3 mm to the highest of1113.4 mm.

Hydrogeology

Ground water occurs in both, the Kaimur sandstone and the unconsolidated alluvial sediments in the district. In the Kaimur sandstone (Vindhyans), the occurrence and movement of ground water is controlled by the size, depth, spacing and degree of intercalated planes of weakness i.e. joints, bedding, fractures and fissures. The availability of ground water in a well depends upon encountering the number of such plane of weakness and the extent of weathering in them. Generally the ground water occurs under water table condition. In the unconsolidated alluvial sediments ground water occurs in the pore spaces in the zone of saturation. The ground water in the unconsolidated deposits of the older alluvium in the area comprises of two bodies, (i) a shallow ground water body which occurs principally in clay and

the land surface and also confines water in the underlying meander belt sand deposits. The meander belt deposits consist of medium to coarse grained sand and underlying impervious back swamp clays, are moderately to highly permeable and constitute a potential ground water reservoir.

The drainage system of the area is controlled by the river Ganga and its tributaries. The river Ganga flows in the east or north-eastern direction along the north-eastern and south western boundaries of the district. The Ganga touches the district at the village Betabar where it is joined by a small stream known as Subbha Nullah, which drains a small area. For a distance of about 11.2 kiloimeters the river separates Varanasi form Mirzapur and then runs roughly north-eastwards across the district to the point where it is joined by the river Gomti. In the early part of its course through the district, it separates the town of Amanat which is on the left bank from the towns of Ralhupur and Ramnagar which are on right bank. The right bank is high and the left bank is steep. After leaving the town of Ramnagar the river flows through the city of Varanasi which is situated on its left bank and rises into a high ridge after the confluence of the Assi with the Ganga. On the right bank there lies an extensive expanse of sand which has accumulated between the river and the high flood bank. After leaving the Malviya bridge the river is joined by the Varuna at Sarai Mohan and continues in an easterly direction beyond the confluence. The river flows in a northerly direction and throughout its stretch; the right bank constitutes a high ridge of kankar. As is generally the case along the Ganga, the banks are alternately steep and shelving , the precipitous bank on one side of the river being faced by a gentle slope of alluvium on the other. The velocity of the Ganga in this district varies from less than 3.2 kms/hour in the dry weather to about 8 kms/hour in the rains, the average maximum rise of the river during the ordinary floods being about 11.58 meters.

The biggest tributary of the Ganga in the district is the Gomti, which maintains south-east trend. This river meanders a lot and this fact might have given rise to its name. The banks are alternately abrupt and sloping, the convex side being mostly low and shelving with broad stretches of alluvial and cultivable land.

Use of Ground Water and Surface Water

The population of Varanasi city and in particular of Trans Varuna area is mostly dependent on the ground water for its domestic use. Varanasi Jal Sansthan also draws water from Ganga river for supply to residential colonies after complete treatment. About 115 MLD ground water is extracted to fulfill the requirement. There are about 111 tube wells in different localities of the city and the Jal Sansthan has provided about 1954 hand pumps to meet the requirement of public, who are unable to get the water connection in their premises. Besides this private boring is also very common.

There are two sources of water available at Varanasi, viz., ground water and river water (surface). Both the sources are utilized for drinking water requirement of the city. These water sources are also used for industrial purposes, irrigation purposes and other domestic usage of the city.

Ground Water Availability at Study Area

Depth of Ground Water at Varanasi

Ground water is one of the earth's most widely distributed resource and is most important because of the physiological needs of man, animal and vegetation kingdoms. This valuable resource not only supports life on the earth but also governs the economic, industrial and agricultural growth of human civilization. More than 45% of the total irrigation in our country depends on ground water resource. Nearly 80% of the extracted ground water is being utilized for irrigational purposes in the state of Uttar Pradesh.

Since the monsoon is unpredictable and the deficit causes sometimes drought conditions, it has become imperative for the planners to look forward

Static Water Table below ground level	16 m
Seasonal Variation	6 m
Head required above ground level for Terminal pressure	15 m—20 m
Losses in rising main bends etc.	1 m
Shallow aquifers	55'
Deep Tube wells	100—200'

for a dependable source of water supply, i.e. ground water which is an assured source for agricultural, industrial and domestic requirements.

The depth of ground water level in Varanasi city is as follows :

With the rapid rise in population and urbanization the demand for water has also increased and the capacity of surface water purification and supply are limited. The only alternative left is to utilize the ground water .Both the government and public have to depend much on ground water source. This over dependency has although not created any problem at present in ground water table but in future the consequences may be serious. Presently the depletion of the ground water table is of minor nature as informed by Central Ground water Board. But as of recently, because of exhaustive drawing of water from deep tube wells in the absence of other alternative, yield of many of the tube wells has come down drastically, and for many reboring has become necessary. It therefore implies that the availability of ground water is reducing day by day.

Data collected from twenty eight National Hydrograph Stations of C.G.W.B. and dug wells monitored in the year 1996 in May indicated that water level varies from 3.02 to 15.25 m bgl in the alluvial area of the district. It is further seen that water level is generally deeper in the areas adjacent to the rivers Ganga and Karmanasa, whereas it is shallower in the areas of heavy canal irrigation.

The depth of water in the plateau area varies between 9.38 and 14.05 m bgl. The data for the period Nov. 1996 indicates that water level in the alluvial area varies between 1.38 and 11.72 m bgl and in the plateau area it varies from 3.78 to 8.64 m bgl.

The deepest water level of 15.25 m bgl has been observed in the western part of the district in the Sevapuri Block, whereas the shallowest is noted in the central part, *i.e.*, 3.03 m bgl in Niamatabad Block at Mughal Sarai, in pre monsoon period, whereas it varies between 11.72 and 1.38 m bgl respectively, in post monsoon period.

The Post monsoon (Nov. 1996) depth to water level map, on perusal gives an identical picture as seen in the pre monsoon, i.e. the deep water levels being confined to areas close to river banks. The water level varies from 2.77 to 10.22 m bgl close to bank of Ganga whereas in pre monsoon it varies between 4.21 and 9.73 m bgl.

On a regional scale, a single aquifer system is seen extending down to 149 m bgl. The thickness of the productive aquifer varies from 40 to 90 m. The aquifer is semiconfined to unconfined in nature. The sediments are fine to coarse sand. The productive aquifer extends down to 282 m bgl touching the bed rock shale at 293 m bgl. The total thickness of the productive aquifer lies between 27 and 282 m. The piezometric head varies from 9 to 19 m bgl and the discharge of the tube wells varies from 2270 to 3950 litres/minute.

Overall Status of Water Supply

The total length of distribution pipeline is 568 Kms. Presently water is being supplied @ 171 litres per capita per day only against the demand of 200 lpcd. As per the requirement of 200 lpcd, 280 MLD of potable water is to be supplied. However, as per the Varanasi Jal Sansthan, if power is made available continuously, 270 MLD of water is being supplied. Thus a shortfall of 10 MLD still exists. The water supply authorities informed that 100% population is served with water supply during an average supply of 8 hours per day. Normal surface water supply is made available between 5 am and 9 am and 5 pm and 9 pm. However, ground water is supplied for 12 hours a day. There are four zonal service reservoirs and three reservoirs situated at Bhelupur Water Treatment Works. In addition to these seven service reservoirs, there are 17 Over Head Tanks (OHTs) which store the water before supply.

Ground Water Flow

The water level data of permanent hydrograph stations of C.G.W.B. of Varanasi district of May, 1996 indicates that the water table elevation varies from 270 m in the extreme south to 70 m amsl in the north. The master slope of the water table is from South to North, and is towards the river Ganga indicating that the river Ganga is effluent in nature. In the central and eastern parts of the

district water table contours are widely spaced showing that the aquifer is good in permeability. The western part of the district shows a ground water mound and at places the close spacing of the water table contours reflects moderately poor permeability of the aquifer. In the plateau area in the south of the Ganga, the water table contours are very closely spaced showing poor permeability of the aquifer.

The post monsoon (Nov. 1996) water table elevation map shows an identical picture with that of the pre monsoon water table elevation map. The moderately poor permeability of aquifer is confined in the western part of the district as the water table elevation contours are further closely spaced. In the southern part of the district also, the very close spacing of water table elevation contours confirms the poor permeability of the aquifer.

On the basis of water table elevation map data, the following interferences have been drawn :

1. Ground water flows from south to north following the general drainage pattern.
2. The sediments are more permeable in the central part of the district.
3. River Ganga is effluent in major part of the district.

Seasonal Fluctuation

Fluctuation of water table depends on the following factors :

1. Replenish able recharge from rainfall.
2. Seepage from surface water bodies.
3. Inputs to ground water body by applied irrigation.
4. Losses due to evapotranspiration.
5. Discharge from ground water extraction structures.
6. Ground water movement.

Annual seasonal fluctuation of water level has been determined from the pre monsoon and post monsoon water level data. It is observed that the maximum rise of water level is present in the southern part of the district covering almost 90% of Naugarh block. Rise in water level, due to the south west monsoon, is seen only in the areas, in the flood plain of Ganga, Gomti and Karamnasa in the western, southern and south-eastern parts of the district. In the eastern part of the district, a small area in Dhanapur block, a decline, i.e. more than 3 m bgl in water level has been observed. The decline in water level is also seen in Chahnian block, i.e. less than one m bgl and in Arazi Lines block in the extreme south, the decline is observed, which is very less, *i.e.* 0.08 m bgl. in the areas, in the flood plain of Ganga, Gomti and Karamnasa in the western, southern and south-eastern parts of the district. In the eastern part of the district, a small area in Dhanapur block, a decline, *i.e.* more than 3 m bgl in water level has been observed. The decline in water level is also seen in Chahnian block, *i.e.* less than one m bgl and in Arazi Lines block in the extreme south, the decline is observed, which is very less, *i.e.* 0.08 m bgl The declining trend is due to over exploitation of ground water resources whereas the rising trend is seen due to non development/under development of ground water for irrigation and the presence of vast uncultivated area in the older flood plain .

Table: 2– Is Showing the nature of water extraction source in the city.

S. No.	Nature of Water Extraction Source	Quantity in Nos.	Amount of Water Extraction in MLD
01.	Deep Tube wells	111	115
02.	Hand Pumps	1954	9
03.	Ganga River	-	125

Ground Water Resource Potential

Estimation of ground water recharge precipitation being the principal source of groundwater recharge in the district, the quantum relates directly to the intensity of rainfall, nature of soils and its textural characteristics, local vegetation cover and land use

Ground Water Recharge

The replenishable recharge is estimated based on pre monsoon (May/June) to post monsoon (October/November) water level fluctuation. The major part of ground water resource estimation is based on ground water fluctuation data generated by observations carried out on strengthened network of hydrograph stations regularly.

The annual replenishable ground water recharge includes the above recharge components except the potential recharge. The total ground water recharge for water table (unconfined) aquifer is taken as annual replenishable ground water recharge plus potential recharge in shallow water table zone, which would be available for utilization for irrigation, domestic, industrial and other uses. As per the recommendations, 15% of total ground water resource is to be kept for domestic, industrial and other purposes. The remaining 85% is for irrigation use.

The objective of the study is to assess the ground water quality in metropolitan city of Varanasi. This includes the study before and after the monsoon season. As the ground water quality in a region depends on a number of factors such as physiography and soil type, surface and subsurface hydrology, potential of ground water, depth of shallow and deep aquifers, direction of ground water flow etc., data on these aspects has also been collected as described above.

Also the quality of ground water depends on point sources like industrial areas, residential areas, petrol pumps and bulk storage of petroleum products, municipal solid waste disposal (landfill) areas, hence the selection of water sampling sites has been done considering the above areas also in mind .

Methodology of study

The information related to physiography, surface and subsurface hydrology, potential of ground water, depth of shallow and deep aquifers, direction of ground water flow has been collected. The identification of industrial areas, residential areas, petrol pumps and bulk storage of petroleum products, municipal solid waste disposal (Landfill) area and back ground area were done for the selection of identified wells (hand pumps, tube wells etc.). The samples were collected for ground water in Pre monsoon (February) and Post monsoon (September) and identified about 25 numbers of locations to cover proportionately in shallow and deep aquifer regions of whole of the city.

The following parameters were analysed as per the Standard Methods for the Examination of Water and Wastewater (APHA), 1999 Edition.

Different Parameters and their Methods of Analysis in above table.

Sampling Locations at Varanasi

The first round of sampling during pre monsoon season was carried out in February and the second round of sampling during post monsoon season was carried out in September as per the scope of work. Details of the work done are as under :

1. Collection of data related to ground water quality.
2. Selection of water sampling sites.
3. Based on the water demand, Varanasi city is divided into eleven zones or wards by Varanasi Jal Sansthan for distribution of water. These are namely Bhelupur, Sigra, Chowk, Benia, Cotton Mill, London Mission, Lahartara, Rajghat, Maldahia, Jaitpura and Lanka. The total storage capacity of all the reservoirs is 79.8 million litres. The storage capacity of zonal reservoirs is 12.0 million litres, of reservoirs situated at Bhelupur is 50.0 million litres and of overhead tanks it is 17.8 million litres.

Banaras Hindu University (BHU) and Diesel Locomotive Works (DLW) have their own water supply network.

The details of water connections in Varanasi city are as given below :

Total Number of Connections	-	109428
Domestic (Metered)	-	79182
Domestic (Non-metered)	-	27100
Non Domestic	-	3146
Others		
Public Taps	-	1402
Hand Pumps	-	1954

4. Collected 25 nos. of ground water samples from the hand pumps and tube wells covering whole of the city, the locations of which are given in the map of Varanasi city in Figure – 3.1. The details of all the hand pumps and tube wells have also been collected which are given in above table.

5. The industrial areas, residential areas, municipal solid waste disposal (land fill) area have also been identified and samples collected accordingly.

6. There is no bulk storage depot of Petroleum products in Varanasi city.

Varanasi basically is a religious place which has historical and tourist importance. The city also enjoys the status of an important place in India in the production of various handicraft items like silk sarees, carpets, jari jamdani, rags, customary knitting of jamavars *etc*. The covering shallow and deep aquifer regions. Banarasi sarees are famous for their uniqueness not only in India but abroad also. The real industrial development started taking place in the city after the year 1950. The city is congested and few industries are present in the city also. The new conforming industrial areas have been developed away from the city.

Various sites are being used in the city for dumping of municipal solid waste. These sites include (1) Purana Pull (2) Palang Sahid (3) Kabir Math (4) Raj Ghat etc. The rest comes under residential area out of which many places are very congested. The intensity of sampling locations is more in residential areas because of the intensity of ground water pumping and close variations in ground water withdrawal from place to place. The quality of ground water is also widely variable in different areas which are in turn varying in quality of recharging source water.

Result and Discussion

The ground water samples collected during pre monsoon and post monsoon seasons from Varanasi city were analyzed for various parameters as per standard procedures. The analytical results of the water quality parameters of the city are compared with the standard for Drinking Water (IS:10500) as the water is being used mostly for drinking purposes.

S. No.	PARAMETERS	METHODS OF ANALYSIS
1.	pH	pH meter
2.	Conductivity	Conductivity meter
3.	Total Dissolved Solids	Gravimetric method
4.	Chloride	Argentometric titration
5.	COD	Dichromate - Reflux
6.	BOD	Volumetric
7.	Sulphate	Turbidimetry
8.	Nitrate & Phosphate	Spectrophotometry
9.	Hardness	Complexometric titration (EDTA)
10.	Alkalinity	Volumetric
11.	Fluoride	SPANDS, Spectrophotometer
12.	Metals	Atomic Absorption Spectrophotometry
13.	Coliforms	Multiple Tube Fermentation Technique
14.	Pesticides	Gas Chromatograph

Table – 3: The samples have been collected covering shallow and deep aquifer regions

Discussion on Water Quality Monitoring during Pre Monsoon

Industrial Area

The pH at all the locations is almost neutral ranging between 7.5-7.7 which is well within the standard limit indicating thereby that the water in this area is suitable for drinking. The Total Dissolved Solids (TDS) are ranging between 396 to 1682 mg/L and the Conductivity ranges between 116 to 1700 µmhos/cm, which shows the correlation between the two that the conductivity has been increasing on increase of TDS. The BOD ranges from 0.2 to 0.9 mg/L in the industrial area and COD ranges from 2.0 to 3.0 mg/L, which are negligible. Though there is no standard value prescribed for BOD and COD, the values indicate that the water is not contaminated. The values of Fluoride are ranging between 0.59 to 0.97 mg/L which are within the desirable limit and Hardness between 316 to 840 mg/L which are within the permissible limits at all the locations, except at Ram Nagar where Hardness is much higher. The Phosphate is ranging between 0.30 to 1.43 mg/L, which is acceptable. The cations and anions are

Sampling Location	Depth (Feet)	Area Description
		Industrial Area
Hand Pump, Ram Nagar	80 - 100	This hand pump is in the Sabzi Mandi area on Kila Road. It is in trans Yamuna area. Ramnagar is an industrial estate of Varanasi city which has come up from 1975 onwards. The area is situated near the bank of river Ganga. The area is densely populated by low income group, middle income and high income group people. The agricultural area is also developed. The source of water for domestic and industrial needs is provided by hand pump and tube well. The quality of water is reported to be satisfactory.
Tube well, Munduadih	70 - 80	This tube well is near the Police Station in Munduadih. This is an industrial area having lot of commercial activities. The tube well is operative since 1997 and the water quality is reported to be satisfactory.
Hand Pump, Chandpur	70 - 80	This hand pump is on the Chandpur Chauraha near the state highway. The hand pump is operative since 2001. A lot of industries have come up in the area which may be contribute to pollute the ground water.
		Residential Area
Tube well, BHU (Lanka)	200- 220	This tube well is near Bhogabir Tanki in BHU (Lanka) area. It is a new tube well operative since 2003. The area is famous for its educational importance and a new Vishwanath temple. No known water quality problem exists..
Hand Pump, Sonarpura	80 - 100	This hand pump is near Radhika Silk Emporium, near Kedar Ghat/Kedar Temple chauraha. This hand pump is operative since 2001. The residents of the area mostly belong to low and middle income group .
Tube well, Gadauliya	350 - 400	This tube well is near Dashashumedh Police Station. The area is very congested and densely populated by people of LIG and MIG. The source of water contamination could be seepage of water from river Ganga.
Tube well, Benia No. 3	40 - 50	This tube well is near Raj Narain Smarak Park and is also located near the river Ganga. The depth of the water level is quite shallow in this area. The source of the water pollution could be due to seepage of contaminants from river Ganga. The area is dominated by low income group people.
Hand Pump, Ram Katora	40 - 50	This hand pump is in the Market area near Banaras Auto Scooters near Gautam Hotel. The area is mostly dominated by low and middle income group people. The water quality in this area is more or less satisfactory.
Tube well, Nati Imli No. 1	80 - 100	This tube well is near Bharat Milap Spot. It is operative since the year 1993. It is a congested area inhabited by LIG and MIG people. The water quality is more or less satisfactory.
Tube well, Bari Bazar	80 - 100	This tube well is near Chaukaghat Pani Ki Tanki and is quite old. The area is mostly dominated by low, middle and high income group of people. The hygienic condition is comparatively better than other area. No known water quality problem has been reported.
Hand Pump, Peeli Kothi	40 - 50	This hand pump is in front of Jamia Hospital and is near HP Petrol Pump of S.P. Varma & Co. The area is having lot of commercial activities. The water quality does not seem to be affected by adjacent Petrol Pump.
Tube well, Bhelupur	80 - 100	This tube well is near Varanasi Jal Sansthan Parisar. This area is located in the heart of the city. This is the important center of commercial activities. There may not be any source of water pollution in this region.
Tube well, Nadesar	130 - 150	This tube well is near Charan Nagar, Dhobi Ghat and Mint House. This is a residential area and is also dominated by commercial activities.
Tube well, Bhojubir	80 - 100	This tube well is near U.P. College. The area is mostly dominated by students. Commercial activity is also high in the region. There is no reported water quality problem in the area.
Tube well, Shivpur	80 - 100	This tube well is near Normal School, Kadipur and Mehta Nagar. The BHEL complex is also situated in this area. This area is also slightly away from the main city. The area is mostly dominated by low and middle income group people. The water quality in this area is more or less satisfactory.
Tube well, Basai	600 - 700	This tube well is near Gyanodaya Balika Vidyalaya Board in Nawalpur and is quite old. This is a deep tube well and the depth of water level is very high. The quality of water is satisfactory.
Hand Pump, Paharia	100 - 120	This hand pump is located near Paharia Chauraha. The area is congested and dominated by mixed population comprising of LIG and MIG. No known water quality problem exists.

Sampling Location	Depth (Feet)	Area Description
Industrial Area		
Tube well, Sarnath	130 - 150	This tube well is near Shiv Mandir in Sarnath. This is a religious place for Buddhists and Hindus. A number of people make silk sarees in this locality. Sarnath is about 10 Kms away from Varanasi city.
Hand Pump, Kotwa	150 - 180	This hand pump is near the Chauraha in Kotwa village which is about 12 Kms from Varanasi city. Only low income group people live here and cultivation is mostly practiced in the area.
Hand Pump, Kamaoli	160 - 180	This hand pump is near a Tea Stall in Kamaoli village. This village is also far from the city. No known water problem has been reported.
Tube well, Khajuri	110 - 120	This tube well is near the District Jail. This area is dominated by people of LIG and MIG. It is a residential area. No known water quality problem exists.
Tube well, Sigra	500 - 600	This tube well is near the building of Nagar Nigam, Sigra. It is in a locality where many Govt. Offices are also situated. The area is very busy. The water quality is satisfactory.
Tube well, Lahartara	430 - 450	This tube well is near Prathmik Vidyalaya and Nagar Nigam. Lahartara has residential colony of railway employees and also important loco shed of railways. The water quality is reported to be satisfactory.
Tube well, Near Cantt. Railway Station	250 - 300	This tube well is located near the Cant. Railway Station and Roadways Bus Stand in Maldahiya. It is a residential area and also has commercial activities. No known problem of water quality exists.
Landfill Area		
Tube well, Rajghat	100 - 150	This tube well is near the Chungi and close to the municipal solid waste disposal site. A few residential colonies are also present in the area. This tube well is also quite old

Table – 3: Site details of water quality sampling stations of Varanasi city

Parameters	Desirable Limit	Permissible Limit
Alkalinity	200	600
Aluminium	0.03	0.2
Arsenic	0.05	NR
Boron	1.0	5
Cadmium	0.01	NR
Calcium	75	200
Chloride	250	1000
Chromium hexavalent	0.05	NR
Colour	5	25
Copper	0.05	1.5
Cyanide	0.05	NR
Fluoride	1.0	1.5
Hardness	300	600
Iron	0.3	1.0
Lead	0.05	NR
Manganese	0.1	0.3
Mercury	0.001	NR
Nitrate	45	100
Oil & Grease	0.01	0.03
pH	6.5-8.5	NR
Phenols	0.001	0.002
Selenium	0.01	NR
Sulphate	200	400
T. Coliform (MPN/100 ml)	10.0	NR
T.Dissolved Solids	500	2000
T. Residual Chlorine	0.2	--
Turbidity (NTU)	5	10
Zinc	5	15

Table – 4: IS:10500 Drinking Water Standard

within limits at all the locations but Sodium is higher in general at all the locations ranging between 23.5 to 88.2 mg/L, which could be due to the addition of bleaching powder. The value of Magnesium is also slightly higher than the desirable limit at one location which is Chandpur. The values of Alkalinity are ranging between 284 to 532 mg/L which are higher than the desirable limit but within the permissible limit and could be mainly due to the nearby industries. The values of Chloride, Nitrate and Sulphate are well within the desirable limit at all the locations. The heavy metals in this area are not very high ranging between ND to 0.31 mg/L, indicating the presence of some pattern. Rainfall and the river Ganga basin are the main source of ground water in the city. The extent of recharge directly depends upon the intensity of rainfall, topography, vegetation and land use pattern. Ground water resource evaluation conducted reveals the information related to ground water recharge, ground water depth, level of development, and category of the city on the basis of the development. The exploitable dynamic ground water resource is estimated to be 1172.46 mcm and the ground water draft is estimated to be 671.87 mcm. The balance of 500.59 mcm of ground water is available for future development both for domestic and irrigation purposes. Thus ground water draft is the quantity of ground water withdrawn from the ground water reservoir .Heavy metals which could be due to the industries in this region. The values of Iron are ranging between 0.35 to 1.21 mg/L, which are exceeding the desirable limit at all the places, whereas at Ram Nagar it is 1.21 mg/L which is exceeding the permissible limit as well. The total and fecal coliforms are also negligible ranging between < 2.0 MPN/100 mL at all the locations indicating thereby that there is no bacteriological contamination. Also no pesticides were found at all the locations indicating thereby that there are no pesticides in this area.

Residential Area

The pH at all the locations in residential area is ranging between 7.3-7.8 which is well within the standard limit indicating thereby that the water in this area is suitable for drinking. The Total Dissolved Solids (TDS) are ranging between 250 to 998 mg/L and the Conductivity ranges between 413 to 3240 μmhos/cm, which shows that both TDS and Conductivity are slightly on the higher side in the residential area at some of the locations. The BOD ranges from 0.1 to 1.0 mg/L in the residential area and COD ranges from 2.0 to 14.0 mg/L, which though being negligible is slightly higher than the industrial area, indicating thereby that this increase is due to higher organic content in the effluents from residential area. The values of Fluoride are ranging between 0.09 to 2.05 mg/L, the highest being at Tube well, Sigra which is 2.05 mg/L and exceeding the permissible limit. The Hardness is ranging between 182 to 871 mg/L which are within the specified limits at all the locations, except at Hand Pump at Ram Katora, Hand Pump at Paharia, Hand Pump at Kamaoli and Tube well near Cant.Railway Station which are exceeding the permissible limit. The value of Phosphate is ranging between 0.24 to 3.30 mg/L at all the locations, which is reasonably acceptable. The cations and anions are also within limits at all the locations but Sodium and Magnesium are slightly higher in general at some locations ranging between 27.0 to 150.8 mg/L and 20.1 to 137.5 mg/L, respectively. The higher sodium content could be due to the addition of bleaching powder. The values of Alkalinity are ranging between 282 to 514 mg/L which is higher than the desirable standard and could be due to contamination from the residential area. The values of Chloride, Nitrate and Sulphate are well within the desirable limits at all the locations. The heavy metals in this area are again not very high ranging between 0.01 to 0.36 mg/L, indicating the presence of some heavy metals. However, Iron is found to be on the higher side at four locations, the highest being 2.14 mg/L at the hand pump at Sonarpura. The total and fecal coliforms are also negligible ranging between < 2.0 MPN/100 mL at all the locations, except at one location where the MPN value has been found to be 4.0 MPN/100 mL. Though the desirable standard value is 10.0 MPN/100 mL and these values

are within the limit, but it indicates that there is some percolation of sewage water into the ground water which could increase in due course of time. Also no pesticides were found in this area.

Landfill Area

Only one sample was collected from the landfill area as one of the municipal solid waste dumping site of Varanasi city is in Raj Ghat. The pH at this location in the landfill area is 7.4 which is well within the standard limit. The Total Dissolved Solids (TDS) are 452 mg/L and the Conductivity is 1370 μmhos/cm, which shows that both TDS and Conductivity are slightly higher in the landfill area. The BOD value is 0.2 mg/L in the landfill area and COD value is 6.0 mg/L, which are quite negligible. The value of Fluoride is 0.48 mg/L which is well within the desirable limit. The Hardness is 401 mg/L which is slightly higher than the desirable limit but within the permissible limit. The value of Phosphate is 0.38 mg/L at this location, which is acceptable. The cations and anions are also within limits at this location but the value of Sodium is again slightly higher. The value of Alkalinity is 450 mg/L which is higher than the prescribed desirable standard and could be due to contamination from the landfill area. The value of Chloride, Nitrate and Sulphate are again well within the desirable limits. The heavy metals in this area are again not very high ranging between 0.01 to 0.22 mg/L, indicating the presence of some quantity of heavy metals. The value of Iron is 1.0 mg/L which is just within the permissible standard. The total and fecal coliforms are also 354 negligible ranging between < 2.0 MPN/100 mL at this location, indicating that they are within limits. Also no pesticides were found in this sample indicating thereby that there are no pesticides in this area.

Discussion on Water Quality Monitoring during Post Monsoon

Water samples were collected in the month of September after the monsoon to evaluate the changes in water quality. All the sampling stations were same as those for pre monsoon period and the results were also compared with the pre monsoon period. None of the samples indicated the presence of pesticides. The inferences derived are mentioned below :

Industrial Area

The average value of pH, of pre and post monsoon period, at all the locations is almost neutral ranging between 7.4-7.6 which is well within the standard limit for drinking water indicating thereby that the water in this area is suitable for drinking. The maximum average value 7.6 of pH was observed at Tube well at Munduadih which is also well within the standard limit. The average values of Total Dissolved Solids (TDS) are ranging between 339 to 1332.5 mg/L and the Conductivity ranges between 79.5 to 1665 μmhos/cm, which shows the correlation between the two that the conductivity has been increasing on increase of TDS. However, the values of TDS are within the desirable limit at all locations except at Hand Pump at Ram Nagar which are within the permissible limit. The average values of BOD range from 0.2 to 0.75 mg/L, the highest being 0.9 mg/L during pre monsoon period at Ram Nagar in the industrial area and COD ranges from 1.5 to 2.0 mg/L, the highest being 3.0 mg/L at Ram Nagar during pre monsoon period, which are negligible. Though there is no standard value prescribed for BOD and COD, the values indicate that the water is not contaminated. The average values of Fluoride are ranging between 0.44 to 0.95 mg/L, the maximum being 0.97 mg/L at Ram Nagar during pre monsoon period and Hardness between 252 to 787.5 mg/L, the maximum being 840 mg/L during the pre monsoon period at Ram Nagar, which is higher than the permissible limit, but the values at other locations are within the specified limits. The average values of Phosphate are ranging between 0.28 to 0.79 mg/L, which are acceptable. The average values of cations and anions are within limits at all the locations but Sodium is higher in general at all the locations ranging between 22.4 to 81.75 mg/L, which could be due to the addition of bleaching powder. The average values of Alkalinity are ranging between 264 to 405 mg/L which is higher than the desirable limit of the prescribed standard and could be mainly due to the nearby industries, although these values are within the

permissible limit. The average values of Chloride, Nitrate and Sulphate are well within the desirable limits at all the locations. The average values of heavy metals in this area are not very high ranging between 0.01 to 0.19 mg/L, indicating the presence of some heavy metals which could be due to the industries in this region. However, the average values of Iron are ranging between 0.3 to 1.0 mg/L which are just within the limit of the prescribed standard. The average values of total and fecal coliforms are also negligible ranging between < 2.0 MPN/100 mL at all the locations indicating thereby that there is no bacteriological contamination. Also no pesticides have been encountered in this area.

Residential Area

The average value of pH, of pre and post monsoon period, at all the locations in the residential area is almost neutral ranging between 7.3-7.7 which is well within the standard limit for drinking water indicating thereby that the water in this area is suitable for drinking.

The average maximum value 7.7 of pH was observed at tube well of Sigra which is also well within the standard limit. The average values of Total Dissolved Solids (TDS) are ranging between 227.5 to 869.5 mg/L and the Conductivity ranges between 378 to 3150 μmhos/cm, which shows that both TDS and Conductivity are on the higher side at some of the locations in the residential area. The values of TDS are higher than the desirable limit at Ram Katora, Peeli Kothi, Paharia, Kamaoli and Cantt. Railway Station but within the permissible limit at all the locations. The highest value of TDS 998 mg/L was recorded at hand pump, Paharia during the pre monsoon period and the highest value of Conductivity 3240 μmhos/cm was recorded at hand pump, Kamaoli, during the pre monsoon period. The average values of BOD range from 0.1 to 0.8 mg/L, the highest being 1.0 mg/L during pre monsoon period at hand pumps at Sonarpura and Paharia in the residential area and COD ranges from 1.5 to 10.0 mg/L, the highest being 14.0 mg/L at hand pump of Paharia during the pre monsoon period, which though being negligible is slightly higher than the industrial area, indicating thereby that this increase is due to higher organic and inorganic contents in the effluents from residential area. The average values of Fluoride are ranging between 0.08 to 1.28 mg/L, the maximum being 2.05 mg/L at Sigra during pre monsoon period and Hardness between 153 to 717 mg/L, the maximum being 871 mg/L during the pre monsoon period at Paharia, which are not within the specified permissible limits at two locations. The average values of Phosphate are ranging between 0.20 to 2.19 mg/L at all the locations, which is acceptable, though no limit has been specified for phosphate in the IS for drinking water. The average values of cations and anions are within limits at all the locations but Sodium is higher in general at some of the locations ranging between 25.8 to 144.15 mg/L, which could be due to the addition of bleaching powder. Also the average values of Magnesium are higher than the desirable limit at most of the places but within the permissible limit at all the places. The average values of Calcium and Potassium are well within the desirable limits at all the places. The average values of Alkalinity are ranging between 216.5 to 479 mg/L, the highest being 514 mg/L during the pre monsoon period at hand pump, Paharia. All the average values of Alkalinity are higher than the desirable limit of the prescribed standard which could be due to contamination from the residential area, although these values are within the permissible limit at all the places. The average values of Chloride, Nitrate and Sulphate are well within the desirable limit at all the places in the residential area. The average values of heavy metals in this area are again not very high ranging between 0.01 to 0.20 mg/L, indicating the presence of some heavy metals. However, all the values of heavy metals are below the desirable and permissible limits of the standard. But the average values of Iron are exceeding the permissible limit at three places, the highest being 2.14 mg/L at hand pump, Sonarpura during the pre monsoon period. The total and fecal coliforms are also negligible ranging between < 2.0 MPN/100 mL at all the locations, except at one location which is hand pump, Sonarpura

where the average MPN value for total coliform has been found to be 3.0 MPN/100 mL and the highest being 4.0 MPN/100 mL at Sonarpura during the pre monsoon period. Though the desirable standard value is 10.0 MPN/100 mL and these values are within the limit, but it indicates that there is some percolation of sewage water into the ground water which could increase in due course of time. None of the samples showed the presence of Pesticides.

Landfill Area

The average value of pH, of pre and post monsoon period, at this location in the landfill area is also almost neutral of the value of 7.3 which is well within the standard limit for drinking water indicating thereby that the water in this area is suitable for drinking. The average value of Total Dissolved Solids (TDS) is 413.5 mg/L and the Conductivity is 1345 μmhos/cm, which shows that both TDS and Conductivity are slightly higher in the landfill area, but the values of TDS are within the desirable limit of the standard. The average value of BOD is 0.15 mg/L at this location, the value being 0.2 mg/L during pre monsoon period in the landfill area and the average value of COD is 4.5 mg/L, which is also quite negligible. The average value of Fluoride is 0.24 mg/L, the maximum being 0.48 mg/L during the pre monsoon period and Hardness is 337.5 mg/L, the maximum being 401 mg/L during the pre monsoon period, which are within the permissible limit at this location. The average value of Phosphate is 0.30 mg/L, the highest being 0.38 mg/L during the pre monsoon period, which is acceptable, though no limit has been specified for phosphate in the IS for drinking water.The average values of cations and anions are within limits at this location but again Sodium is slightly higher in general. The average value of Alkalinity is 381 mg/L, the highest being 450 mg/L during the pre monsoon period. Both the values of Alkalinity are higher than the desirable limit of the prescribed standard which could be due to contamination from the landfill area, although these values are within the permissible limit. The average values of Chloride, Nitrate and Sulphate are well within the desirable limits of the prescribed standard. The average values of heavy metals in this area are again not very high ranging between 0.01 to 0.12 mg/L, indicating the presence of some quantity of heavy metals. However, all the values of heavy metals are below the desirable and permissible limits of the standard except Iron, the average value of which is 0.7 mg/L, the highest being 1.0 mg/L during the pre monsoon period. This is exceeding the desirable limit but is within the permissible limit. The total and fecal coliforms are also negligible ranging between < 2.0 MPN/100 mL at this location indicating that they are within limits. No pesticides have been found in this area

Findings & Recommondations

Based on the observation and assessment made during pre and post monsoon monitoring of Ground Water Quality of Metro City of Varanasi, the following recommendations are made

1. Variation in water quality was observed during both the periods of the study.
2. Ground water quality varies from place to place with the depth of water table.
3. Water source should be thoroughly investigated before recommending it for use, whether it is private or government boring.
4. Periodical investigation should be conducted every two to three years on quarterly basis to evaluate the level of ground water contamination in the study area.
5. Alternative drinking water source may be provided along the river bank because people residing nearby are using hand pump water for drinking and other domestic purposes.
6. Public awareness should be created among the masses particularly for the people residing along the bank of the river Ganga for consumption of safe drinking water.
7. It is suggested that some low cost and easy to implement technique may be provided to the consumers for removing hardness, total dissolved solids and chloride in water where the values exceed the permissible limit.
8. The Alkalinity and Hardness are exceeding the desirable limits at most of the places in Varanasi. It is a natural cause for ground wa-

ter in tropical alluvial basin. So Varanasi being a city in Ganga basin, these high alkalinity and hardness values are common.

9. With respect to the other physico-chemical properties of the samples collected, it is either conforming to desirable or permissible limits.
10. The Iron content was found to be exceeding the permissible limit at some of the locations. One of the reasons could be due to the characteristic of the stratum of the area.
11. The concentration of Boron, Chromium and Arsenic were observed as not detectable.
12. The samples in respect of concentration of Copper, Lead, Manganese and Zinc were conforming to the desirable limits.
13. The Aluminium was found to be within either the permissible limit or desirable limit.
14. Bacteriological contamination was observed at one location in the residential area,but it was within the limit of the prescribed standard.
15. A thorough examination of water supply pipelines should be conducted by Jal Sansthan to check the infiltration of sewage or other kinds of pollutants into pipeline.
16. The doses of chlorine should be adjusted in such a way, so as to maintain a minimum concentration of residual chlorine, in the range of 0.2 mg/L at the consumer's end.
17. Presently trans Varuna area is facing acute shortage of potable water. Efforts should be made to increase the water supply.
18. The steady decline in water level in major part of the district has caused an adverse effect on ecological balance as minor drainage ways that used to have water are now almost dry. This obviously is the result of massive ground water exploitation for irrigation uses. It is imperative to control the declining trend by developing surface water irrigation system. Conjunctive use of surface and ground water should also be adopted. The deeper ground water aquifer system should also be developed.
19. The exploration of deeper aquifers should be undertaken between 190 and 700 m bgl in a systematic manner so that as suggested in above point, the development is facilitated.
20. The abandoned existing dug wells should be closed up to the land surface to avoid dumping refuge and in turn causing pollution to the ground water.
21. Regular monitoring of water level should be practiced.
22. The water management practices should be utilized, such as sprinkler irrigation should be encouraged.
23. The Central Ground Water Authority should check over exploitation of ground water wherever necessary, with help of State agencies.
24. The quality of ground water from a few shallow hand pumps or tube wells has been impaired in some of the areas. However, the deep bore hand pumps or tube wells have not yet been affected.
25. The pollution of ground water in the affected areas with respect to various bacteriological, health related and aesthetic parameters and over dependency on ground water should be viewed seriously.
26. Efforts should also be made for water harvesting wherever necessary

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