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Assessment of Ground Water Quality of Central and Southeast Districts of NCT of Delhi

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ABSTRACT

The river Yamuna has become a waste water reservoir due to the disposal of municipal and industrial waste into the river. Most of the water treatment plants are either not working at all or they are overloaded for their respective capacities. Yamuna is the main source for the replenishment of ground water in the study area. Hence the assessment of ground water quality seems to be essential. The present study is confined to evaluate the groundwater quality of central and southeast districts of NCT of Delhi. In this study, arithmetic weighted water quality index (WQI) method is applied for analysing the quality of groundwater. Spatial interpolation model was applied to depict the groundwater quality potentiality map of the area. The results so obtained reveal that the groundwater of the study area is completely unpotable for drinking as well as for other domestic usage without proper treatment because maximum part of the study area exhibits a very high WQI value.

INTRODUCTION

Delhi is one of the fastest growing cities of India (India Census, 2011; Desa, 2014).). It is facing increasing environmental issues due to various reasons such as rapid population growth and continuously enhanced commercial and industrial activities as well as other anthropogenic activities (Cohen, 2006). This makes water resources more prone to deterioration both in terms of quality as well as quantity (Ravichandran and Pundarikanthan, 1991; Sarkar and Shekhar, 2016; Amerasinghe, et al., 2013). The groundwater resources are at higher risk as ground water recharge is very difficult (Gupta and Sarma, 2016; Sarkar et al., 2016; Kumar et al., 2018). In central and southeast districts of Delhi drinking water is mainly supplied through pipes by Delhi Jal Board (DJB).

DJB is the government organization which is sole in charge of taking care of water demand and supply in the city (Sheikh et al., 2015; Heller et al., 2015). The rapid urban development, mostly because of impromptu and uncontrolled growth of unauthorised colonies, more influx of in-migrants and old water supply infrastructure due to all such factors DJB has gone under serious pressure. Despite the fact that the per capita accessibility of water in Delhi is as yet the most noteworthy in the country, the insufficiency of water supply in the most part is because of irregular supply of water, spill and thrashing of water through leakage of water channels (http://www.delhijalboard.in); CGWB, 2009; Rohilla and Tyagi, 2001; Dutta and Tiwari, 2005; Heller et al., 2015).

Water is a fundamental human need adequate for the health and wellbeing of individuals. The availability and provision of a specific amount of consumable water is a basic need for all humans who are residing in different localities of planned and unplanned settlements (McConnan, 1998; Dubreuil et al., 2006; Solon, 2010). In the study area in order to fill this gap in the demand and supply of water, people look towards the alternative sources for meeting out their water demand like digging their own tubewells and borewells within their premises (Bidhuri et al., 2017). The study area has facing difficulties in managing its water resources and due to persisting shortfalls in production of potable water supply to the households which makes them dependent on groundwater for drinking purpose (Shekhar and Prasad, 2009). Such water degraded situation necessitates the present study to evaluate groundwater quality for working out proper water management plans in central and southeast districts.

Generally, the quality assessment of groundwater is done by testing various physio-chemical and biological water parameters in laboratory. The determination of different parameters of water is essential for finding the appropriateness of water quality for various types of uses (Enderlein and Peter, 1997; Ongley, 1996; Edition, 2011. The assessment of drinking water quality using Water Quality Index (WQI) is one of the best tools which was developed in the 1970s by the Oregon Department of Environmental Quality to summarize and assessing the status of water quality (Brown et al., 1972; Yogendra and Puttaiah, 2008; Alobaidy et al., 2010; Latha and Rao, 2010; Ketata et al., 2012; Tyagi et al., 2013; Li, 2016; Krishan et al., 2016).

STUDY AREA

The central and southeast districts of NCT of Delhi are the part of the Indo-Gangetic alluvial plain which lies between 28º26'0" to 28°48'00" N latitudes and 77°7'30" to 77°24'0" E longitudes (Fig.1). "It is spread over an area of 194.99 sq. km with a maximum length of 33.21 km and the greatest width of 8.69 km. The central and southeast part of Delhi has an elevation of 198 to 220 m above mean sea level. These districts of Delhi share border with the north district of Delhi in the north, New Delhi and southwest districts of Delhi in the west. Southern side is bounded by the state of Haryana and the eastern side by the state of Uttar Pradesh (Bidhuri and Jain 2018).

DATABASE AND METHODOLOGY

The present study is based purely on primary data which are both collected from the field and generated through the laboratory testing. However spatial data used in this study are secondary data which are collected from the secondary sources like USGS website and Google earth. The area of interest (AOI) was carved out in GIS environment.

Physico-chemical and bacteriological analysis of groundwater samples taken from Central and Southeast Districts of Delhi were analysed at a private laboratory namely Quality Lab-Defining Quality Analytically. These samples were collected from twenty different locations in the pre-monsoon period in month of June, 2017 (Fig. 1). The planimetric locations of sample sites were ascertained using Global Positioning System. All samples were located in residential areas along the right bank of river Yamuna at different distances from the river bank for which buffering was carried out at a distance of 1km using ArcGIS 10.2. The water samples sites from each buffer were also randomly selected. Locational sampling sites of Burari, Mukundpur,

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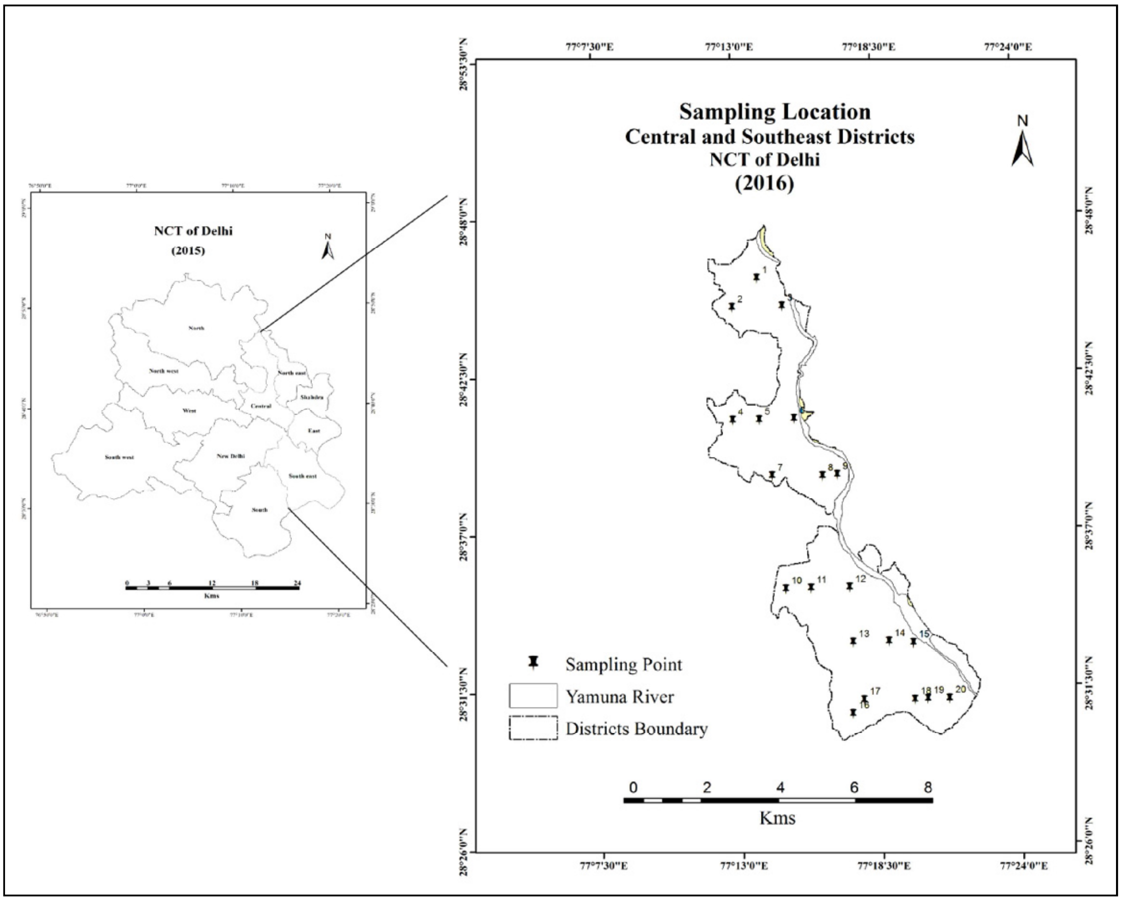

Fig.1. Location Map of the Study Area. (Source: USGS website and Google Earth).

Jharoda, Inderlok, Mukherjee Nagar, Timarpur, Model Basti and Chandni Chowk are located in Central District of Delhi while Bhogal, Lajpat, Kasturba Nagar, Govind puri, Jasola, Madanpur, Sangam Vihar, Tughlakabad, Badarpur, Jaitpur and Tajpur are from Southeast District of Delhi (Table 1).

For gathering data on the sources of water used by the households for drinking and domestic purposes a primary survey was conducted on 810 households which were randomly selected from the water sample collection sites and the head of each of the household was interviewed as per the designed questionnaire.

Water Quality Index (WQI) Calculation

Twelve drinking water quality parameters were analysed for working out WQI of the groundwater. These are pH, total dissolved solid (TDS), chemical oxygen demand (COD), biological oxygen demand (BOD), faecal coliform, total alkalinity, total hardness, chloride, sulphate, arsenic, nitrate and fluoride.

The calculation of "WQI using Weighed Arithmetic Index method" after Brown et al. (1972) (Table 2) was used which involve the following steps:

Firstly, each of the thirteen parameters was ranked and assigned a weight ranging from 1 to 5 depending upon its potential health effects.

Secondly standards for the drinking water as recommended by Indian Standards Bureau (ISB) were considered for the computation of relative weights (RW). These weights were calculated by using the formula given below.

$$RW = \frac{AW_i}{\Sigma_{i=1}^{n} AW_i} \quad (1)$$

Where RW is the relative weight, AWi is the assigned weight of each parameter and n is the number of parameters considered.

The so computed weight values of each parameter are given in Table 3.

Table 1 Selected Water Sample Location Central and Southeast Districts of Delhi

Water Sample Location	Location	Source of Water Sample	District	Water Sample Location	Location	Source of Water Sample	District
1	Burari	Handpump	Central	11	Lajpat	Borewell	Southeast
2	Mukundpur	Handpump	Central	12	Kasturba Nagar	Borewell	Southeast
3	Jharoda	Handpump	Central	13	Govind puri	Borewell	Southeast
4	Inderlok	Borewell	Central	14	Jasola	Handpump	Southeast
5	Mukherjee Nagar	Borewell	Central	15	Madanpur	Handpump	Southeast
6	Timarpur	Borewell	Central	16	Sangam Vihar	Borewell	Southeast
7	Model Basti	Borewell	Central	17	Tughlakabad	Borewell	Southeast
8	Chandni Chowk	Borewell	Central	18	Badarpur	Borewell	Southeast
9	Darya Ganj	Handpump	Central	19	Jaitpur	Handpump	Southeast
10	Bhogal	Borewell	Southeast	20	Tajpur	Handpump	Southeast

Table 2. WQI range and the status of Water Quality

WQI	Description
0 – 25	Excellent
26 – 50	Good
51 – 75	Bad
76 – 100	Very Bad
100 & above	Unfit For Drinking

Source: Classification of WQI after Brown 1972

As a third step, quality rating scale (Qi) was calculated by dividing the concentration of each parameter (Ci) obtained from the laboratory testing except pH in each water sample with respect of its standard permissible value recommended by the BIS result so obtained was multiplied by 100 (Table 4).

$$Q_i = \frac{C_i}{S_i} \text{ x } 100 \quad (2)$$

The quality rating scale for pH was calculated by using the following equation.

$$Q_{pH} = \frac{C_i - V_i}{S_i - V_i} \text{ x } 100 \quad (3)$$

Where Q_{pH} is the quality rating scale for pH, Ci is the value of concentration parameter obtained from the laboratory testing, Si is the recommended value of BIS of each parameter and Vi is the ideal value for pH which is 7.0

In fourth step, calculation of the Sub-indices (SI_i) for each parameter was done by using the following equation:

$$SI_i = RW \times Q_i \quad (4)$$

Where RW represents relative weight of the parameter considered and Qi expresses value of quality rating scale of the same parameter.

As a final step the sub-indices values of every parameter were used to compute the WQI using the following equation. The calculated values of SI and WQI are furnished in Table 5 and 6.

$$WQI = \Sigma_{i=1}^{n} SI_i \quad (5)$$

GIS Interpolation Model

The inverse distance weighted (IDW) interpolation is a procedure which is to a great extent an impression of "Waldo Tobler's, American first law in topography which state that everything is related to everything else, but near things are more related than distant things" (Tomislav, 2009). The IDW is a convex interpolation mapping method that represents the continuous model of spatial attribute or variation in an area (Latha and Rao, 2010).The IDW determines the value of the selected variable at some new location using values obtained from known locations (Burrough et al. 2015). It is utilized for the present examination to portray the locational dissemination of drinking water quality status. The distinctive areas of the sampling stations were imported into GIS programming through point layer. Each location point was assigned by a unique sample ID. The geodatabase was utilised to produce the spatial distribution maps of WQI of ground water (Fig. 3). The study is carried out by using topographic sheet no. 53D13/14, 53H1/2, 53H1/5 and 53H1/6 and ArcGIS 10.2. To deal with the multiple data and to enable an overall assessment of the spatial variations in groundwater quality. Inverse Distance Weighted Raster Analysis (IDWRA) technique is used. This technique allows for grouping of groundwater quality data with similar values within monitoring area for data analysis (Stachelek and Madden 2015).

Selected Water Quality Parameters

It is essential to test the physical, chemical and biological parameters of water before it is used either for drinking and other domestic activities. Selection of different water quality parameters for the testing of water relies on for what purpose water is to be utilised and to what extent we require its quality and purity. Water contains different types of pollutants in form of dissolved solids, suspended particles and microbiological impurities. Therefore certain parameters are considered including physical parameters like pH, TDS etc. and the chemical parameters like the testing of BOD, COD, alkalinity, hardness and other characters for water testing. The presence of Total Coliform is tested in order to assess the presences and likelihood of pathogens present in the water. The selected parameters of water quality and their possible effects on the human health are discussed below.

pH (potential Hydrogen) it is the measure of concentration of Hydrogen ions (acidity) and hydroxyl ions (alkalinity) concentration in water. Any change in the concentration of any one types of ions brings about a change in the concentration of the other. The solutions having pH value 7 are considered as neutral. Potable water is considered neutral with pH close to 7.0 at 25° C (Patil et al., 2012). A drop in the value of pH in water promotes reduction in nitrate assimilation. This consequently helps in maintaining the higher Adenosine Triphosphate (ATP) levels which generates energy to be used by through cellular processes (Fewtrell and Bartram, 2001).

Total Dissolve Solids (TDS) express the total amount of inorganic as well as trace of organic material present in the water in dissolved state. TDS of water may be due to natural causes like the rate of water flow and turbidity along with the chemistry of the bed rocks etc, The TDS concentration in water sample may also be due to anthropogenic reasons like municipal waste, industrial waste and chemicals used for water treatments. TDS are primarily composed of inorganic substances like minerals, salts and metals, their cations (positively charged particles) as well as anions (negatively charged particles). The commonly found cations are those of calcium, magnesium, sodium and potassium while commonly found anions are bicarbonates, carbonates, sulphate and chloride, etc. The presence of TDS in different quantities in water samples is a general indicator of water quality. Its presences below and above permissible limits in drinking water and the water used for other purposes can cause various types of health disorders to humans as well as to fauna and flora (Fewtrell and Bartram, 2001; Patil et al., 2012).

Total Alkalinity is the measure of the buffering capacity of water which resists the change in pH level. It can also be taken as capacity of bases present in water to neutralize the acids or hydrogen ions (H+). It does not in fact refer to pH but it acts as a stabilizer for pH. The buffering materials are primarily carbonates and bicarbonates. Total Alkalinity value with less than 100mg/l (million per liter) is desirable for domestic use and for drinking purposes (Patil et al., 2012). It is 200 to 600 mg/l (BIS 1991) Laboratory testing of alkalinity is important in finding out the streams ability to neutralize the inherent acquired acidity due to rainfall or waste water. With added acids to water body, its pH decreases and the buffering capacity of water is consumed. Alkaline water has both positive and negative health impact. It is good in providing support to immune system of the body and provides better hydration and skin health, weight loss and cancer resistance. On the other hand excessive alkalinity may produce alkalosis leading to nausea, vomiting, muscle twitching, hand tremors, etc (Fewtrell and Bartram, 2001).

Total Hardness water hardness qualitatively speaking has the attributes like bad taste and odour. However, the chemical properties

Table 3. Assigned weight and relative weight to the water quality parameters

S. No.	Parameters	Unit	Indian Standard		Weight (AW)	Relative weight (RW)
			Desirable Limit	Permissible Limit		
1.	pH		6.5-8.5	No relaxation	4	0.093
2.	Total Dissolved Solids	mg/l	500	2000	4	0.093
3.	Chemical Oxygen Demand	mg/l	-	-	4	0.093
4.	Biological Oxygen Demand	mg/l	-	-	4	0.093
5.	Faecal Coliform	CFU/100ml	10	-	5	0.116
6.	Total Alkalinity	mg/l	200	600	2	0.047
7.	Total Hardness ($CaCO_3$)	mg/l	300	600	1	0.023
8.	Chloride (Cl)	mg/l	250	1000	3	0.070
9.	Sulphate (SO_4^{2})	mg/l	200	400	4	0.093
10.	Arsenic	mg/l	-	-	3	0.070
11.	Nitrate (NO_3)	mg/l	45	No relaxation	5	0.116
12.	Fluoride (F)	mg/l	1.0	1.5	4	0.093

Source: Indian Standard Drinking Water Specification, 2005

Table 4. Physical, Biological and Chemical Parameters of Ground Water Samples Collected (June, 2017)

Water Sample Location	pH	TDS	Total Alkalinity	Total Hardness	COD	BOD	Faecal Coliform	Chloride	Sulphate	Arsenic	Nitrates	Fluoride
1	7.74	1864	534	719	15.7	3.8	17	424	471	0.01	2.92	2.3
2	7.21	1741	588	697	47	12	31	342	553	0	0.70	1.26
3	7.08	3103	435	1041	27.5	9.1	15	1168	540	0	0.30	0.87
4	7.81	1781	598	699	48	13	32	348	583	0	1.85	1.66
5	7.21	1741	588	697	47	12	31	342	553	0	0.75	1.26
6	6.21	801	481	523	30	08	0	374	127	0	1.93	2.9
7	7.01	761	381	393	06	03	0	224	102	0	3.3	2.1
8	6.01	711	281	323	04	01	0	174	137	0	1.3	2.5
9	7.01	811	381	429	08	09	06	674	130	0	1.9	2.1
10	7.22	1452	634	656	11.8	4.1	0	299	166	0	0.31	0.87
11	7.01	1634	261	843	7.8	2.1	05	433	455	0	38.5	0.75
12	7.05	1857	525	521	7.8	2.5	03	309	346	0	27.7	0.30
13	7.01	1604	241	813	7.4	2.1	04	403	385	0	36.5	0.55
14	6.89	1968	462	885	13	4.1	12	530	382	0.01	42	0.95
15	7.19	1681	344	583	31	7.6	17	665	132	0	1.6	0.12
16	7.05	1957	565	537	10.8	6.5	05	389	376	0	37.7	0.80
17	7.35	1657	325	311	7.4	1.5	0	209	126	0	17.7	1.60
18	7.98	1692	334	876	8.1	2.6	08	511	479	0	36.6	0.86
19	7.01	1634	261	843	7.8	2.1	05	433	455	0	38.5	0.75
20	7.89	1752	324	896	8.2	2.5	08	521	489	0	37.2	0.82
Min	**6.01**	**711**	**261**	**311**	**4**	**1**	**0**	**174**	**102**	**0**	**0.31**	**0.12**
Max	**7.98**	**3103**	**634**	**1041**	**15.7**	**13**	**32**	**1168**	**553**	**0.1**	**38**	**2.9**
Mean	**7.147**	**1610.1**	**427.15**	**664.25**	**17.715**	**5.43**	**9.95**	**438.6**	**349.35**	**0.001**	**16.463**	**1.266**

Note: All the parameters expressed in mg/l unit except pH value and Faecal Coliform (CFU/100ml)

of water hardness refer to the capacity of water which can enhance the palatability due presence of insoluble calcium and magnesium salts. These salts are the main constituents of hardness which is added from the detergents and cleanser soap used in the domestic activities. The essential hardness causing cations are divalent calcium, magnesium, iron, manganese as well as anions like bicarbonates, sulphate, chloride, nitrate and silicate. The temporary hardness can be removed basically by boiling the water while the permanent hardness cannot be removed by boiling. The maximum permissible limit of total hardness in drinking water should range between 300-600 mg/l (WHO 2008). The natural hardness may also be called as contact hardness of water which owe its existence to the nature of geological formations through which the water flows down. The natural hardness of water to some extent has a positive health impacts as it addresses the calcium and magnesium requirement of human body. Among the negative health impacts which are more serious in nature are cardiovascular diseases, hyper tension, restricted growth of children and various skin ailments (Fewtrell and Bartram, 2001).

Biological Oxygen Demand (BOD) refers to the amount of oxygen needed in dissolved state in a water sample by the present biological micro organisms in order to decompose the organic matter in aerobic environment at a certain temperature over a given period of time. So BOD is a measure of organic pollution which is mainly due to sewage. Higher the level of BOD the greater would be the level of organic matter present for the oxygen consuming bacteria. If the requirement of dissolved oxygen (DO) by oxygen consuming bacteria increase then the supply of DO from the aquatic flora creates stress on the aquatic aerobic micro organisms. Consequently the living environment for them becomes hypoxial which is a condition referring to a poor or unfit living environment for waste water treatment. BOD is extensively used in which decomposition of organic waste is facilitated by micro organisms (Patil et al., 2012).

Chemical Oxygen Demand (COD) is represents the limit of water to consume oxygen during the process of disintegration of organic or natural matter in the water. The term is generally used in conjunction with BOD (Patil et al., 2012). High organic materials present in water trigger deoxygenating i.e. a condition leading to a potential or complete exhaustion of dissolved oxygen. Without the presences of oxygen, the whole aquatic life is endangered. The only micro-organisms which can sustain within this environment are air- breathing insects and anaerobic bacteria. If total dissolved oxygen is depleted, than organic breakdown is accomplished anaerobically. Anaerobic organisms obtain energy from oxygen bound to different molecules, for example, the compounds of sulphate. The COD test is an alternative to BOD for it is comparatively a less time consuming process (Fewtrell and Bartram, 2001).

Faecal Coliforms are anaerobic rod like gram stain negative anaerobic non sporulating bacteria present in water through faeces of animals and humans. Coliform microorganisms are probably not going to cause illness. However, microbiological testing of their presence in drinking water in totality indicates the potability of water. Their presence also indicates that sickness-causing organisms (pathogens) may likewise present in the water such as giardia, cryptosporidium, E-coli, etc. Total coliform bacteria testing are therefore conducted in order to be ensured become sure about the presence or absence of these bacteria in the consumable water. E. coli is a subgroup of the Faecal Coliform through harmless but some of their strains can cause illness. E. coli in a drinking water test is indicative of faecal contamination also involving a greater risk of other pathogenic contamination (Edition, 2011).

Chloride occurs in several forms in natural waters like the chloride of sodium, potassium, calcium etc. Its high concentration in water is considered as pollution. The excessive chloride content in water is added through organic waste of animals, sewage and industrial waste or intrusions of the saline water (APHA, 1989). Water that contains less than 150 ppm (parts per million) of chlorides is satisfactory for multipurpose uses. A chlorides content of about 250 ppm is generally desirable, however, a level up to 1000ppm is permissible and safe for human consumption. The chloride level above 1000ppm discharges and eliminates the growth of microorganisms. It also reduces taste, promotes bad odours and colour of the water also changes. It also destroys decomposable organic substances and reduces the Biomedical Oxygen Demand (BOD) of water (Fewtrell and Bartram, 2001).

Sulphate ions are one of the major polyatomic anions found in all types of natural water having high salt contents particularly in arid and semi arid regions. It occurs due to geological formation and by the oxidation of pyrite and different sulphides which are generally disseminated in different types of rocks. Local sewage and industrial effluents additionally include sulphate content in water. In areas, where environmental sulphur content is high which is a result of anthropogenic activities, the rain water has a higher level of sulphate content. In humid regions the sulphate is generally removed through run- off whereas in arid and semi-arid region it is accumulated at the surface or in ground water on account of low precipitation and inadequate drainage. Sulphate particles do not affect the taste of water, if present in low concentrations (Patil et al., 2012).

The Sulphates salts like sodium sulphate, magnesium sulphate and calcium sulphate are one of the least toxic substances and WHO recommended their permissible presence of 400mg/L in drinking water (World Health Organization, 2008). According to BIS, water with 200-400mg/l sulphate have bitter taste and the water with 400mg/L or more of sulphate being laxative in nature may cause intestinal disorders of varying nature like gastrointestinal irritation commonly known as GI (Fewtrell and Bartram, 2001).

Arsenic is a colourless odourless and tasteless metalloid extensively occurring in natural form in the earth's crust in crystalline, powdered and amorphous states. It is a pollutant recognized as a poison and is carcinogenic in nature. The inorganic forms of arsenic are more toxic than organic forms of arsenic. The organic arsenic is present in sea food. The presences of inorganic arsenic in the environment is due to natural and anthropogenic seasons like natural weathering of arsenic rich rocks, biological activity, geochemical reactions, and volcanic emissions etc (Oremland and Stolz, 2003; Mohan and Pittman, 2007). The geothermal reactions and deep down percolation of water through the arsenic rich soil profiles increase the level of arsenic in the groundwater as well as to some extent in surfacewater also. Mining, smelting, and the waste from industries are the examples of anthropogenic activities which increases arsenic contamination in water (Smedley and Kinniburgh, 2002). The drinking of arsenic loaded water produces serious health hazards of various kinds (Fewtrell and Bartram 2001). The permissible limit of arsenic in drinking water as per WHO guidelines is 10 μg/L and as per BIS standard it is zero (WHO, 2008).

Nitrate is one of the significant oxidizable forms of nitrogen which is acquired by a water body either through natural means or by careless anthropogenic interventions. Nitrate is one of the most important nutrients in an ecosystem that causes eutrophication. It provides the growth of algae on one hand and anoxia on the other which is caused by decay of algae. In anoxic conditions aquatic fauna like insects and fish dies out. Metabolic waste of aquatic community and dead organisms further add to the nitrogenous organic matter of the surface water body. In ground water, nitrates are added mainly through leaching from soils which are rich in nitrogen either through the application of nitrogenous fertilizers or through the direct flooding of soils by sewage and industrial waste. High nitrate concentration in water from a well may be due to direct flow of nitrate rich surface water into the well or due to the percolation of such water into the aquifer from overlying soli zones. If the concentration of nitrate is greater than 45 ppm, the water is unfit for drinking as well as for domestic purposes because of the possible toxic effect particularly on young infants (WHO, 2008). These health effects are cyanosis of skin particularly around eyes and mouth. Such health effects are also reported in animals which consume nitrate loaded water. Use of reverse osmosis (RO) water can address the stated health problem to a greater extent (Fewtrell and Bartram, 2001).

Fluoride: It occurs naturally in the water source. The term fluoride is derived from the word fluorite which is a translucent mineral which chemically speaking fluoride of calcium. "The maximum permissible limit of fluoride in drinking water as recommended by both WHO and BIS is 1.5 mg/l. Due to presence of strong electro negativity, fluoride is attracted to positively charged calcium rich parts in human body like teeth and bones(WHO, 2008). The fluoride rich drinking water if taken for a longer period of time causes dental fluorosis and skeletal fluorosis resulting in stiffness and deformation of body joints and forward bending of vertebral column as well as black coating on teeth. However, the lack of fluoride in drinking water may cause dental caries (Fewtrell and Bartram, 2001).

RESULTS AND DISCUSSION

The inevitable rapid growth of urban population lead to congestion and crowding, rapid unplanned urbanization creates conditions of inaccessibility to various types of basic amenities and basic facilities including those of safe drinking water. Since water is the basic necessity and if it is not available within safe limits quality as well as quantity then it will increases the levels of vulnerability to water borne diseases. Presently the study area has been in the grip of water crises due to increasing gap between demand and supply since last few decades. In

Table 5. Quality Rating Scale (Q*i*) for all the Parameters

Water Sample Location	pH	TDS	Total Alkalinity	Total Hardness	COD	BOD	Faecal Coliform	Chloride	Sulphate	Arsenic	Nitrates	Fluoride
1	148	372.8	267	239.7	0	0	170	169.6	235.5	0	6.5	230
2	42	348.2	294	232.3	0	0	310	136.8	276.5	0	1.6	126
3	16	620.6	217.5	347	0	0	150	467.2	270	0	0.7	87
4	162	356.2	299	233	0	0	320	139.2	291.5	0	4.1	166
5	42	348.2	294	232.3	0	0	310	136.8	276.5	0	1.7	126
6	158	160.2	240.5	174.3	0	0	0	149.6	63.5	0	4.3	290
7	2	152.2	190.5	131	0	0	0	89.6	51	0	7.3	210
8	198	142.2	140.5	107.7	0	0	0	69.6	68.5	0	2.9	250
9	2	162.2	190.5	143	0	0	60	269.6	65	0	4.2	210
10	44	290.4	317	218.7	0	0	0	119.6	83	0	0.7	87
11	2	326.8	130.5	281	0	0	50	173.2	227.5	0	85.6	75
12	10	371.4	262.2	173.7	0	0	30	123.6	173	0	61.6	30
13	2	320.8	120.5	271	0	0	40	161.2	192.5	0	81.1	55
14	22	393.6	231	295	0	0	120	212	191	0	93.3	95
15	38	336.2	172	194.3	0	0	170	266	66	0	3.6	12
16	10	391.4	282.5	179	0	0	50	155.6	188	0	83.8	80
17	70	331.4	162.5	103.7	0	0	0	83.6	63	0	39.3	160
18	196	338.4	167	292	0	0	80	204.4	239.5	0	81.3	86
19	2	326.8	130.5	281	0	0	50	173.2	227.5	0	85.6	75
20	178	350.4	162	298.7	0	0	80	208.4	244.5	0	82.7	82

Source: Outcome of primary data analysis

Table 6. The Sub Indices (SI_i) Calculated for Each Parameters

Water Sample Location	pH	TDS	Total Alkalinity	Total Hardness	COD	BOD	Faecal Coliform	Chloride	Sulphate	Arsenic	Nitrates	Fluoride
1	13.8	34.7	12.4	5.6	0	0	19.8	11.8	21.9	0	0.8	21.4
2	3.9	32.4	13.7	5.4	0	0	36.0	9.5	25.7	0	0.2	11.7
3	1.5	57.7	10.1	8.1	0	0	17.4	32.6	25.1	0	0.1	8.1
4	15.1	33.1	13.9	5.4	0	0	37.2	9.7	27.1	0	0.5	15.4
5	3.9	32.4	13.7	5.4	0	0	36.0	9.5	25.7	0	0.2	11.7
6	14.7	14.9	11.2	4.1	0	0	0.0	10.4	5.9	0	0.5	27.0
7	0.2	14.2	8.9	3.0	0	0	0.0	6.3	4.7	0	0.8	19.5
8	18.4	13.2	6.5	2.5	0	0	0.0	4.9	6.4	0	0.3	23.3
9	0.2	15.1	8.9	3.3	0	0	7.0	18.8	6.0	0	0.5	19.5
10	4.1	27.0	14.7	5.1	0	0	0.0	8.3	7.7	0	0.1	8.1
11	0.2	30.4	6.1	6.5	0	0	5.8	12.1	21.2	0	10.0	7.0
12	0.9	34.5	12.2	4.0	0	0	3.5	8.6	16.1	0	7.2	2.8
13	0.2	29.8	5.6	6.3	0	0	4.7	11.2	17.9	0	9.4	5.1
14	2.0	36.6	10.7	6.9	0	0	14.0	14.8	17.8	0	10.8	8.8
15	3.5	31.3	8.0	4.5	0	0	19.8	18.6	6.1	0	0.4	1.1
16	0.9	36.4	13.1	4.2	0	0	5.8	10.9	17.5	0	9.7	7.4
17	6.5	30.8	7.6	2.4	0	0	0.0	5.8	5.9	0	4.6	14.9
18	18.2	31.5	7.8	6.8	0	0	9.3	14.3	22.3	0	9.5	8.0
19	0.2	30.4	6.1	6.5	0	0	5.8	12.1	21.2	0	10.0	7.0
20	16.6	32.6	7.5	6.9	0	0	9.3	14.5	22.7	0	9.6	7.6

Source: Outcome of primary data analysis

spite of the government efforts to improve production or availability of potable water, the water supply infrastructure has yet not matched the increasing demands owing to the shortfalls in availability of the potable water. This has led to significantly reduced DJB piped water supply to the residents. It is also examined that households were not satisfied with the quality of water supplied by Delhi government. They reported that at times, the water supplied to them can have an unpleasant odour, taste and appearance which could indicate a public health concern. However, for inequitable distribution of water supply by DJB most of the residential colonies in the Central and Southeast districts of Delhi are dependent on ground water sources including borewell and handpumps in order to meet out augment their water supply for daily needs. Figure 2 represents that of the total surveyed 810 households, about 32% of the household consume groundwater for their daily basic needs in the study area. Out of these bore well water is used by 25% and handpump water by about 7% of the households. Therefore present study is designed in order to assess the quality of ground water in Central and Southeast districts of Delhi.

Analysis of the Assessment of Ground Water Quality

The assessment of groundwater quality was made by aggregating several number parameters and their dimensions into a single entity. It is observed on the basis of the WQI that ground water of the study area is not acceptable for human consumption because maximum number of samples 15 out of 20 fall in the 'Unfit or very poor category'. The unfit for drinking category of ground water was found at 40% locations and this category was followed by very poor category of water found at 35% locations in the study area. The poor category of water was found at the locations of 25% of water samples (Table 7). It

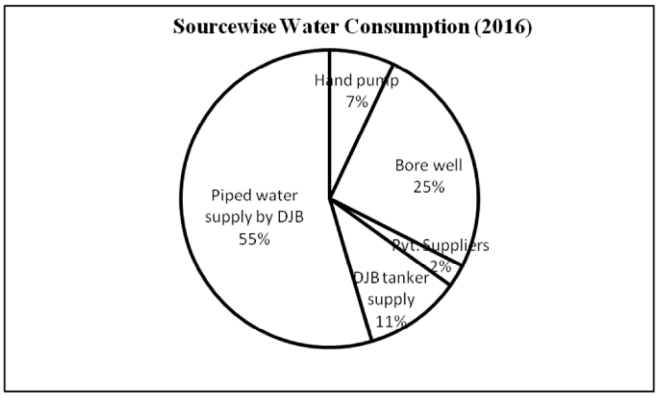

Fig.2. Source wise water consumption (source: primary survey 2017)

is important to note that not even a single location the water quality could qualify the 'Excellent' or 'Good' categories.

As illustrated in Table 4 the Physical, chemical and biological parameters and their mini-maxi value and mean demonstrate that in majority of the water samples the pH value lie within the permissible limits (6.5-8.5), except the two samples which exhibit a pH value below the lower limit. They are the samples location 6 and 8 which belongs to Timarpur and Chandni Chowk localities respectively. This shows that the groundwater of the study area in general is slightly alkaline.

The TDS values of the samples of ground water range from 711 to 3103mg/l with an average value of 1610.1mg/l. According to the BIS specification, 100% of the sample locations exceed specified desirable limits indicating the ground water unsuitability for drinking use and other domestic purposes. High TDS value in ground water may results due to ground water pollution when waste water from both residential and industrial sectors are discharged into open streets which percolated down to the water table.

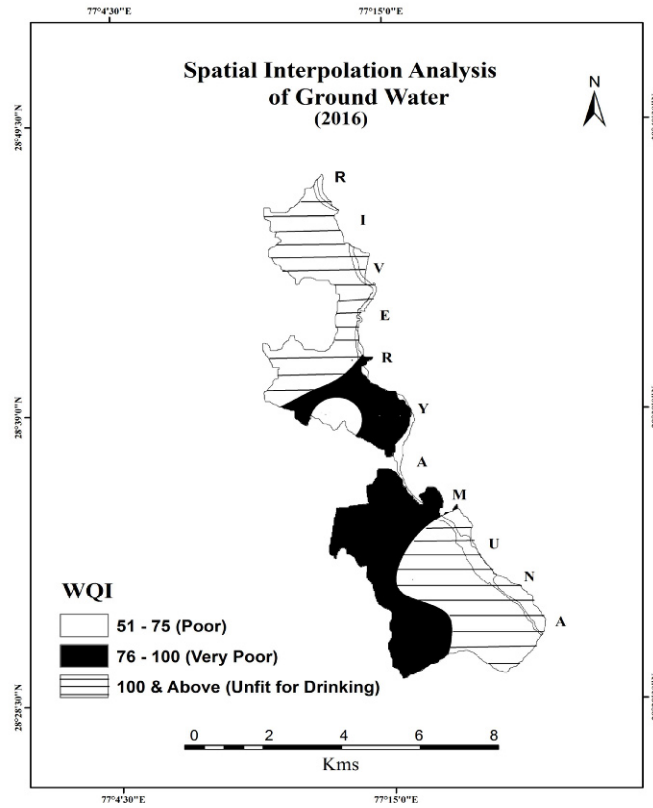

Fig.3. Spatial interpolation analysis of groundwater (source: primary survey 2017)

Table 7. WQI value of the Selected Ground Water Samples Central and Southeast Districts of Delhi

Water Sample Location	WQI	WQS
1	141	Unfit for drinking
2	138	Unfit for drinking
3	160	Unfit for drinking
4	156	Unfit for drinking
5	138	Unfit for drinking
6	88	Very poor water quality
7	57	Poor water quality
8	75	Poor water quality
9	78	Poor water quality
10	74	Poor water quality
11	98	Very poor water quality
12	89	Very poor water quality
13	89	Very poor water quality
14	121	Unfit for drinking
15	92	Very poor water quality
16	105	Very poor water quality
17	78	Poor water quality
18	127	Unfit for Drinking
19	98	Very poor water quality
20	126	Unfit for Drinking

Note: WQI= Water Quality Index; WQS= Water Quality Status.

Alkalinity is the dominant pollutant and its concentration values range from 261 to 634mg/l. The mean value of alkalinity of the ground water of Central and Southeast districts was 427.15mg/l which exceeded the desirable limit of 200 (BIS). All sample locations exhibits high alkalinity levels.

The total hardness values were above the desirable limit of 200 (BIS) and were recorded between 311 and 1041mg/l with an average value of 664.25mg/l. The ground water of the Central and Southeast Districts of Delhi is characterized with heavy loadings of sulphate concentration. Its concentration was ranging between 102 and 553mg/l with an average value of 349.35mg/l. However these values for sample locations number 6, 7, 8, 9, 10, 11, 15 and 17 were registered within the limits.

The reported average value of COD and BOD accounts for 17.71mg/l and 5.43mg/l respectively. The quality of water is also determined by the presence or absence of contamination microbial. It is identified that ground water of the present study has a high load of coliform when compared with BIS standards. According to which the maximum value of Faecal Coliform should be under 32mg/l, except five ground water samples location (S6, S7, S8, S10 and S17) were the concentration of Coliform was totally absent and all the remaining water samples registered the concentration of coliforms fairly above the permissible limits (Table 4).

The chloride concentration also exceeds the maximum desirable limit of 250mg/l at many of the water sample locations, however, at only three sample locations i.e. location number 7, 8 and 17 it was found within the desirable limits. The values of chloride varied from 174 to 1168mg/l with an average of 438.6mg/l.

Arsenic in all the ground water samples traced undetected. Nitrate values in the water samples varied from 0.31 to 38mg/l with an average value of 16.46mg/l. This reflected that in the study area, nitrate concentration is below BIS specified permissible limit (45 mg/l).

Fluoride concentrations were found from 0.12 to 2.9mg/l with an average value of 1.26mg/l and were it within the permissible limits, except for sample locations number of S1, S2, S3, S4, S5, S6, S7, S8, S9 and S17 where it was found above the 1 mg/l. High fluoride concentration make the ground water unsuitable for various purposes such as for drinking and bathing.

The representation of groundwater quality status in the study area at different locations is depicted in Fig. 3. It shows that available ground water is unfit for drinking purpose. Nearly 35 per cent of the water samples fall in very poor category water quality. The calculated WQI analysis of the study area indicates that most of the locations are having WQI values of more than 100, indicating the class which is considered unfit for drinking purposes (Table-7). None of the water sample exhibits 'Excellent' and 'Good' water quality categories. However at some locations in the Central, Western and Southwestern parts drinking water quality falls under poor to very poor category.

CONCLUSION

The analysis of the water quality parameters of groundwater from twenty different sample locations in the study area shows that in terms of the selected parameters, expect arsenic were beyond the BIS prescribed desirable limits. The computed WQI values ranges from 57 to 160 indicated that water collected from sites is not satisfying the drinking water quality standards as prescribed by the BIS as most of the water samples from different locations falls under unfit category for drinking purpose. The high concentration of pollutants is producing detrimental effects on health of the residents of the area (Bidhuri and Jain, 2018).

The results obtained from the study are eye opener for the public as well as for the administrative bodies and calls for the proper actions towards effective groundwater quality management. In this regard public awareness on the existing groundwater quality crisis and their involvement and cooperation with the local administrators would play a significant role in achieving the goal. It is suggested for the continuous ground water quality monitoring and the implementation of water quality improvement methods and techniques. It is also suggested that the households should avoid direct consumption of water from borewells and handpumps. They should treat the water properly before consumption in order to avoid any of the health disorder.

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