**Hydro-chemical Study of Groundwater in North-Eastern Haryana**

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**Abstract-** Hydro-chemical features of 30 dug-wells from Yamunanagar and Ambala districts of north-eastern Haryana were monitored following analytical methods outlined in American Public Health Association or APHA, AWWA, WEF. The goal of this paper was to analyse the status of the dug-wells aqua pre-eminence for any pollution for monograph action to ensure the pre-eminence of well-being of the mankind in the study region. The aqua pre-eminence elements appraised included TDS, pH, prime ions, nutrients, and metal ions. The investigation presented that most of the hydro-chemical parameters were within the Bureau of Indian Standards and World Health Organization prescribed ranges. pH concentrations varied from 7.07 - 8.12, while TDS ranged between 220 – 2770 mg/l, TA from 200 – 870 and TH from 120 – 900 mg/l. However, a few of the elements fall outside the ranges specified by the BIS. Twenty, 3.33, 3.33, 3.33, 20, 3.33, 3.33 and 6.67% of the dug-wells traversed the Bureau of Indian Standards prescribed concentrations for TA, F, SO4, TDS, TH, Ca and Fe, respectively. Sites where elevated values of these hydro-chemical elements occurred, endeavours should be made to remove them to discourage the use of sub-surface water which may be polluted by detrimental bacteria.

**Keywords**: Dug-wells, Groundwater quality, Hydro-chemical parameters.

**1 Introduction**

Aqua is necessary to the existence of all living things and mankind. Sub-surface aqua occurs almost everywhere beneath the ground-surface not only in a single wide-spread aquifer, but also in thousands of spatial aquifer compartments and systems that have identical features. Human’s activities such as nutrition, food production, are incumbent/rely on aqua availability in good pre-eminence and sufficient quantities. Rural communities in India, which form about 85% of the total populace, depend mostly on sub-surface aqua as the prime source of drinking [1]. Sub-surface aqua accounts for more than 89% eduction via drilled wells for tube wells or hand pumps in India [1]. However, the occurrence of hydro-chemical metals i.e. pH, EC, TDS, TA, TH, Cl, SO4, F, NO3, Cl, HCO3, Fe, Cr and As in the sub-surface aqua reserves in some regions of the India is a challenge confining the limit to which this resource can be dried up. Drilling records have presented that on the average, 9% of the extracted groundwater via dug-wells drilled for domestic use contain high levels of fluoride, iron, arsenic and electrical conductivity, above the Bureau of Indian Standards allowable ranges of 1.5 mg/l (F), 0.05 (As) and 0.3 mg/l (Fe) in N-E regions of Haryana in India namely Ambala, Barara, Naraingarh, Shehzadpur, Saha [2]. Though Yamunanagar and Ambala have achieved fostered economic development and political stability over the last decade, not all of its populace has access to good drinking water. According to World Bank [3] water should be accessible at-least 20L/person/day from a sprig within one kilometre of the dwelling. Sub-surface aqua contamination occurs extensively from a diversity of human activities. These comprise point sources i.e. as on location sanitation, waste-aqua treatment works, waste disposal facilities, cemeteries, industrial contamination etc. Non-point sources contamination comprises environmental fall-out, agrarian activities etc. Pursuance to Tredoux et al. [4] sub-surface water contamination can also significantly contribute by changes in land-usage, i.e. excavation below the water table or over-abstraction of sub-surface water and as the clearing of vegetation. According to Milovanovic [5] the sub-surface aqua contamination not only influences aqua pre-eminence, but also deteriorates people well-being, social prosperity and economic development. Groundwater is highly permeable to contamination due to transportation and absorption of agricultural, domestic, and industrial waste aqua. Therefore, it is important to access aqua pre-eminence and control aqua contamination [6]. Work done by Rout et al. [7] focused on trace ion contents in the Ambala cantonment area, Haryana, India. The outcomes presented that groundwater is alkaline in nature and the TH confined between 116.6-129.4 mg/l, which indicated that aqua in the deep aquifer is moderately hard and hard. Therefore, it is not suitable for drinking purpose as recommended by BIS. Groundwater samples had total dissolved solids (TDS) concentrations in excess of BIS specified standards. Twenty six samples of the groundwater had excess TH compared to the BIS guideline of 200 mg/l. Therefore, it has been found that no groundwater samples are soft, seventy three percent are hard, and twenty three percent are moderately hard in nature. Besides, the sub-surface water quality has been studied in various part of Haryana comprising of Hisar [8-10], Jind area [11-12], Rohtak and Faridabad [13]. Meenakshi et al. [12] observed the F concentration in rural areas of Jind district between the limits of 0.3 - 6.9 mg/l. Therefore, the primary objective of this investigation is to find out the physico-chemical parameters and fluoride (F-). The pre-dominant anion was HCO3, but no clear cut pre-dominant cation with low contents of trace elements. Earlier published work by Rout and Sharma [7] presented that most of the hydro-chemical elements in the sub-surface water of the Ambala cantonment area were within the BIS ranges for drinking aqua, causing no well-being hazard to people. However, the concentrations of TDS and pH in some regions traversed the prescribed value of BIS. Khaiwal et al. [9] also significantly observed the groundwater quality in the district of Hisar, Haryana. Elevated concentration of fluoride (F) was confined between 0.03 – 16.6 mg/l in the Hisar district. N-E Haryana (Yamunanagar and Ambala Districts) in North-West India is con-fronted with 03 agents of de-gradation: contamination, deforestation, and bad farming activities. Practices of farmers (Excess use of other chemicals and fertilizer) both large scale and subsistence commercial farmers in the study area are accounting a lot of challenges both to the aqua quantity and quality. Thus, accounting hydro-chemical pollution. The aim of this article is to monitor the groundwater pre-eminence status of considered dug-wells in the N-E Haryana to ensure the pre-eminence of well-being of the consumers in the region.

**2 Materials and Methods**

**2.1. Study region**

N-E area of the province of Haryana has been selected as the study region for assessing and appraising the groundwater. The investigation was conducted in Ambala districts and Yamunanagar of Haryana. The study area is extended between 74.28oE and 77.36oE longitudes and 27.37oN and 30.35oN latitudes (Fig. 1). has an net and gross irrigated area of 2190 km2 and 3730 km2 with an average annual rainfall of 2183 mm [2]. Its major tributaries are the Yamuna, Markanda, Tangri and Beghna. Total geographical area of the study area is 3330 km2 comprises of twelve blocks in N-E Haryana namely: Ambala I, Ambala II, Barara, Naraingarh, Shehzadpur, Saha, Bilaspur, Chhachhrauli, Jagadhri, Radour, Sadhoura and Mustafabad and falls under five tehsils administrations. The study area is the most industrialized region in N-E Haryana comprising of the 02 prime industrialized districts in N-E Haryana i.e. Yamunanagar and Ambala districts. The study area plays a significant role in the socio-economic development of people of these 02 districts and satellites villages, many blocks dotted within it [2]. Most of the public centers i.e. bus stand, railway stations and among others get treated/filtered aqua from the Public Health Department and Yamuna River. Other small settlements also depend on untreated water from the Densu River and its tributaries. The study area is also intensively used for the agriculture of both food and cash crops. Main food crops grown within the study area are wheat, sugarcane, gram, maize, and paddy. Cash crops include Sunflower, watermelon, muskmelon, mangoes, apricot etc. Cultivation of vegetables also takes place within the study area. The study area falls under, mild and dry winter, hot summer, sub-tropical monsoon and sub-humid which is probably with cold winter and hot summer except during monsoon period. The prime rainy period extends from June to September and attains a peak in July and August. The second rainfall period is a minor one that occurs between September and November. The normal annual precipitation varies from 1076 mm–1107 mm in the study region. The mean maximum temperatures and mean minimum temperature are varies from 40.8˚C-48.8˚C and 6.8˚C in the study area, respectively [2], with May/June being the hottest (48.8˚C) and December/January being the coldest months (6.8˚C). The study area is located in the Indo-Gangetic alluvial plain and foothills of the Siwalik Hills of Haryana and is predominately underlain by Indo-Gangetic alluvial plain of Tertiary and Quaternary age [14]. It is highly jointed and folded and comprises of quartz schist, quartzite’s, sandstones, some tale mica schist, shale, and phyllites. Study area generally comprises of gravels, silt, sand, and clay associated with kankar and form highly potential aquifers.

**2.2. Groundwater sampling and appraisal**

Thirty groundwater samples were collected from dug-wells in the Yamunanagar and Ambala districts of N-E Haryana, India during April 2017 (Pre-monsoon period). In order to collect representative and fresh aqua samples, the dug-wells were identified and pumped on the average five minute before the water samples were collected. Water samples were kept into acid cleaned poly-ethylene one litre bottles with preservation. The TDS (Total Dissolved Solid) and pH were determined in- situ applying TDS meter (HACH, HQ40d) and pH meter (EUTECH Instruments pH 700) analyzer, respectively. All the water samples were stored in an ice-box and were transported to the Environmental Engineering Laboratory of National Institute of Technology, Kurukshetra, India, kept in a freeze at a four degree celsius temperature until appraisal was done. All laboratory appraisals on the water-samples were applied applying suitable certified and desirable international methods given in the guidelines procedures for the analyses of aqua and Waste-aqua [15]. Potassium (K) and sodium (Na) were appraised by Flame Photometer EI-380, magnesium (Mg) by computation after EDTA

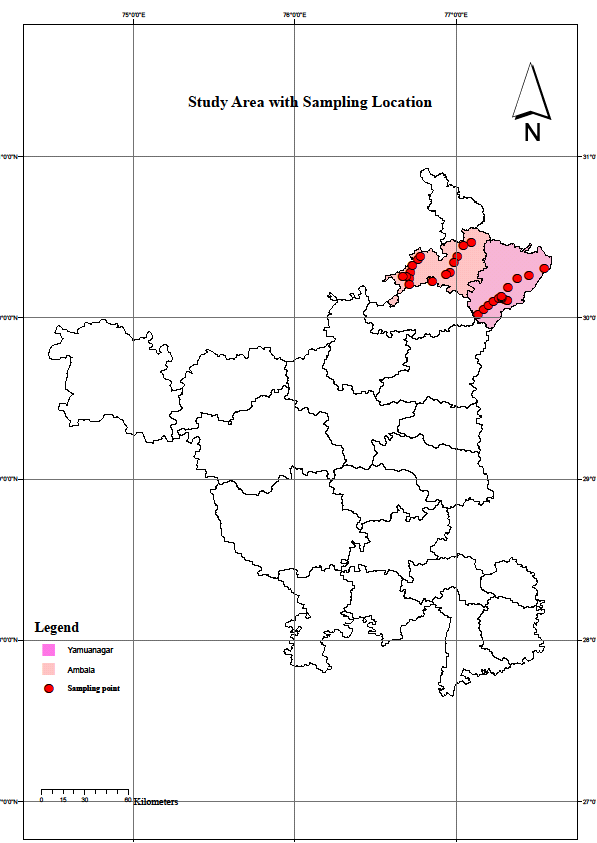


Fig. 1 Map of study area showing the sampling sites

titration method of Ca and total hardness (TH), calcium (Ca) by EDTA titration method, chloride (Cl) by argento-metric titration method. Sulphate, fluoride, iron and nitrate were measured by spectrophotometer (HACH DR- 2800 ion analyzer). Hydro-chemical parameters outcomes were checked by calculating the IBE (Ionic Balance Error). Outcomes with IBE greater than five percent were rejected in pursuance with international guidelines.

**3 Results and Discussion**

***3.1. Chemical constituents in groundwater samples***

**3.1.1. pH, TDS and TA**

The dug-wells were generally alkaline with pH varying from 7.07 to 8.12, showed in Fig. 2. No water samples were traversed the BIS standard limit of 6.5–8.5. The lowest pH was observed at Ballana Bus Stand and the highest observed at DCR Thermal Pansara. Rout and Sharma [7] found pH limit of 6.92–8.12 in the same study area. Though the well-being influences of such non-compliance are not clear, concentrations of high pH would make the water basic/alkaline and thus cause further strain on instrument/equipment [16]. According to Samantara et al. [17], the nature of the hydro-geology in an area could lead for high-pH contents. Basicity enhances the capacity of the aqua to strain equipment, instruments and leach toxic chemical ions into the aqua making it potentially dangerous for the consumption of human. Investigations on sub-surface water in the Barara block, Ambala district in the N-E region of Haryana by Rout and Attree [18] reported a pH limit of 6.6–8.5, though a few of the dug-wells presented strong acidic feature (i.e. pH limit < 7). Total dissolved solids (TDS) are an indication of the content of total ionic concentration and major metals in considered aqua-body. TDS content estimated by TDS meter varied from 220 -2770 mg/l within the study area. This is denotative for huge variability in salinity of the sub-surface aqua. The largest number of groundwater samples fall within the limit of 220–1500 mg/l (Fig. 3). Rout et al. [7] reported the TDS of 490.81 mg/l. A total of 26 water samples (i.e. 100%) not exceeded 1,000 mg/l. A well-being rooted level has not been prescribed by the BIS. However, total dissolved solids above 1,000 mg/l may be harmful to the people. The highest total dissolved solid (2770 mg/l) was found at Ambala district. Ambala lies along a contact zone between the WNW-ENE trending series of parallel ridges of Siwalik rocks, alluvium plain unit of the surface of Late Quaternary sediments deposited by fluvial processes, piedmont alluvial plain zone and the impendence of gravelly sediments below the ground in the northern part of Haryana [19]. The prime rock-types underlying the considered location are grey & brown sand, silt, silt-clay, clay with calcrete, limestone and gypsum on



Fig. 2. Variation of pH concentration observed in samples



Fig. 3 Variation of TDS observed in samples



Fig. 4 Scatter plot of calcium and magnesium as a function of TDS



Fig. 5 Variation of TA observed in samples



**(a)**

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**(b)**

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**(c)**

Fig. 6 Variation of values in samples a) Cl, b) NO3 and c) SO4



Fig. 7 Scatter plot of chloride ion value as a function of TDS

one hand and boulder conglomerate, sandstone, clay/mudstone and pebble beds, sandstone with variegated clay/ mudstone, sandstone, mudstone/shale, Fine grained sandstone, clay and limestone on the other [19]. These rocks either weather to remain massive depending upon the degree of structural deformation or form overburden material of coarse permeable sandy sediments that the rocks may have undergone. The study region may be subjected to hydrodynamic activities, thermodynamic and serious tectonic, resulting in mixed-aqua with various hydro-chemical signatures or concentrations, like all geologic contact zones. TDS was strongly correlated with the contents of Mg and Ca as pointed in the relationship (Fig. 4). 3.33% of the water samples of study area crossed the maximal permissible value of 2000 mg/l. Total alkalinity concentrations varied from 200-870 mg/l with a mean of 484 mg/l. Most of the dug-wells (19 water samples) analysed were in the 500–1500 mg/l cluster (Fig. 5). Five dug-well samples presented TA above 600 mg/l. Elevated levels of TA may be attributed due to due to the action of CO32- upon the base paraphernalia’s in the soil, some anthropogenic and geogenic activities in the study area. Rout et al. [7] observed TA in the limit of 90.83–187.70 mg/l in most dug-wells aqua throughout Ambala cantonment area.

***3.2. Nutrients in groundwater samples***

The limits of Cl, NO3, and SO4 are presented in Fig. 6. Sulphate and chloride do not have well-being rooted standards, but may account problem due to taste if observed at higher contents. The BIS standard recommends that chloride concentrations above 250 mg/l may reduce the suitability of the aqua due to taste, as well as causing to metals corrosion. Chloride concentrations in the water samples varied from 56.8-766.8 mg/l of which 6.67% of the total water samples traversed the taste-standard. Elevated levels (766.80 mg/l) of Cl occurred at Ambala (Matedi Bus Stand). Cl represented a fairly firm correlation with TDS (Fig. 7), which pointed huge mineralization. Elevated concentrations of Cl may be ascribed to inartificial hydro-geochemical activities. Cl content of dug-wells in the Ambala district of the cantonment area varied from 7.83-57.80 mg/l as recorded by Rout et al. [7]. Rout and Attree [18] reported Cl contents in the limit of 8.9–71.95 mg/l in the Ambala district. As mentioned earlier, SO4 does not have a well-being rooted standard level. However, the BIS suggests that concentrations over than 400 mg/l should be recorded to ‘‘the well-being departments’’ due to issues to the gastro-intestinal system [20]. Sources can be both industrial and inartificial. The contents of SO4 in the water samples varied from 18-460 mg/l. The highest content of 460 mg/l observed at Matedi Bus Stand, Ambala district. One of the water samples traversed the BIS prescribed standard. Rout and Sharma [7] reported SO4 concentrations between 32.33-102.57 mg/l in the Ambala district. The average value of sulphate for the Ambala district was 79.04 mg/l, respectively [7]. NO3 is a pollutant that is regulated as it has important well-being hazards associated with huge NO3 consumption in the people-diet. These cause ‘blue baby syndrome’ in infants (‘‘methaemoglobinaemia’’) [21]. NO3 contents varied from 0.4-2.7 mg/l. The BIS has specified the 10 mg/l guideline as the maximal pollutant concentration (MPC) for NO3. None of the water samples were above the standard concentration of 10 mg/l. NO3 in sub-surface water may also observe from point sources i.e. livestock facilities and sewage disposal systems, diffuse sources i.e. naturally occurring or fertilized cropland nitrogen sources. F is one of the most re-active ions that are usual in sub-surface water in N-E Haryana. Investigations showed that the higher F contents (>1.5 mg/l) in the water samples of the study area [2]. Elevated levels of F contents may be attributed due to the pre-dominated bed-rock hydro-geology (some Indo-Gangetic alluvial, Tertiary and Quaternary age rocks) [19]. F provides safety against dental-caries at lower levels, but at high concentrations leads harmful issues i.e. skeletal and dental fluorosis [16]. The F contents of the water samples varied from 0.14-1.65 mg/l. The BIS standard concentration for F is 1.5 mg/l. About 3.33% of the water samples traversed the BIS standard. An elevated level (1.65 mg/l) of F was observed in a dug-well in Mhamudpur, Narayangarh in the Ambala district. Figure 8 showed the variation of F content in the water samples. Basic statistics of the prime cations is presented in Table 1. The Ca levels varied from 36- 188 mg/l. The mean Ca content in the dug-wells was 83.07 mg/l and the standard deviation value was 35.06 mg/l. Mg concentrations were between 4.8-88.8 mg/l with mean of 31.79 mg/l and standard deviation of 15.22 mg/l. Na levels for the season of sampling varied from 8.5-521 mg/l. The mean and standard deviation values were 118.8-127 mg/l, respectively. The K concentrations were between 0-20.9 mg/l and its mean and standard deviation were 5.88 and 4.07 mg/l, respectively. The cationic dominance encountered in the Basin was Na>Ca>Mg>K. Major cations in the study area were generally high. It reported median values of 59.83 mg/l for calcium, 19.66 mg/l for magnesium, 20.37 mg/l for sodium, and 2.25 mg/l for potassium [7]. Hence, the cationic pre-dominance in the study area was Ca>Na>Mg>K.



Fig. 8 Distribution of Fluoride concentrations in the samples

Table 1 Basic statistics of major cations (all in mg/l) in dug-wells in the study area

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| Elements | Min. | Max. | Mean | Standard Deviation |
| Magnesium, Mg | 4.8 | 88.8 | 31.79 | 15.22 |
| Calcium, Ca | 36.0 | 188 | 83.07 | 35.06 |
| Potassium, K | 0.0 | 20.9 | 5.88 | 4.07 |
| Sodium, Na | 8.5 | 521 | 118.8 | 127 |

**4.3. Iron (Fe)**

Fe is existent in sufficient quantity in rocks and soils, mainly in undissolved form. However, many sophisticated chemical-reactions, which originate inartificially in sub-surface formations, can give rise to more dissolvable forms of Fe, which will, therefore, be existent in aqua running via such formations. Elevated contents of Fe do not cause well-being issues, but they are of concern for taste and aesthetic causes/accounts [20]. Nevertheless not having a well-being rooted standard for iron, a content of 0.3 mg/l is specified in the BIS drinking aqua standards as a safe content, with the remarks that taste will often be influenced over this value [16]. Sanitary and laundry ware shall stain at iron contents over 0.3 milligrams per litre. The content limit of iron ranged extensively 0.01-1.41 mg/l (Fig. 9). CGWB [2] reported the highest content of 8.47 mg/l in Rasulpur, Yamunanagar district. Some of the water samples were above BIS standard level of 0.3 mg/l. This benchmarks favourably with what has been recorded by CGWB [2] in Ambala district. Some percent of the water samples were above BIS standard level. In the Ambala district, a few of the water samples had iron levels (2.41 mg/l) crossing the BIS standard level [2].



Fig. 9 Iron (Fe) variation of samples

Other chemical ion appraised included chromium (Cr), and Carbonate (CO3). The acceptable limit of Cr in drinking aqua is 0.05 mg/l, as specified by BIS [20] and WHO [22]. Appraisals of water samples collected from the study area showed a negative detection of Cr and CO3 in all the aqua samples.

**4 Conclusions**

The investigation revealed that the sub-surface aqua in the Yamunanagar and Ambala district of N-E Haryana, India was of good pre-eminence. Notwithstanding, some of the elements traversed their Bureau of Indian Standards guideline levels, most of the hydro-chemical elements appraised were tolerable. The dug-wells were generally alkaline in nature with pH varying from 7.07- 8.12. For the TDS contents, 3.33% of the water samples traversed 2000 mg/l. Most of the dug-wells had TA in the limit of 200-870 mg/l. Five dug-well samples presented TA above 600 mg/l. Cl concentrations in the water samples were not satisfactory. Cl levels in the water samples varied from 56.8-766.8 mg/l of which 6.67% of the total water samples traversed the taste-standard. Elevated levels (766.80 mg/l) of Cl occurred at Ambala (Matedi Bus Stand). Cl represented a fairly firm correlation with TDS, which pointed huge mineralization. One of the water samples had SO4 concentrations above the BIS standard level of 400 milligrams per litre. None of the dug-well samples had NO3 concentrations outside the BIS standard level of 10 milligram per litre. F pollution was found in 3.33% of the total 30 water samples. Notwithstanding, high iron contents may not cause any well-being issues to the people, the occurrence of the yellowish brown-coloration may pose abnegation of such aqua by users. Fe was observed in all the water samples. 6.67% of the total water samples traversed the BIS standard for iron. Of interest would be for aqua pioneers and other policymakers in the aqua-sector to assess more comprehensive water sampling in regions of articulate huge inorganic pollution like F because high concentrations of F poses harmful issues i.e. skeletal and dental fluorosis. Appropriate location selection for the site of drinking aqua dug-wells and suitable dug-well construction can alleviate potential NO3 pollution of domestic aqua sprig. To alleviate highest levels of Fe, the study area assemblies could facilitate the construction of Fe expulsion plants. This shall dis-courage the application of surface aquas which may be polluted by dangerous bacterium. The N-E Haryana secretariat should target mass-awareness practices on aqua contamination to increase aqua pre-eminence in the study area.

**ACKNOWLEDGMENT**

The authors are grateful to the National Institute of Technology, Kurukshetra, India for providing funds for this investigation. The facilities provided by National Institute of Technology, Kurukshetra, India are hereby acknowledged. The Institute is acknowledged for their immense contribution during the laboratory work.

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