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A Study on physio-chemical and biological analysis of drinking water quality from the residential areas of Islamabad, Pakistan

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Abstract

The project "Monitoring of drinking water quality from residential area of Islamabad" was carried out from June 2010 till August 2010 to attempt recent monitoring of the drinking water supply system of selected areas of Islamabad, keeping in view the recent National and International quality standards available on the subject. Samples were collected from differentCapital Development Authority(CDA) tube wells installed at four different sector ofIslamabad *viz.*F7, F8, F9 and F10 areas. A standard method for sample collection was followed and, in each case, three different plastic bottles used for bacteriological, physical and chemical parameters. These samples were then analyzed following reliable analytical procedures available in American Society for Testing and Materials (ASTM) standards and as adopted by Pakistan Council of Research in Water Resource (PCRWR) and National Institute of Health (NIH) institutions. The analytical data has been compiled. Results of all the parameters have been individually depicted in different figures and have been discussed keeping in view the area monitored and the requirements of the applicable standards. Almost half of the samples were found to be contaminated with respect to the coliform and fecal coliform bacteria, making it unsuitable for drinking. However, detail studies should be conducted to know the cause of bacteriological contamination. The results regarding the physical and chemical parameters were found within the recommended national and international guidelines for drinking water. It is further recommended to undertake such further studies over a wider area in order to elucidate the relationship between the underground hydrology and parameters important with respect to the water quality.

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Introduction

Water is one of the most vital and plentiful compounds of the ecosystem. All living organisms on Earth have inevitable requirement of water for their survival and development. Due to amplified human population, industrialization, use of fertilizers in the agriculture and man-made activity, it is extremely polluted with diverse damaging contaminants. Therefore it is essential that the quality of drinking water should be confirmed at regular time interval, because due to use of filthy drinking water, human population agonizes from varied of water borne diseases. It is hard to understand the biological phenomenon fully because the chemistry of water revels much about the metabolism of the ecosystem and explain the general hydro - biological connection (Simpi *et al.,* 2011). Main sources of water such as stream water, springs, impounding reservoirs and ground water. In Islamabad stream water would normally come from korang and Shahdara, springs water from Saidpur and Nurpur, impounding reservoirs water from Simly and khanpur and ground water from tube wells sunk in national park and in many other sectors in Islamabad (Farooq, et. al. 2008).Water divining is a type of dowsing employed in attempts to locate ground water, buried under metals or ores, gemstones, oil, gravesites,and many other objects and materials, as well as so-called currents of earth radiation, without the use of scientific apparatus(Naylor, 2009).

The accessibility to good quality water is a key feature for stopping diseases and refining quality of life. Currently 1 billion of the world populations are deprived to safe drinking water (WorldBank, 2009). Water resources are of critical importance to both natural ecosystem and human development. It is essential for agriculture, industry and human existence. The healthy aquatic ecosystem is depended on the physio-chemical and biological characteristics (Venkatesharaju *et al.,* 2010). Domestic pollution of drinking water sources may involve seepage from broken septic tanks and pit latrines. Agricultural pollution emanates mainly from irrigation water and runoff water after rains, carrying fertilizers, pesticides, herbicide and faecal matter (Kumasi *et al.,* 2011). The main bacterial microorganisms of concern in contaminated water include *Salmonella sp., Shigella sp., Escherichia coli*and *Vibrio cholera*(Rajendran*et al.,* 2006).

The water supply in Islamabad is being also pumped from private tube wells as well as government tube wells and used not only for drinking but also for gardening, washing and other purposes. Capital Development Authority (CDA) is managing hundreds of such tube wells for public supply. Some of them are connected to distribution network and water is supplied directly to recipient area whereas in caose of others it is collected first in sump and then supplied to the recipient area (Nazir *et al.,* 2001). As claimed chlorination is performed at tube well pumping at the sump storage/water works, however during our visit to their site (sampling sites) we did not notice any such installed chlorination system there (Clinic, 2007). The use of contaminated water results in large number of diseases and mass- mortality, invoking the need for quality assessment of drinking water. In Islamabad both ground water and surface water are used for drinking purpose. Research Conducted on ogun river in Nigeria on July 2012. Ten samples were collected and after analysed those samples his finding was that the amount of TDSs were permissible and suggested that need to avoid from polluting the ground water (Singh *et al.,* 2012).Quality determination of five ponds of district Bhimber of Azad Jammu and Kashmir revealed that the analyzed physical parameters in WHO standards like conductivity 310-503 µs/cm (Mirza *et al.,* 2006).Due to environmental pollution by the untreated human induced waste and unchecked industrial activities, water sources are supposed to be polluted constantly (WHO, 2008).The main issues of the area are water shortage and water born diseases. Water is being supplied once a day and for short durations, which is insufficient, another significant issue is that most of the locals have installed suction pumps due to which water is not available to a few others, neighboring such a situation. According to an estimation every second house has bore water source. With such bore underground water sources people do not install a proper filtration and decontamination system due to which there existed chances of water contamination followed by diseases like diarrhoea, bone deformity disease, gastroenteritis etc. The CDA or any other government agency has no control over such a situation. (Tahir *et al.,* 1994). There are several drinking water relating studies which were conducted in the past in the area of interest i.e Islamabad by certain organizations or individuals. Thus the objectives of the study are; to analyze different water quality parameters of the studied sites, to generate data for assessing the level of contamination of the samples taken and to alert public health officials and related agencies regarding tube well contamination.

Material and methods

Study area

The current research was designed and carried out for the assessment of Physio-chemical and biological drinking water quality analysis of different tube wells of four different sectors of Islamabad Pakistan i.e F-7, F-8, F-9 and F-10 of Islamabad, Pakistan. Research focused on the quality of water. These wells ate the main sources of water for dwellers of study area. Due to shortage of water in Islamabad, Peoples used the bore water for the domestic use.

During the study samples were taken from different tube wells of sectors F-7, F-8, F-9 and F-10 of Islamabad. Samples were collected in plastic bottles and appropriate preservative was added according to the standard methods (APHA, AWWA & WEF, 2005) and WHO guidelines for chemical parameters. Field data was collected in two stages; for physiochemical analysis and bacteriological analysis. A total of 42 samples were taken from 14 different locations, from each site, 3 separate samples were collected for biological, physical and chemical parameters which is shown in fig 1. All the samples were collected during the dry season i.e, in the month of June, 2010. For physiochemical analysis: Samples were collected in 500 ml plastic bottles and were treated with 1 ml nitric acid for chemical parameters and kept as such without any addition for the physical parameters. For bacteriological analysis: 250 ml sterilized bottles were used for sample collection. Samples were analyzed within30-48 hours ofcollection. Samples were analyzed for parameters such as: pH, turbidity, TDS and residual chlorine. Coliform and Fecal Coliform tests were performed to check the microbiological quality of water. The method of analysis for physiochemical tests and biological were chosen on the basis of availability of Lab equipment. However standard methods as available were followed (APHA, AWWA & WEF, 2005).

Physical parameters

The samples collected for physical parameters were preserved in cleaned polythene bottles and were stored for maximum 2 days. In order to get the true picture of source, no preservative was added. The following method of analyses were followed.

Colour

Colour was estimated as Clear and Turbid by observation with naked eye.

Turbidity

This parameter was measured using turbidity meter (Hanna HI 93703) following the procedure of instrument manual and employing proper recommended standards American Society for Testing and Materials (ASTM, 1983).

pH

The pH values of the sample solution were measured using pH Meter (Hanna Instrument) Model -HI 8424. All readings were taken following the procedure given in the instrument manual. Prior to the recording of sample values the instrument was standardized using pH standard of 4.01 and 10.01 of National Institute of Science and Technology (NIST), USA.

Conductivity

Electrical conductivity of the samples was measured by model-152 of Hanna Conductivity Meter. Prior to undertaking measurement of sample conductivity the instrument was calibrated using proper conductivity standard. All measurements were carried out according to the procedure given in the instrument manual and undertaking all operations for the samples and the standard solutions in a similar way.

Total dissolved solids (TDS)

Total dissolved solids are the portion of total solids that passes through a filter of 2.0 micrometer nominal pore size. The TDS are generally measured using one of the procedures given below (ASTM, 1983).

This involved the measurement of the TDS using a TDS meter earlier standardized using a proper standard of this parameter. In the present case, we used TDS meter of HANNA Model 98301 which was standardized using proper NIST standard before undertaking TDS measurements of our samples.

Alkalinity

For measurement of total alkalinity the original solution without addition of any other chemical was used. The procedure followed for the carbonate and bicarbonate was the same except that the titrations were carried out to the final end point with phenolphthalein and methyl orange as indicators respectively. A semi-automatic digital burette model no. 655 (Dosimat) was employed for such titration. The titrant used was 0.02M HCl solution. In all the samples the presence of carbonate was below the detection limits and therefore the titrations carried out to the methyl orange endpoint provided an estimate of the bicarbonate and total alkalinity content. The procedure used was tested using a standard sample with known values of bicarbonate/alkalinity (ASTM, 1983).

Hardness (as $CaCo_3$)

Total Hardness was measured using Direct Reading Titrator (LaMotte, Model PHT-DR, Code 4482 DR). The detailed procedure is given below.

Procedure:The titration tube (0769) was filled up-to the 12.9 mL line with water sample to be tested, Addition of 5 drops of Hardness Reagent # 5 (4483) and mixing, Addition of one Hardness Buffer Indicator Tablet (3719), cap the tube and gently shook to disintegrate the tablet. A red color will appear, Filling of the Direct Reading Titrator(0382) with Hardness Reagent 7 (4487) in the manner described in the instruction manual. Insertion of the titrator in the center hole of the titration tube cap, While gently shaking the tube, slowly pressing the plunger to titrate the sample until the red color changes to blue. Readings were taken where the plunger tip meets the titrator scale. The result is expressed as Total Hardness in ppm $CaCo_3$, which is a representative of the total quantity of calcium and magnesium salts. (ASTM, 1983)

Chemical parameters

Nitrate-nitrogen

Nitrate Test Kit (LaMotte, Model NCR, Code 3110) was used to measure the nitrate content. The detailed procedure is as follows.

Procedure: Filling of sample bottle (0688) with sample water, Filling one test tube (0820) to the 2.5 mL line with water from the sample bottle, Dilution of the bottle to 5mL line with Mixed Acid Reagent (V-6278). Capped and mixed. The solution was then allowed to settle for 2 minutes, 0.1 gram of Reducing Reagent (V-6279) was added, capped and inverted gently and then allowed to settle for 10 minutes. The tube was then inserted into the Nitrate-N Comparator and readings were taken. (ASTM, 1983)

Sulfate

Sulfate Test Kit (LaMotte, Model PSAT, Code 7778) was used to measure the sulfate content of the samples.

Procedure:A test tube was filled with water upto the specified level, A Sulfate Turb Tablet was added, the tube was capped and shook vigorously for at least one minute to disintegrate tablet, Test tube was then immediately inserted into the comparator and reading was taken. Indication was the matching of sample cloudiness with the reference given in the comparator. (ASTM, 1983).

Chloride

Chloride Test Kit, Automatic Buret (LaMotte, Model AB-COS, Code 7249) was used for the detection of the chloride content of the samples.

Procedure: The graduated cylinder was used to measure the appropriate sample of the water to be tested. Transferred this to the Erlenmeyer flask, Added 2 drops of Chloride Reagent C were added. A red color appeared immediately,2.0 mL of Chloride Reagent D was added. The mixture was shaken and mixed thoroughly. Chloride Reagent E, one drop at a time, was added until the red color disappeared,0.5 mL of Chloride Reagent A was then added. The solution was gently mixed,Automatic Burette with Chloride Reagent B was used to titrate the solution. While gently shaking the flask, titration was done of the sample with Reagent B until the yellow color changed to orange brown. Readings were taken from buret endpoint. (ASTM, 1983).

Fluoride

Fluoride Test Kit (LaMotte, Model CC-F3, Code 4227-R) was used to determine the fluoride content.

Procedure: Filling of two Erlenmeyer flasks exactly to the 50 mL line with the water to be tested. The flasks were marked “A” and “B”, One Fluoride Excess AL Tablet was added to Flask "A". Using the plastic rod, crush tablet and stir until dissolved, One Fluoride AZ Tablet was put into Flask "A", and one Fluoride AZ Tablet to Flask "B". Plastic rod was used to crush and stir tablets until dissolved, Both the flasks were allowed to settle for 15 minutes, A test tube was filled upto the 10 mL line with the solution from Flask "A". Call this Test Tube "A". A second tube to the 10 mL line with the solution from Flask "B". Call this Test Tube "B", Test Tube "A" was inserted into the Axial Comparator to obtain Reading "A". Then Test Tube "B" was added in the Axial Comparator to obtain Reading "B". The Reading from “A” was then subtracted from “B” to get parts per million fluoride, "B" - "A" = ppm. Fluoride. (ASTM, 1983).

Calcium, Magnesium, Sodium, Potassium, Iron and Arsenic

For determination of these parameters a separate sample was taken from all the sampling points for the determination of these parameters. The samples taken for this purpose were immediately acidified with Analar Grade nitric acid (1%). These samples were analyzed for these parameters using GBC Atomic absorption Spectrophotometer. The main steps involved in each case were followed as under;
Preparation of standard solutions, Selection of analysis program for the selected element and setting of all the analytical parameters as per recommendation of the methods manual of the instrument for precise analysis of the element, Aspirated standards and adjusted the instrument parameters accordingly, Aspirated the unknown sample and noted the instrument reading in terms of the ppm or mg/l of that particular element present in the sample (ASTM, 1983).

Microbiological parameters

Thebiological parameters included detecting the presence and number of coliform and faecal coliform bacteria using multi tube method given as under.

The sample bottle was shaken vigorously to achieve a homogeneous dispersion ofbacteria. 5 ml of MacConkey’s Broth (double strength) was inoculated into the test tube. After inoculation the tubes were shaken gently to distribute the sample uniformly throughout the medium.Introduced 5ml of the sample water into each of the five tubes containing MacConkey Broth (double strength). This would make a total of 10 ml of solution between the broth and the sample. The solution would be double strength. Now used the same technique and 1 ml of sample water was inoculated into a tube containing 1 ml of broth and 3-4 drops of sample into 0.1 ml of broth. Both the tubes mentioned earlier would be of single strength. The whole set of test tubes was stored in an incubator for 24 hours at a temperature of 35°C to 37° C. Each tube was then examined for the presence of gas at the end of the 24 hour incubation period. (If some samples don't show any positive signs of contamination they should be stored for further in the incubator). Now, the samples that had shown contamination after the above mentioned period are further tested, by using the same technique as described above, for the MacConkey Broth. 3 different quantities of peptone water i.e. 5 ml, 1ml and 0.1 ml was used to determine E.coli content. Whereas for Faecal Coliform the Beryllium Green Broth (BGB) was used in same quantity. Samples were introduced into the tubes and then stored at 44 +- 0.5°C for 24 hours.

The presence of Fecal coliform was determined by the presence of gas in the durham tube kept in the beryllium green broth.For E.coli the samples containing peptone water and the solution were injected with 0.1 ml of Kovacs reagent and then mixed gently. The presence of indole was indicated by the forming of a film (ring) over the aqueous solution. (ASTM, 1983).

Results and discussion

The results regarding the bacteriological parameters i.e coliform and faecal coliform are depicted in the fig 1 and 2.From the study of these results it is obvious that bacterial contamination defined is, as most probable number, varies in the range 0-17. According to the WHO and PSQCA limit value of coliform and faecal coliform is supposed to be nil in any drinking water sample, and in the fig it is showing values for a number of samples analyzed.

Table 1. Sample site description.

Sample no	Sampling site
1	Tube Well # 189, Kulza Park, F-7/1 ,IBD.
2	Tube Well # 64, St # 37, F-8/1 ,IBD.
3	Tube Well # 218, ST # 44, F-8/1 ,IBD.
4	Tube Well # 192, ST # 30, F-8/1 ,IBD.
5	Tube Well # 204, 9th Avene, F-8 ,IBD.
6	Tube Well # 199, ST # 10, F-8/3 ,IBD.
7	Tube Well # 198, ST # 03, F-8/3 ,IBD.
8	Tube Well # 202, Green Belt, F-8/4 ,IBD.
9	Tube Well # 65, Nazmudin Road, F-8/4 ,IBD.
10	Tube Well # 146, F-9 Fatima Jinnah Park, IBD.
11	Tube Well # 147, F-9 Fatima Jinnah Park, IBD.
12	Tube Well # 201, F-9 Fatima Jinnah Park,IBD.
13	Tube Well # , F-10 Green Belt ,IBD.
14	Tube Well # 82, F-10/4 ,IBD.

All these samples represented contaminated product and thus not recommended for human consumption, keeping in view the WHO and PSQA standards. According to Aziz (2005), fresh water sources including ground water are contaminated highly with bacteria of total and faecal coliform origin.A study conducted by Pakistan Council of Research in Water Resources (PCRWR) (2005), in major cities of the country found that 35% and 65% of ground water samples were contaminated with total coliforms and *E. coli respectively*. It is expected that, due to the long dry season witness in this area some rearrangement of water movement pattern giving rise to such contamination from the nearby nullahs, might have become operative. This could be cited as the main reason for such contamination.

Physical parameters

The physical parameters include, parameters such as color, taste, odor, turbidity, total hardness, TDS, pH. The physical parameters covered in the project are explained with their test results in the following section. The samples are analyzed with respect to their spatial variation. The ranges are given representing all samples in graphical form.

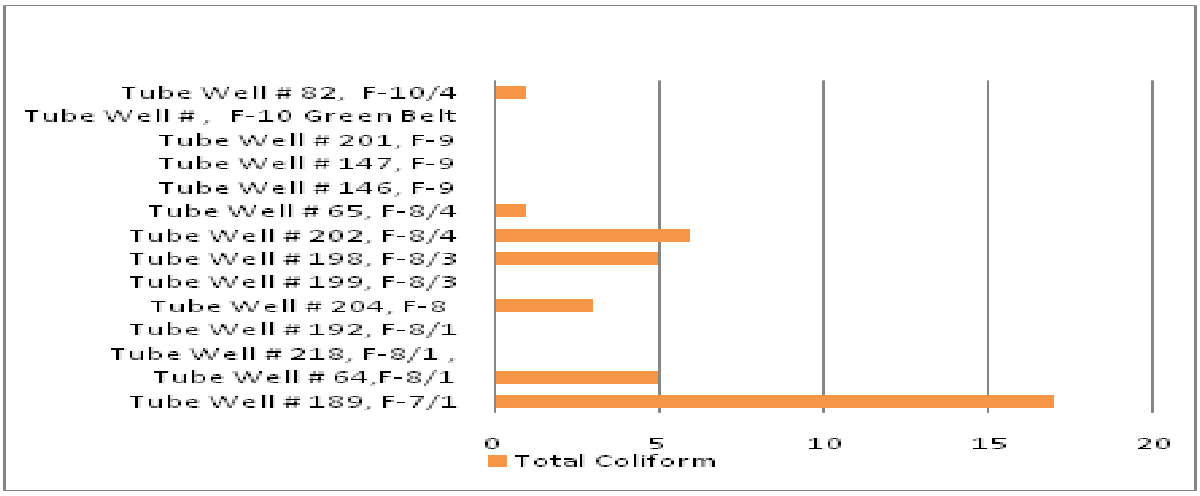

Fig. 1. Total Coliform level(CFU/100ml) concentration.

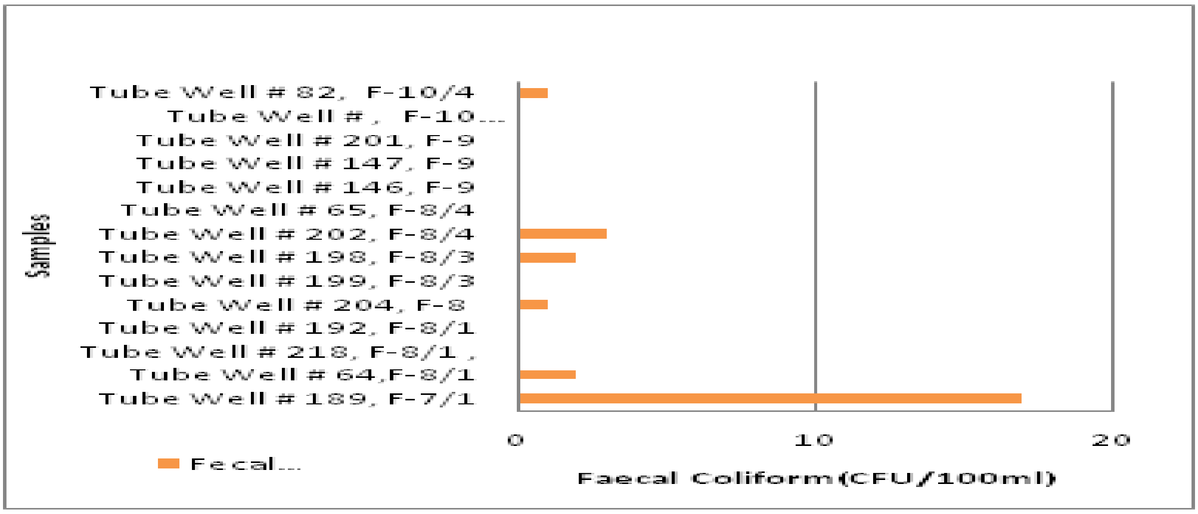

Fig. 2. Faecal coliform(CFU/100ml) concentration.

Color

All the samples collected from the entire sampling sites were colorless, which meets National standards for drinking water quality and WHO (World Health organization) standards.

Turbidity

The Fig.3, represents the turbidity value of the sampling sites. The graph shows a higher curve for the areas of F-8 sectors, but the values are still well below under the standardized range given by WHO, PCRWR, Pakistan standard institution and National standards for drinking water according to which required value for turbidity should be <5 NTU. Observed values for turbidity in the study area ranged from 0 to 0.81 NTU.

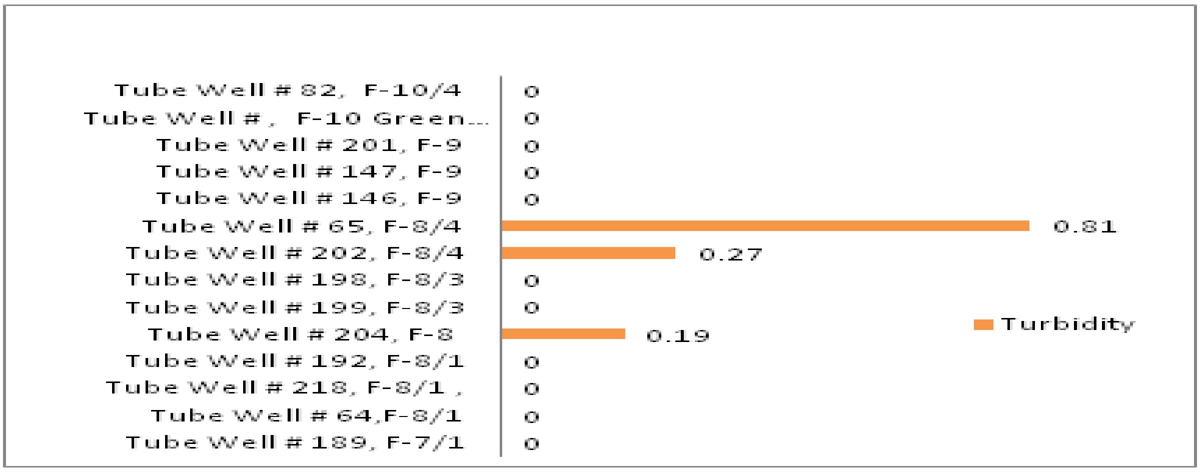

Fig. 3. Turbidity(NTU) values of selected sites.

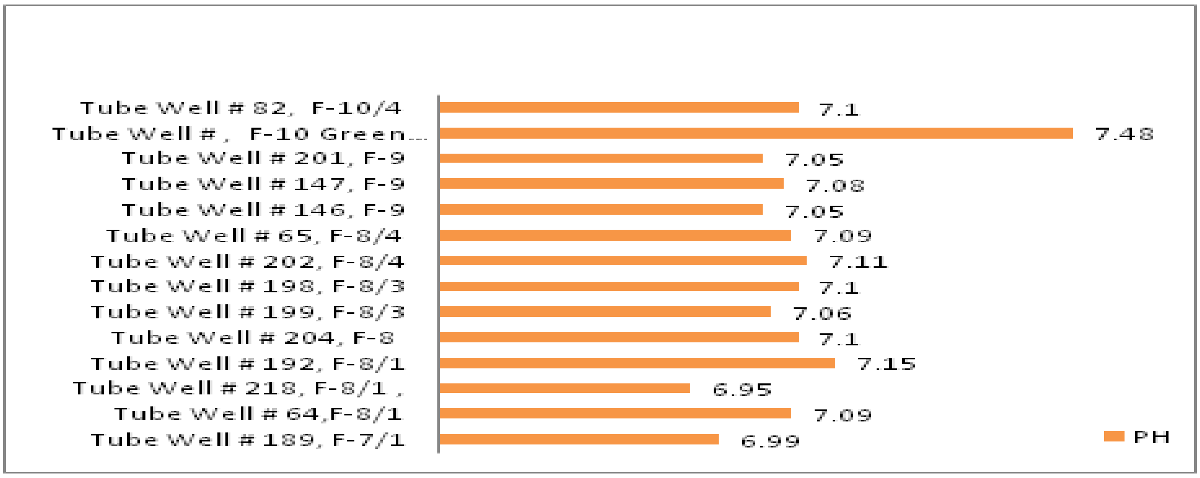

Fig. 4. pH of sampling sites.

pH

The Fig 4, values of pH are fluctuating but are well within the standard limits accept for tube well no T.W#189, F-7/1 and T.W#218, F-8/1 which shows the values of the pH less than 7, making it slight acidic in nature according to PCRWR guidelines for highest desirable level but still lies within the maximum permissible level. Such slight pH variations some time may render unnoticeable change in taste which again depends on person to person adaptability.

Total dissolved solids

The standard value of TDS for drinking water should be <1000 mg/l as per WHO and National standards for drinking water quality. The tested samples shows values with in specified limits. However, for bottled drinking water having good taste, the expert opinion do recommend a value of around of 200 to 300 mg/l for this parameter. The results are shown in Fig 5.

Alkalinity

The value of this parameter for drinking water has no set guideline value. The results on alkalinity of the samples presented in graph are within the desirable range given by PCRWR, WHO and PSI guidelines being <500 mg/l. This factor is no doubt very closely connected with bicarbonates contents and is supposed to be of the same order in case there is no presence of any carbonate specie. From the results expressed in Fig 6, this aspect is very much evident showing a very good relationship. Thus it could be very clearly suggested that presence of bicarbonate contributes to this parameter expressed as equivalent to $CaCo_3$

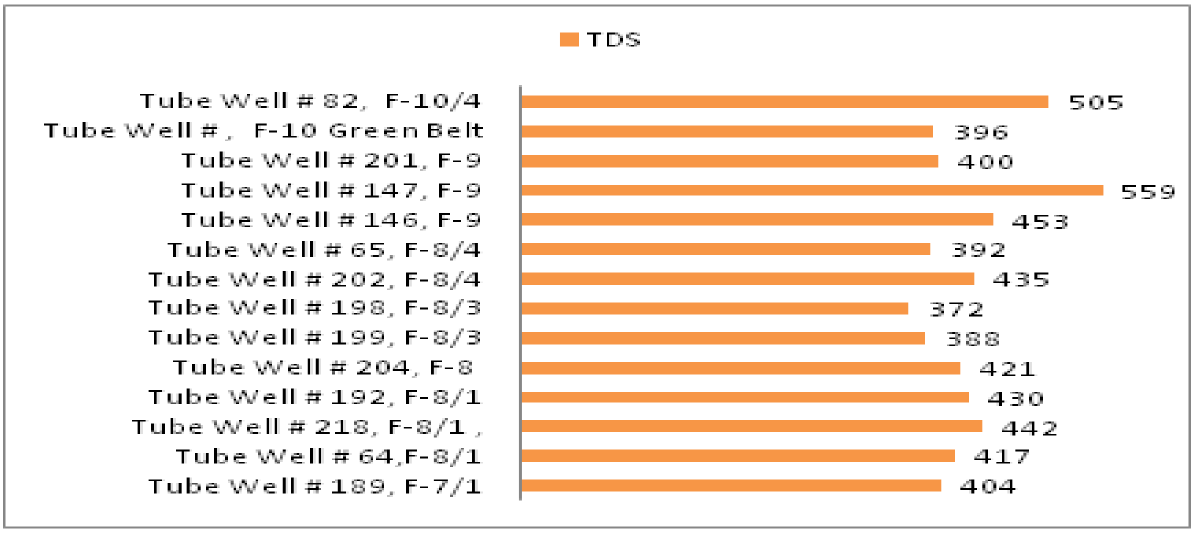

Fig. 5. TDS(Total Dissolved Solid) mg/l.

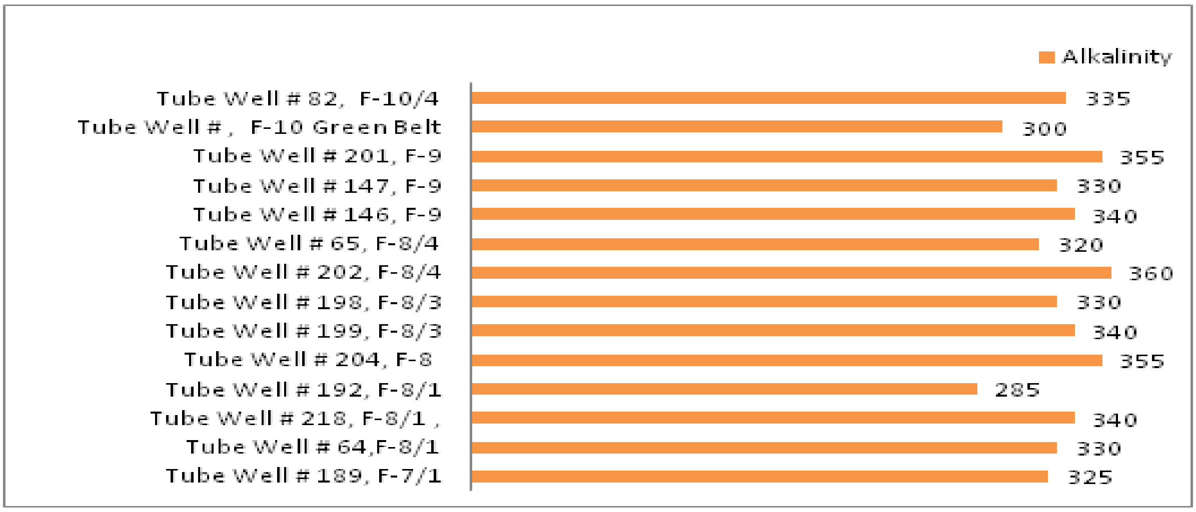

Fig. 6. Alkalinity (mg/l)of selected sites.

Hardness

According to PCRWR the maximum permissible level for hardness of drinking water is <500 whereas highest desirable level is <200 mg/l. The value for National standard for drinking water quality is also <500 mg/l.

The results as depicted in graph show that all the samples fall within the maximum permissible level. This factor no doubt bears a relation to the total Ca+Mg content and is often referred to calcium magnesium hardness. Although this parameter may not be very important with respect to the drinking water quality, yet it is considered an important factor with respect to the other domestic uses and some time may also be important with reference to taste. For better taste of such samples it is often recommended to boil the water which would reduce the Ca, Mg dissolved content/hardness of the samples which are shown in Fig 7.

Electrical conductivity

There is no guideline value provide by the WHO and PCRWR standards. However it is recommended to have a value of < 1000 µS/cm for this parameter which is generally equivalent to TDS value of < 500 mg/l considered to be the highest desirable level suggested in PCRWR standards. The graph depicting this parameter show that all samples lie within the desired ranges. In many cases this parameter is very closely related to the TDS values. Many instruments are designed to measure the TDS just by multiplying the measured conductivity values with a factor which varies from 0.5 to 0.8 depending upon the chemical composition of the sample. In the present case this factor lies within the range 0.55 to 0.67. Results are shown in Fig. 8.

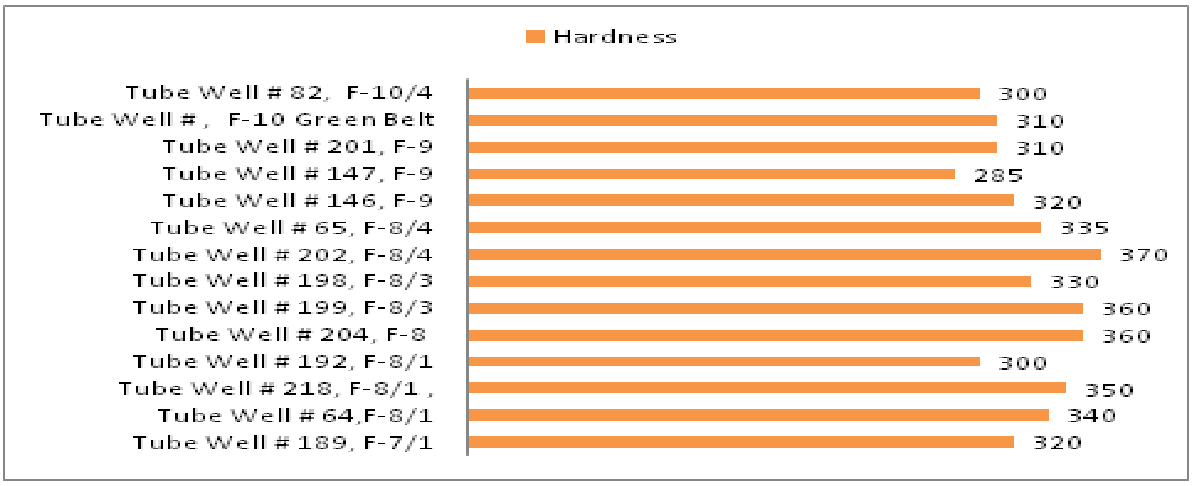

Fig. 7. Hardness (mg/l).

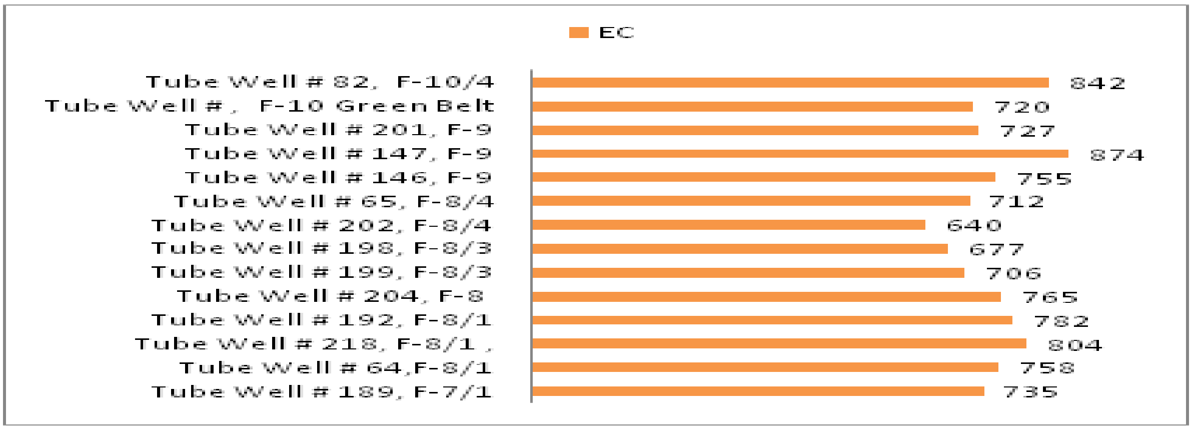

Fig. 8. Electrical Conductivity(EC) (µS/cm).

Chemical parameters

Following chemical parameters were observed in water sample.Calcium (Ca), Magnesium (Mg), Carbonates (Co_3) and Bi-Carbonates (HCo_3), Chloride (Cl), Sodium (Na), Fluoride (F^-), Iron (Fe), Potassium (K), Nitrate (NO_3), Sulphate (So_4)and Arsenic (As).

Calcium(Ca)

The calcium values in this profile lies within the MAC limits set by PSI being 75 to 200 mg/lwhile WHO drinking water limit is 100 mg/l.Lower calcium values are sometimes connected with the calcium deficiency of the population of that area and higher values are also sometimes considered to be undesirable, keeping in view its possible contribution to the formation of kidney stones. However the best quality bottled drinking water maybe designed to have this value up to 60 mg/l. Results as shown in Fig. 9 ranged from 54 mg/l to 104 mg/l, where one out of all wells sampled exceeded the WHO limit. According to PRWR studies (2005) encompassing major cities of the country, 28% of the ground water samples exceeded permissible limits for drinking water regarding calcium, attributing these high levels to calcareous nature of underground rock strata.

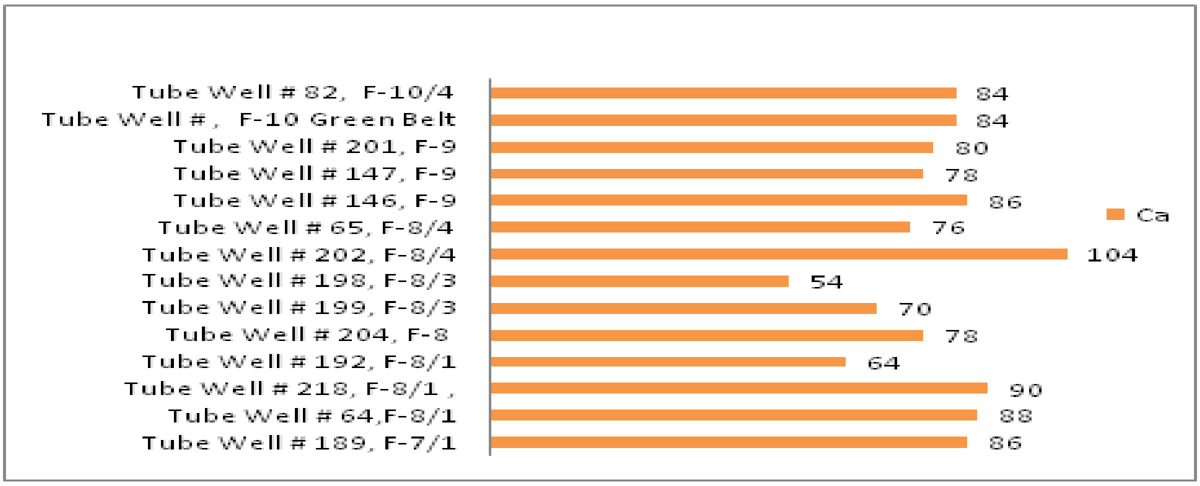

Fig. 9. Calcium Concentration (mg/l) of selected sites.

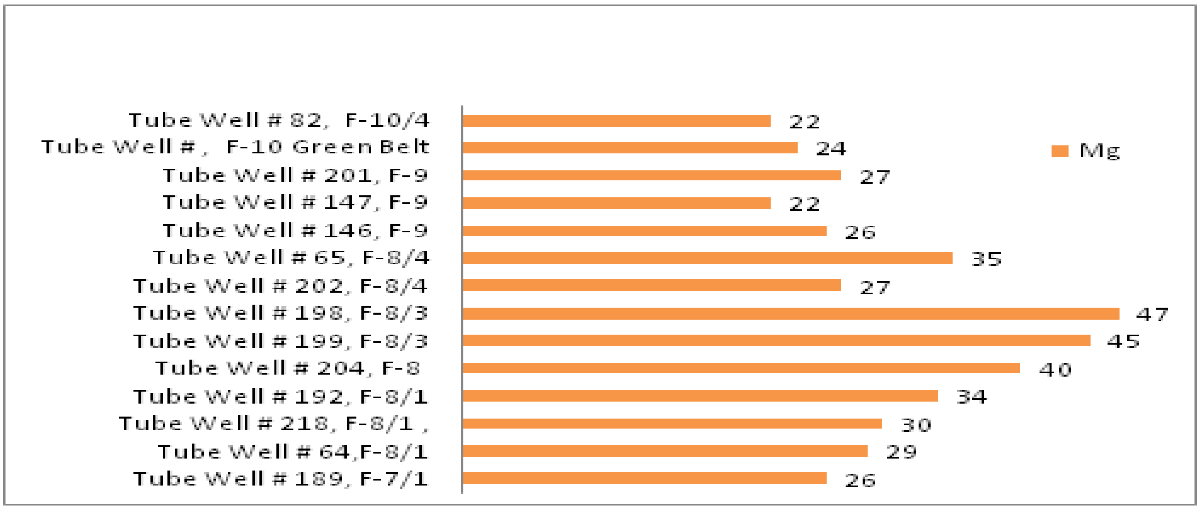

Fig. 10. Magnesium concentration (mg/l) of the sampling site.

Magnesium(Mg)

The magnesium values depicted in Fig.10 of the water samples ranges from 22 ppm to 47ppm, which are well within the limits 30 mg/l to 150 mg/l set by PCRWR and PSI. This element normally follow trend of calcium and have similar effects on body. Higher values are sometimes related to stomach disturbances for some of the people. Azizullahet. al. (2011) reviewed magnesium in ground water quality assessment studies and found a general trend of below limit concentrations of the metal in studied samples.

Carbonates (CO_3^{2-}) and Bicarbonates (HCO_3^-)

According to the WHO and PSQCA limits the value of HCO_3^-/CO_3^{2-} are within the given range which is <500 mg/l, the value of carbonates (CO_3^{2-}) being below the detection limit. This parameter is important in relation to the total Ca, Mg content and hardness of the sample. Higher values sometimes are connected with some corrosive properties. However within the MAC limits, this parameter sometimes must be associated with taste forming properties. Results are depicted in Fig. 11.

Chloride (Cl^-)

The standard PSQCA value for Cl is < 250 ppm. The sample values as shown in the Fig 12, fall very low within the desirable limitsranging from 7 to 28 mg/l. Lone et. al. studied chloride in groundwater of Hassanabadal and found highest value of 0.21 mg/l during the study. Higher values have a contribution to the crossing nature of the samples. These values for the tube well water are, sometimes representative of the presence of salt content of the soil around.

Sodium(Na)

There are no guidelines values set by PSQCA but according to WHO guidelines it should < 200mg/l. The ranges shown in the Fig. 13 are within the desired limits. Higher values even within the guidelines sometimes are considered undesirable for blood pressure patients who instead are recommended to take potassium salts instead of sodium. Further the higher values are also connected with the corrosive nature of water especially when utilized for industrial applications.Study conducted by PCRWR (2005) in 23 major cities of Pakistan showed that 9% of ground water samples had high Sodium concentration than recommended level. This high concentration may be due to salinity or due to cation exchange reactions with Ca and carbonate precipitation due to alkaline conditions (Raza et. al. 2007).

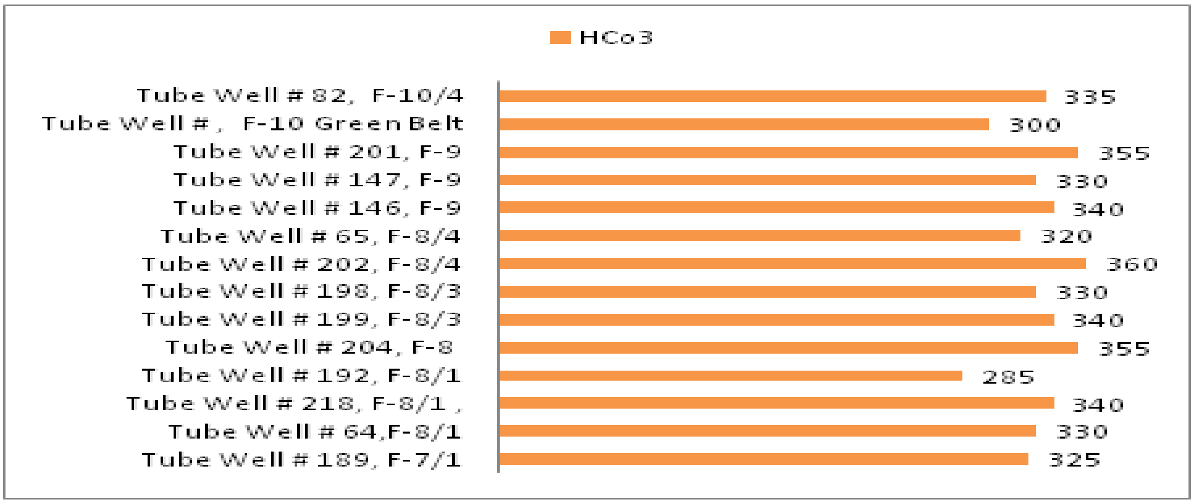

Fig. 11. Bicarbonate content (mg/l) of selected sites.

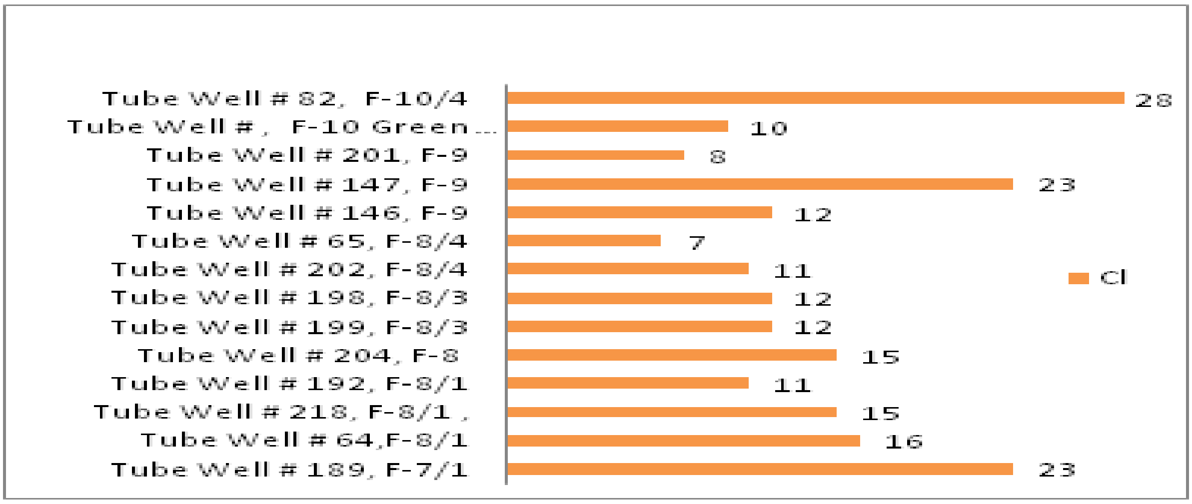

Fig. 12. Chloride concentration(mg/l) of selected sites.

Flouride (F)

According to PSQCA guidelines the value for F^{-} for drinking water is 1.5 mg/l. Result of all the samples as depicted in Fig. 14 fall within the desired range from 0.14 to 0.52 mg/l. Both its overexposure and deficiency lead to health implications. According to PCRWR (2005) Fluoride levels are found well below the limit in 23 cities studied, except for 6% of total ground water samples exceeding the limits set for Fluoride.

Iron (Fe)

The iron values lies within the desirable limits of ≤ 0.3 mg/l, in accordance with the PSQCA set limits. Higher value may give rise to slight coloration and undesirable change in taste.Results shown in Fig. 15 reveal that Iron values in the study ranged from 0 to 0.1 mg/l Tariq et. al. (2008) found Iron concentration ranging 0.02-11.8 mg/l in their study. That is higher than our observed values.

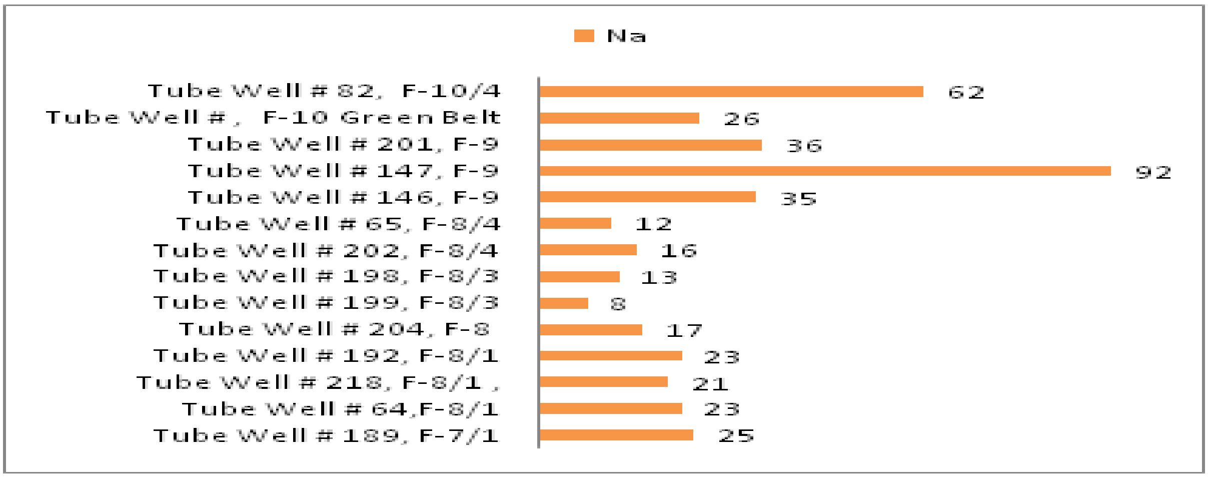

Fig. 13. Sodium concentration(mg/l) of selected sites.

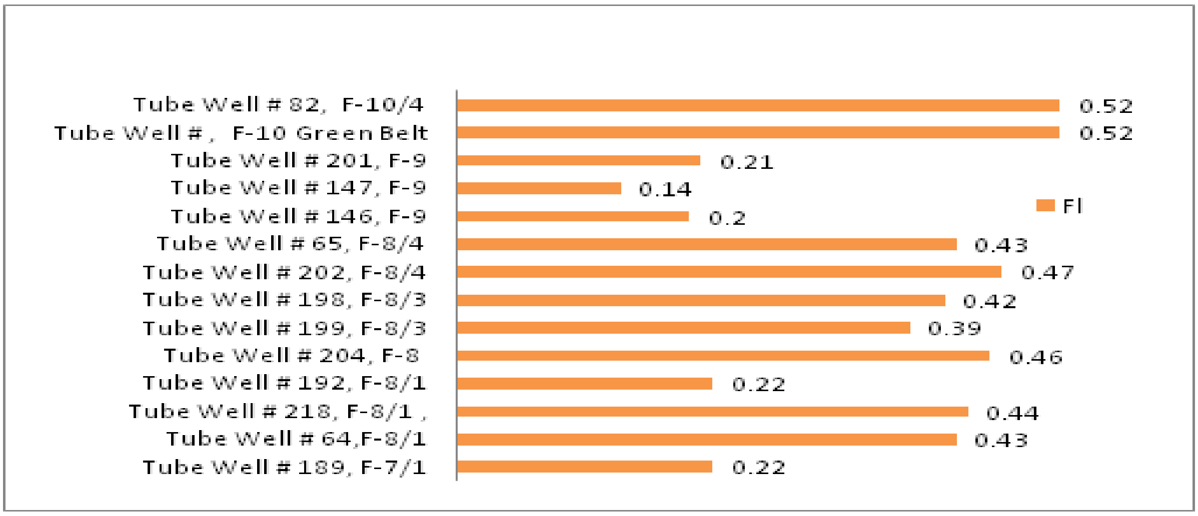

Fig. 14. Flouridelevel(mg/l).

Potassium (K)

There are no set guidelines set for potassium, but European Union recommends 12 mg/l. The valuesareillustrated in Fig 16, and range from 1 to 1.8 mg/l. According to PCRWR (2050) its values exceeded in 36-46% of samples from Faisalabad.

Nitrate (NO_3^-)

The standard PSQCA guidelines have a set value of 10 mg/l, whereas WHO standards are 50 mg/l. The nitrate values ranged from 1.8 mg/l to 5 mg/l in the study area as shown in Fig. 17. Higher nitrate values are sometimes related to the contamination from nitrate fertilizers and livestock manure finding their way to the underground water bodies. Nitrate is given the status of fourth most potential contaminant in

Pakistan by National Water Quality Monitoring Program. (PCRWR, 2005).

Sulfate (SO_4^{2-})

According to WHO standards the water should have 250 mg/l. The values lie within the desirable limits ranging between 13 mg/l to 162 mg/lillustrated in Fig 18..Nicksonet. al. (2005) found high levels of Sulfate in ground water study in Muzaffargarh district Pakistan and found values between 26-1313 mg/l.Higher sulfate contamination sometimes may have some laxative effects and could be corrosive.

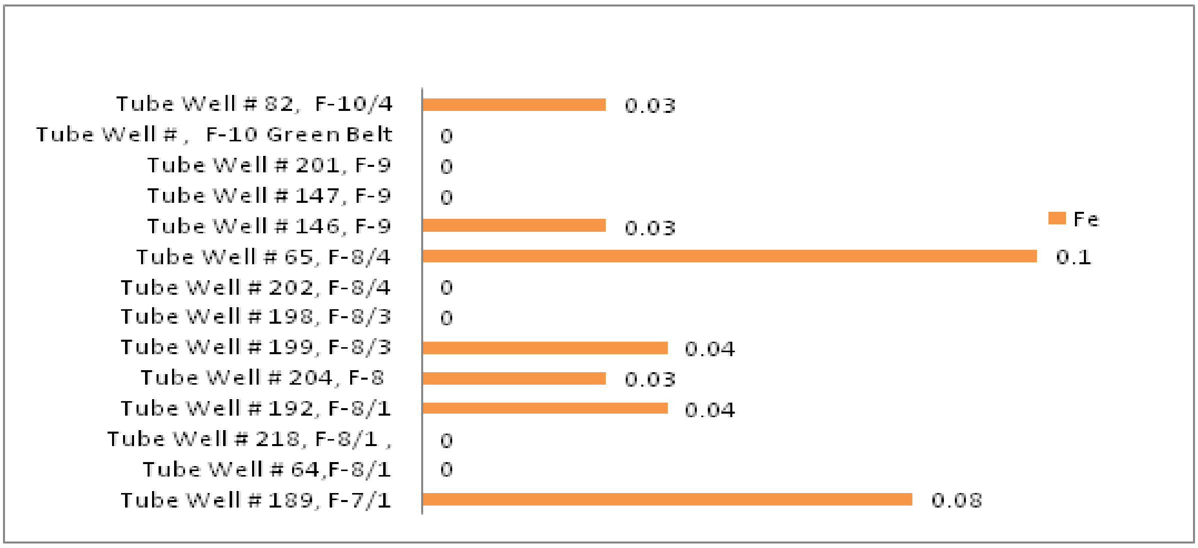

Fig. 15. Iron concentration(mg/l) from selected sites.

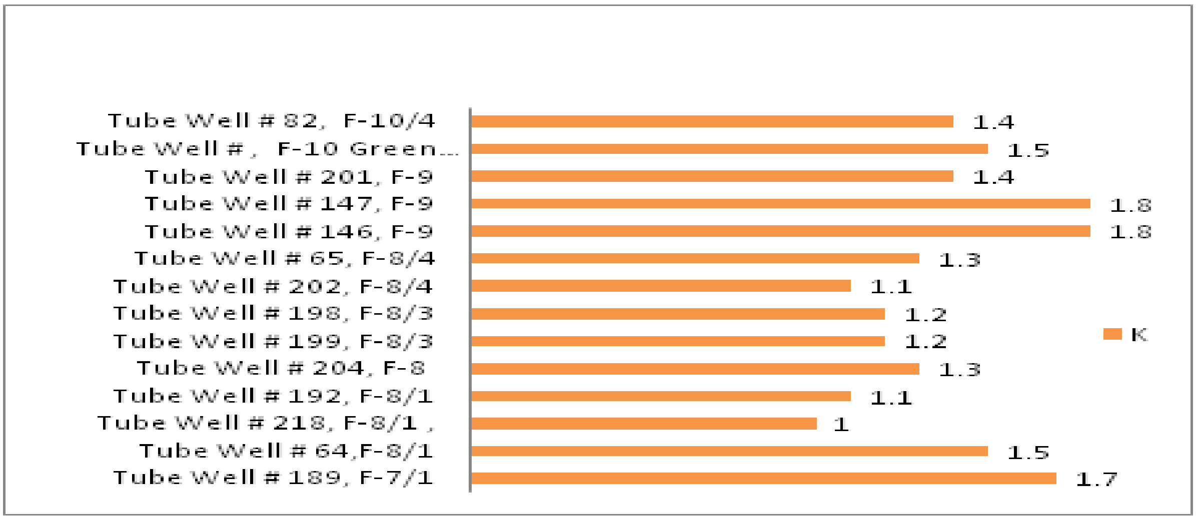

Fig. 16. Potassium level(mg/l).

Arsenic (As)

The WHO standard values for As in drinking water is 10 µg/l and for standard value for Pakistan it is ≤0.05 mg/l. The values lie within the desired range.

Higher values normally cause bone deformity specially in kids which are elaborated in Fig 19.Arsenic contamination in ground water of Pakistan has not been studied extensively as the case in India, Bangladesh and Nepal (Islam-ul-Haque, et. al. 2007), However, a joint study conducted by PCRWR and United Nations Children Fund (UNICEF) in 2000 found ground water contaminated with Arsenic exceeding the WHO limit of 10 µg/l (PCRWR, 2008).

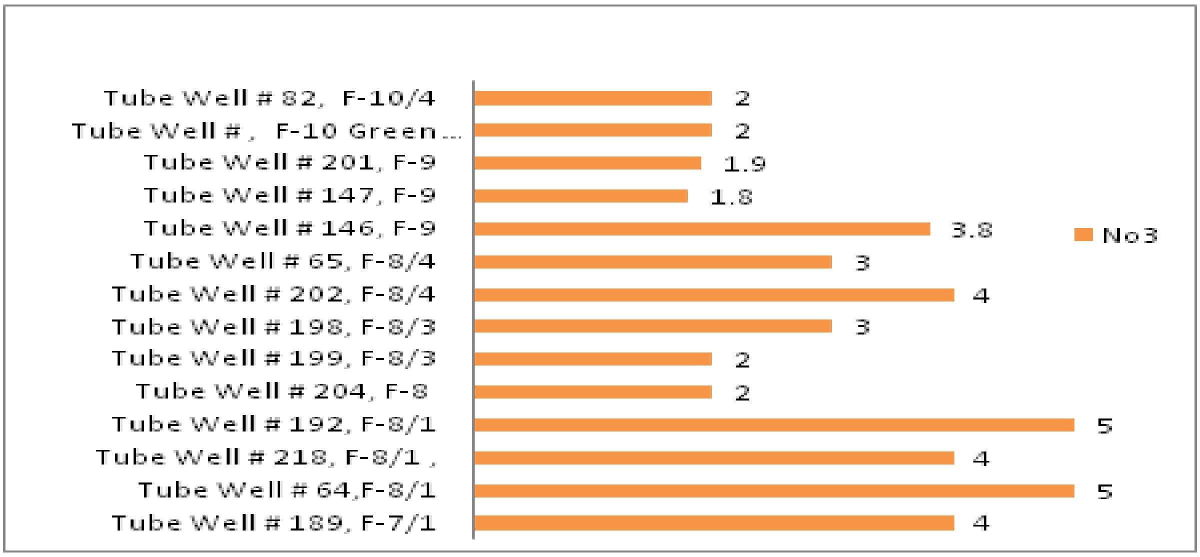

Fig. 17. Nitrate concentration(mg/l) of the selected sites.

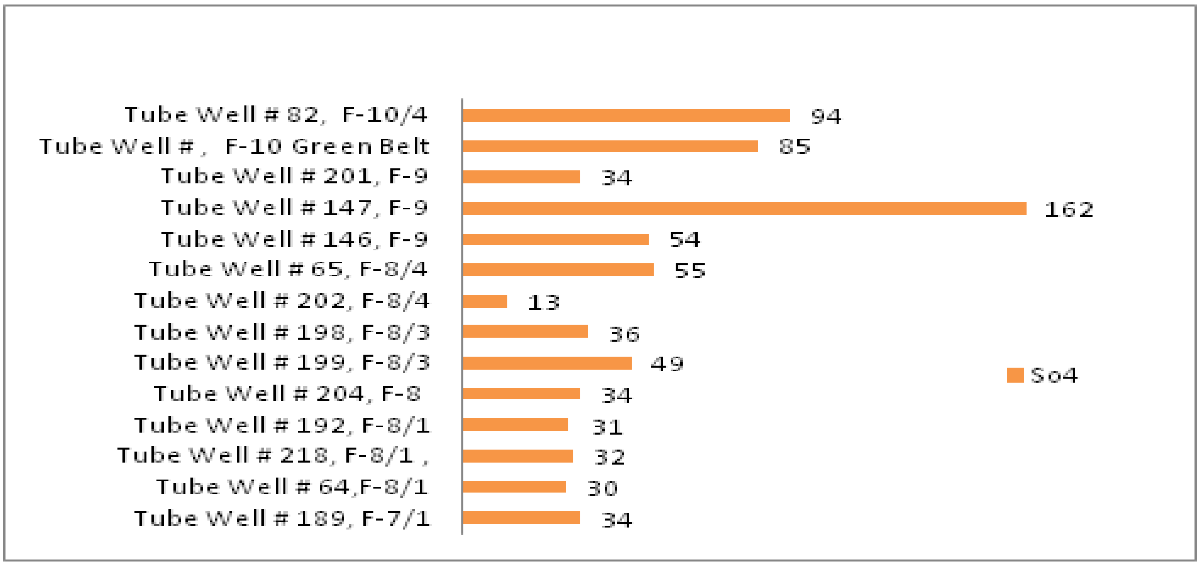

Fig. 18. Sulphate concentration(mg/l) in samples.

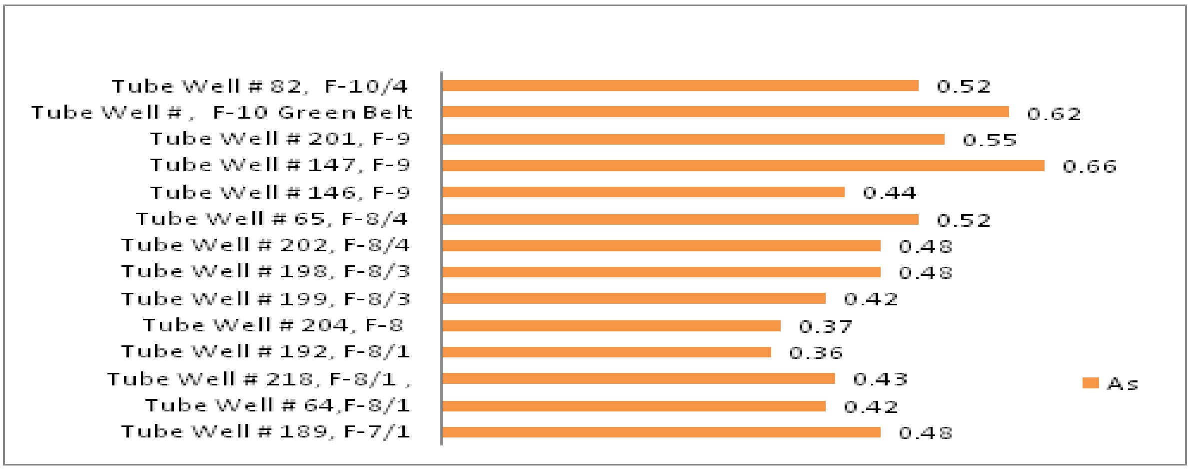

Fig. 19. Arsenic concentration(μg/l) of selected sites.

Conclusion

During the course of this study, 14 drinking water samples, one each, from different CDA installed tube wells in sectors F-7, F-8, F-9 and F-10 were collected and analyzed following the standard methodology available on the subject. The results obtained have been discussed in details. Almost half of the samples were found to be contaminated with respect to the coliform and Feacal coliform bacteria and hence adjudged to be unsafe for drinking purpose. Detail studies should be conducted to know the cause of bacteriological contamination. However, for all the samples, the results regarding the physical and chemical parameters were found within the recommended national and international guidelines for drinking water. Further, the data on electrical conductivity versus TDS and calcium versus magnesium followed a recognized logical pattern.

While sampling it was ensured to take samples in a prescribed east-west direction within the area under investigation. The results show a variation of different parameters which follows the underground strata pattern from east to west. This certainly reflects availability of different underground hydrological condition of the area under investigation. Keeping in view the results of the study, it is recommended to undertake such further studies over a wider area in order to elucidate the situation further.

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