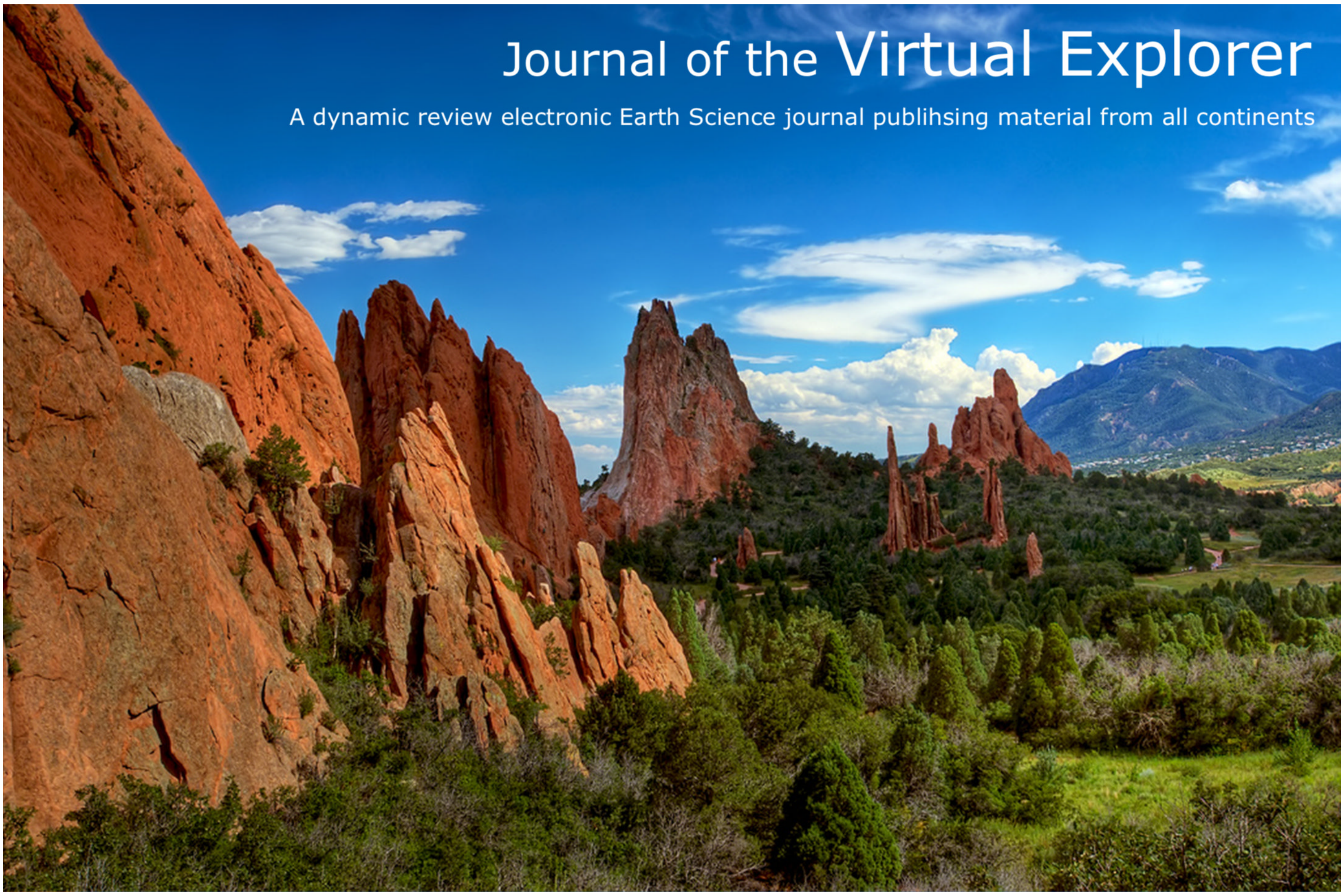

Groundwater Contamination Study of the Islamabad Aquifers and their Graphical Projection using "HC-GRAM" Software

Zia Ul Hasan Shah, Zulfiqar Ahmed

Journal of the Virtual Explorer, Electronic Edition, ISSN 1441-8142, volume **23**, paper 4
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Abstract: Physiochemical and hydrochemical study of the groundwater aquifers of Islamabad Sectorial and National Park areas were made. Water samples collected randomly from fifty-nine tube-wells/dug-wells were analysed chemically in the National Institute of Health, Islamabad (Pakistan). Chemical quality data thus obtained have been verified statistically for its reliability and conformity in terms of chemical identity among aquifers. This data is then projected graphically on the Trilinear Piper and Stiff Pattern diagrams by using USGS software "HC-GRAM". The Stiff Pattern diagrams thus developed for each well are projected on the map of Islamabad to visualize the distribution of groundwater chemistry. "WATEQ", USGS Water Equilibrium software, is used to evaluate the variety of chemical parameters to be used for further extending this study. Results indicate that most of the Islamabad aquifers are of excellent quality and fall in the category of HCO_3-type, Ca-HCO_3 type, Na-HCO_3 type, and Na-type. Groundwater available at Dhok Mori, Dhok Chapran and in some sites of Sectors I-8 and I-9/4 are highly contaminated.

http://virtualexplorer.com.au/article/2006/153/groundwater-contamination-of-islamabad-aquifers

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Introduction

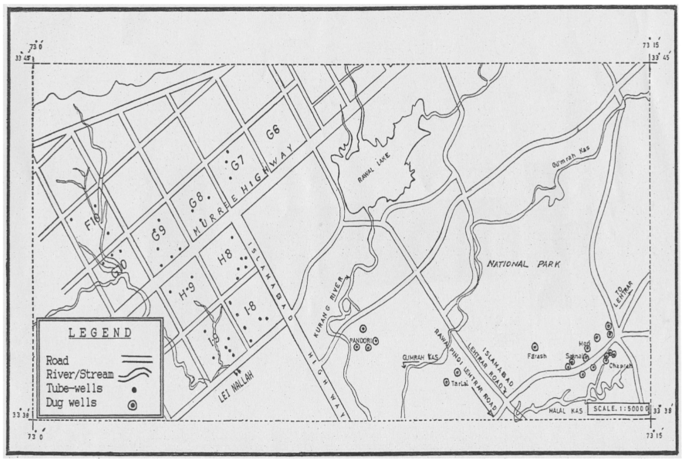
Groundwater contamination study of the Islamabad aquifers has been investigated in sectors G-7, G-8, G-9, G-10, F-10, H-8, H-9, I-8 and I-9, and in the villages of Tarlai Kalan, Pandori, Alipur, Farash, Dhok Saknal, Jhang Saiyadan, Ziaratgah, Dhok Mori, and Dhok Chapran of the National Park Area (Figure 1). The whole area lies between longitudes 73° 0´ to 73° 15´ East and latitudes 33° 38´ to 33° 45´ North.

Water contamination is one of the important environmental issues in the world now a day. Water is an essential item to mankind, and the largest available source of fresh water lies underground. Due to increasingly felt demand for water among the community, a thorough study in the search of surface water storage, exploration / exploitation of groundwater, and procedures to avoid water contamination are being outlined by various agencies.

Pollution can impair the use of water and can create hazards to the public health through toxicity and the spread of diseases. According to World Health Organization (WHO) more than three billion people did not have enough clean water to meet their daily needs. Even more alarming above all is that 80% diseases and sicknesses are water borne.

Physiochemical and hydrochemical analyses of groundwater samples obtained from fifty-nine different tube / dug wells (Figure 1) were made in the National Institute of Health (NIH), Islamabad, and their results were used to study and interpret the aquifer's chemical characteristics. Physiochemical analysis include the laboratory measurements of temperature, pH-value, electrical conductivity, hardness as $CaCO_3$, whereas hydrochemical analysis entail determination of major dissolved ions such as Na^+, K^+, Ca^{+2}, Mg^{+2}, HCO3-, CO_3^{-2}, Cl^-, SO_4^{-2} and total dissolved solids (TDS). Ionic balance of each well was determined which lies within the range of 0.00% to 2.03% showing the results to be reliable.

Figure 1. Distribution of tube wells



Location Map showing the distribution of tube wells and dug wells (sampling sites) in Islamabad Sectorial and National Park area respectively.

Hydrogeological Study

The study area is mainly drained by four perennial streams such as Kurang River, Gumrah Kas, Malal Kas and Lei Nullah, and many other seasonal streams, which are either intermittent or ephemeral (Figure 1). The water table in the pre-existing wells vary from 10 to 90 feet in the National Park area and 42 to 165 feet in the Islamabad Sectorial area. The series of stratified confined aquifers have been identified during a recent crash drilling program by the Capital Development Authority and Oil & Gas Development Corporation in different sectors such as G-10, F-8, F-10, and H-8 etc. These aquifers are mainly comprised of gravels, gravels and boulders, well-defined large bed of limestone boulder (partially fractured), and friable sandstone. The hydraulic characteristics of these aquifers widely vary due to the nature of upper confining layer of aquiclude and/or semi confining layer of aquitard.

The geophysical well-logging consisted of natural gamma and resistivity sonde is carried out in dozens of trial bores, 350 to 400 feet deep, to make the filter design and to estimate the ultimate well yield prior to the advancement of further reaming/development operation. Few of them for sectors F-10, H-8 and G-10 are shown in (Figure 2), (Figure 3) and (Figure 4) respectively, which show a complete filter design and subsurface lithological features. In these sectors, yield of the permeable strata is also estimated by assuming two hydraulic gradients (i =

0.007 and i = 0.01) with the suitable hydraulic conductivities of the gravel and boulder formation. Darcy's law expressed in terms of groundwater flow notation is used to estimate this yield. The estimated yield for boreholes located in sectors F-10/4, H-8 and G-10 appears to fall in the ranges of 15,000 to 20,000 U.S. gph (0.55 – 0.74 cusecs), 17,000 to 22,000 U.S. gph (0.63 – 0.81 cusecs), and 10,000 to 12,000 U.S. gph (0.40 – 0.44 cusecs) respectively.

Figure 2. Filter Design of Tube Well # 166, F-10/1 Green Belt, Islamabad.

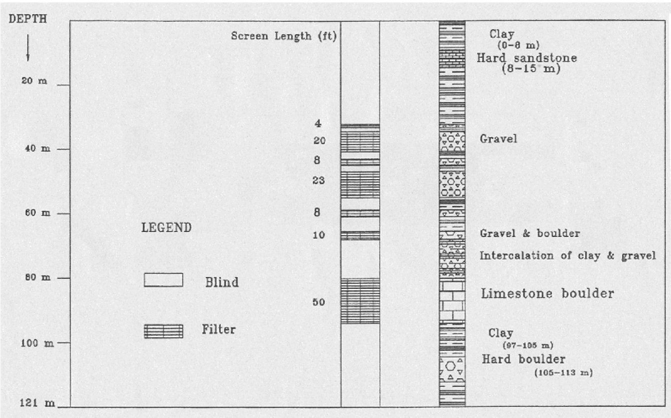


Figure 3. Filter Design of Tube Well # 207, H-8 & H-9 Green Belt, Islamabad.

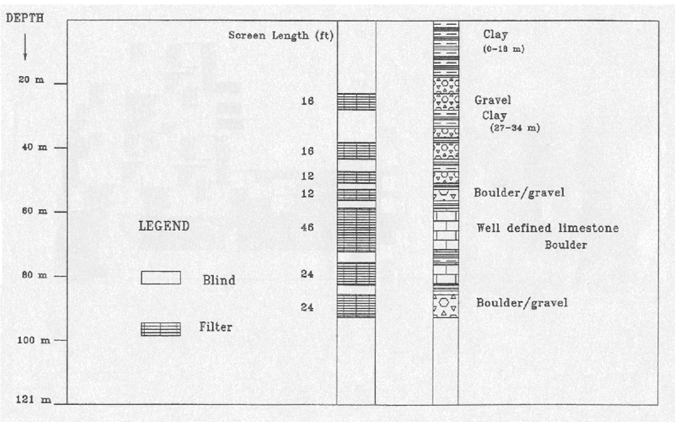
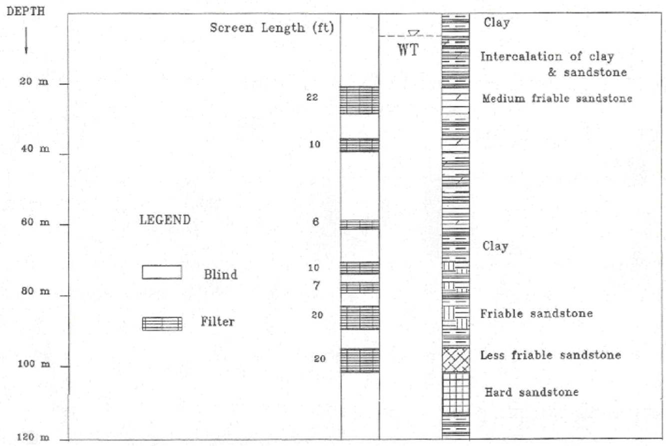


Figure 4. Filter Design of Tube Well # 15, G-10 & G-9 Green Belt, Islamabad.



In some sectors, the water table in the shallow aquifer is highly vulnerable to contamination due to the processes of infiltration and percolation, which carry along different volatile pollutants of sewerage waste and effluent industrial waste etc. Recent spread out epidemic disease of jaundice in Islamabad is water borne possibly resulted due to the use of contaminated groundwater from wells in sector G-10. These old wells, now completed abandoned, were penetrated adjacent to the perennial nallah whose flow is mainly maintained by the sewerage water. The upper portion of the shallow aquifer is being recharged by this nallah.

New well design based on the geophysical well-logging by a sophisticated machine starts from deeper horizon (at least 80 feet) and whatever water either perched and/or seepage in the upper horizon has been completely sealed by the M.S. Pipe (blind pipe) to control the contamination (Ahmad et al., 1992).

Basic Univariate Statistical Study

Hydrochemical data consisted of all major cations and anions have been studied statistically to establish a relationship between the means and variances of the population of aquifers and to enhance the reliability and validity. T-test and F-test (Davis, 1986) were performed manually and by computer modelling to compare the equality of the means and variances of the chemically analysed data. In both tests, the null hypotheses of equal means and equal variances were accepted. It is therefore categorically stated that samples drawn from the area/sectors of Islamabad have the same mean and variance and are chemically identical. This is to be mentioned here that these samples represent the water table depth (top of the aquifer). A computer program is developed in C++ to calculate the statistical parameters much faster and efficiently with great accuracy. It determines and compares the calculated and tabulated values deduced either from T-test or F-test. Validity of the laboratory results is increased if the hypothesis is accepted.

Presentation of Results of Chemical Analysis

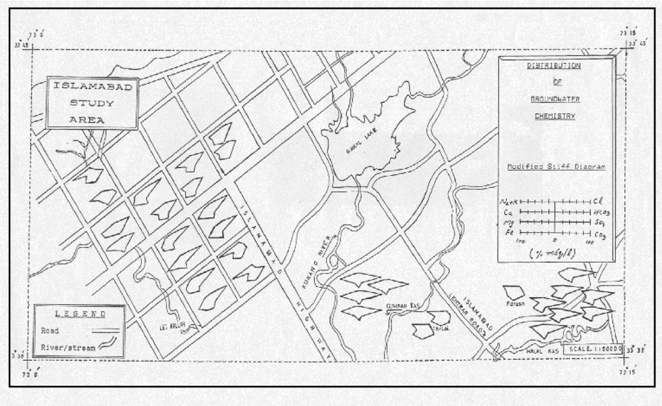
The major ionic species obtained from the hydrochemical analysis are projected graphically on the modified Stiff Pattern and Trilinear Piper diagrams (Stiff, 1951; Piper, 1944; and Hem, 1959 and 1983) using USGS software "HC-GRAM" (Hydro-chemical Graphic Representation Analysis Method), version 1.42.

Stiff Pattern Diagrams

Tables of chemical data are expressed in milli-equivalent per litre (EPM) to be used for these diagrams. The Stiff method uses four parallel horizontal axis extending on each side of a vertical zero axis. The concentration of cations and anions are plotted to the left and right of vertical zero axis. The resulting points are connected to give an irregular polygon shape or pattern, which shows water composition differences or similarities. The width of the pattern is an approximate indication of total ionic contents.

The Stiff Pattern diagrams were prepared for each well and shown all together on the location map of Islamabad to visualize the distribution of groundwater chemistry at first glance (Figure 5). Stiff diagrams indicate sodium and magnesium as the most dominant cations and bicarbonate as the most dominant anion available in the groundwater of Islamabad. However, in the areas like Tarlai Kalan, F-10, I-8 and I-9/4 dominant anions are sulphate and chlorides.

Figure 5. Distribution of groundwater chemistry



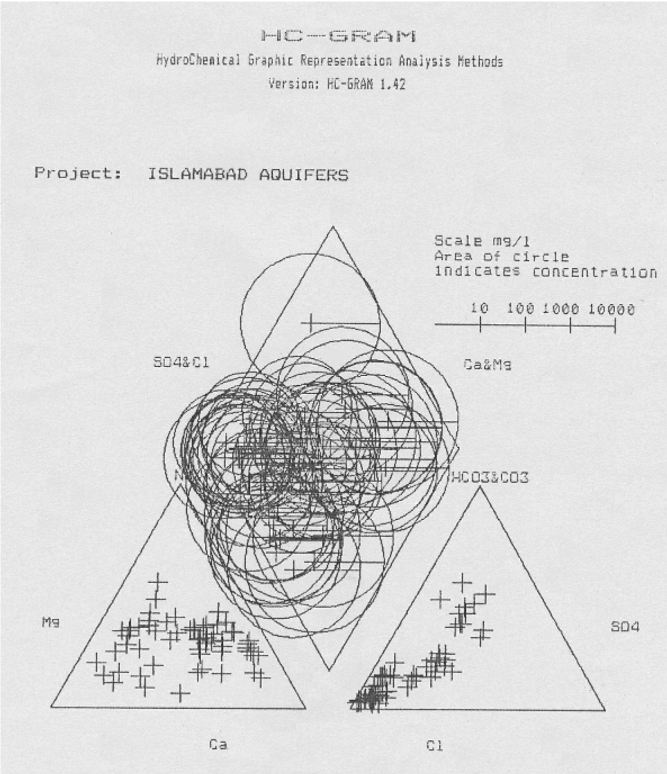
Distribution of groundwater chemistry for Islamabad Sectorial and National Park area using Stiff Pattern diagrams (after Stiff, 1951).

Trilinear Piper Diagram

The Trilinear Piper diagram is commonly used in water-chemistry studies, which can show the percentage composition of different ions. By grouping Na^+ and K^+ together, the major cations were displayed on the trilinear diagram. Likewise, CO_3^{-2} and HCO_3- are grouped resulting in three groups of the major anions. The cations and anions were plotted in left and right triangles as a single point. These points are then projected into the central diamond-shaped area parallel to the upper edges of the central area. All these points in the diamond-shaped area represent the total ionic distribution. For each water sample, a single point was obtained in the diamond-shaped area, which represents the total ionic distribution (Figure 6). The water-types interpreted from Trilinear Piper diagrams are summarized in (Table 1). Ahmad (1985) described the significance of groundwater chemistry of Tahlab valley, Balochistan using Stiff Pattern and Trilinear Piper Diagrams.

Plummer et al. (1976) FORTRAN WATEQ (Water Equilibrium) software is used to evaluate different chemical parameters such as numerical values of activity, activity co-efficient (and their logs), molality, equilibrium constant and ion activity product. These could be promptly utilized to further extending this study.

Figure 6. Trilinear Piper diagram



Trilinear Piper diagram (after Piper, 1944) representation of ionic concentrations of tube / dug wells (Islamabad Aquifers).

Table 1. Summary of water-types available in Islamabad.

Sr. No.	Sector/Area	Water Type
1.	Tarlai Kalan	Na Type
2.	Farash	Na Type
3.	Pandori	Ca-HCO_3 Type
4.	Dhok Saknal	HCO_3 Type
5.	Jhang Saiyadan	HCO_3 Type
6.	Ziaratgah	HCO_3 Type
7.	Dhok Mori (NP-12)	HCO_3 Type
8.	Dhok Mori (NP-13)	Ca-HCO_3 Type
9.	Dhok Chapran	Na-HCO_3 Type
10.	Sector G-7	HCO_3 Type
11.	Sector G-8	Na-HCO_3 Type
12.	Sector G-9	HCO_3 Type
13.	Sector G-9 (TW-42)	Ca-HCO_3 Type
14.	Sector G-10 (TW-73)	Ca-HCO_3 Type
15.	Sector G-10 (TW-87)	Na-HCO_3 Type
16.	Sector G-10 (TW-108)	HCO_3 Type
17.	Sector F-10	Na-SO4 Type
18.	Sector F-10 (TW-105)	HCO_3 Type
19.	Sector H-8	Ca-HCO_3 Type
20.	Sector H-8 (TW-96 & 120)	Mg-HCO_3 Type
21.	Sector H-9	HCO_3 Type
22.	Sector H-9 (TW-6)	Ca-HCO_3 Type
23.	Sector I-8	Na Type
24.	Sector I-9	Ca-HCO_3 Type
25.	Sector I-9 (TW-8)	Na-HCO_3 Type

Causes of Lower Quality Groundwater in National Park Area

Presence of several poultry farms in National Park area play an important role in deteoriating the quality of groundwater. Prior to start of this study, a landfill site was existed in Dhok Chapran where all wastes of Islamabad and Rawalpindi were dumped. Few years back this landfill site was abandoned and a new landfill site has now been operated in sector H-12.

Results indicate moderate to highly contaminated groundwater in this area caused by the combined effect of poultry farms and previous landfill site. The groundwater is enriched with nitrate concentrations and the colonies of fecal coliform bacteria (Shazia, 1989). As a result many groundwater of the National Park area are not recommended for drinking purposes and other domestic uses.

Conclusions

The following conclusions have been made on the basis of interpretative results, statistical analogies, on-site geological information and geophysical well logging:

1. Overall conclusive interpretation indicates sodium and magnesium as the most dominant cations available in the groundwater of Islamabad. However, in some areas like Pandori, Dhok Saknal, H-8, H-9 and I-9 calcium is the dominant cation, and is also found dominantly in the several water samples of wells such as, NP-13 (Dhok Mori), TW-43 (G-9/2), TW-42 (G-9/4). TW-63 (G-8/4) and TW-73 (G-10/2).

2. Likewise, bicarbonate is the most dominant anion available in the groundwater of Islamabad, except in areas like Tarlai Kalan, F-10, I-8 and I-9/4 where dominant anions are sulphate and chlorides.

3. Groundwater available at Dhok Tarlai, Dhok Farash, Dhok Mori, Dhok Chapran, and in some sites of sectors I-8 and I-9 are of saline nature, and they exhibit high values of TDS (1189 - 5570 PPM) and E.C. (990 - 2230 micro-mhos/cm). Moreover, presence of nitrates and fecal coliform bacteria are also found.

4. The values of hardness appear to be much above the permissible limit from the analysis of fifty-nine groundwater samples. Such water would normally cause scale formation (carbonate mineral precipitation) if boiled in container.

5. Trilinear diagrams of sectors G-7, G-8, G-9, G-10, H-8, and H-9 show that groundwater is magnesium-bicarbonate type, which in turn reflects its source of recharge from the adjacent Margalla hills mainly composed of limestone. Trilinear diagrams of Sectors I-8, I-9/4 and F-10, Tarlai and Farash show that groundwater is sodium/sodium-sulphate type with minor amount of Ca^{+2}, Mg^{+2}, Cl^- and HCO_3-.

6. The existence of four types of aquifers is concluded on the basis of their ionic behaviour. These have been classified into HCO_3 type, Ca-HCO_3 type, Na-HCO_3 type, and Na type categories.

Recommendations

From the above conclusive results, it is recommended that:

1. Groundwater of most sector/areas is suitable for human consumption and other domestic uses, except at Dhok Tarlai, Dhok Farash, and Dhok Chapran and in some sites of sectors I-8 and I-9/4. Aquifers underlain these areas/sectors contain saline groundwater.

2. It is further recommended that a wellhead protection plan must be undertaken in those areas where the quality of groundwater is being deteriorated from surface pollution.

3. A groundwater well field is recommended to establish in any of these Sectors G-7, G-8, G-9, H-8, H-9, Dhok Pandori and Saknal to abstract an excellent quality of groundwater.

4. In newly design tube-wells, upper part of the aquifer and/or aquifer No. 1 in the series of stratified confined aquifers must be sealed with the M.S. Pipe (blind pipe) to reduce the risk of groundwater contamination.

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