Assessing Public Health Risks by the Use of Deterministic Method for Multivariate Interpolation of Physicochemical Characteristics for Assessing Ground Water Quality Index Using Geo-Spatial-Based AHP Technique and Calculating Saturation Index of Alluvial Aquifer of Bahawalpur City, Pakistan

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Rec date: July 30, 2018; Acc date: August 13, 2018; Pub date: August 16, 2018

Abstract

Bahawalpur is the twelfth biggest metropolitan of Pakistan situated in South Punjab near to the bank of River Sutluj, Pakistan. This study focuses at the physico-chemical properties of drinking water of Bahawalpur which were assessed experimentally. 13 parameters were tested for 40 ground water samples. These parameters incorporate pH, EC, Total Hardness, TDS, Calcium, Magnesium, Carbonates, Bicarbonates, Chloride, Lead, Chromium, Copper and Arsenic. Testing was done for indiscriminate premises. A GPS device (GARMIN GPS) was utilized to gather samples’ geospatial data. The physico-chemical results were compared with the standard values as suggested by the World Health Organization (WHO) and Pakistan Standards and Quality Control Authority (PSQCA) for drinking. Geographic Information System (GIS) was utilized to speak to the spatial conveyance of the parameters and raster maps were made using Inverse Distance Weighted (IDW) Interpolation to classify water quality in different zones. Water Quality Index (WQI) was ascertained using Analytical Hierarchy Process. The results showed that most of the inspected areas were found unsuitable for the drinking purpose. Maximum value for TDS rose to 1904 which represented elevated amount of EC and pH also. Total hardness reached to a maximum of 602.4 mg/L which is the potential indicator of high carbonate and bicarbonate content which in turn represents high positive metallic content i.e., calcium and magnesium. Arsenic was found out to be more than permissible limits in most of the samples which is associated with many diseases such as tooth decay, Knee joint pain, kidney problems, skin pigmentation, stomach ulcer and even different types of cancer etc. among the residents of that area. The data for the diseases associated was collected from Bahawal Victoria Hospital and questionnaires being filled by natives Langelier Saturation Index was calculated to observe the corrosivity and scale forming properties of water. Results showed deterioration of piping system of water supply system from commercial to domestic level. These characteristics have direct effect on the architectural structures and also are esthetically unacceptable. Prior to the initiation of the SCARP project in Pakistan before 1990’s, that area was water logged and saline. Due to this potential reason the ground water quality of that area is highly deteriorated. Hence, the water was found out to be unfit for human consumption.

Keywords: IDW interpolation; Analytical hierarchy process; Geographic information system; Water quality index; Langelier saturation index; Pakistan standards and quality control authority

Introduction

In view of extending people improvement, human water enthusiasm for private, mechanical and rustic purposes to supply adequate food for the nation is growing and water transforming into an uncommon item in most bit of the world. Populace concentrations have made a gradually expanding contamination of the soil and ground water underneath the urban areas. By and by, it has been estimated that 20,000-60,000 km² of the region of the ground-water system in the European Communities, which adds up to 2-4 percent of the soil surface, might be contaminated inside a time of 50 years, if no move is made [1]. What’s more, present day farming has transformed into a noteworthy wellspring of ground-water contamination. The Asian range continues going up against authentic water quality issues that add to freshwater lack, wiped out prosperity, and even passing [2]. In many spots quality is continuing to diminish and lacking attempts are being made to screen and cure the condition amidst institutional and social troubles [3]. In Pakistan access to safe drinking water falls underneath pleasing levels with only 25% of the people has sensible access to quality drinking water. In an indistinguishable path from other diverse countries on the planet, Pakistan is also under amazing danger as for openness of secured and clean drinking water. Citing a review, Arrangement of Safe Drinking Water, led by the Pakistan Council of Research in Water Resources (PCRWR), Serving for Science and Innovation Rana Tanvir Hussain said just 72% of water supply plans were observed to be utilitarian, and 84% of those had provided water that was not fit for utilization [4]. The water from 14% of water supply sources in Sindh and Punjab were observed to be intensely tainted with arsenic, well over the admissible furthest reaches of 50 sections for each billion.
Study Area

Bahawalpur is found at south of the Sutlej Waterway and lies in the Cholistan area close to the Thar Abandon. It is situated 420 km from Lahore, and 270 km from Faisalabad, 90 km south of Multan, one of the Modern urban groups of Pakistan and on the southern bank of river Sutlej. Bahawalpur city lies at 29°59′55″ N Latitude and 73°15′12″ E Longitude at an elevation of 521 ft above mean sea level (Figure 1).

Previous studies indicate that Groundwater quality in Bahawalpur is deteriorating like in other main cities of Pakistan. The situation is much aggravated in Islamic colony where 55% of residents have brackish water. In Satellite town, 70% of the residents have access to water without any smell [5].

Climate and Hydrology

The most blazing months are May, June and July. The mean most extreme and least temperatures amid this period are 42 and 29 degrees centigrade separately. The winter is lovely. The coldest months are December, January and February. Amid this period the mean most extreme and mean least temperatures are 21 and 5 degrees centigrade individually. The majority of the rain falls amid rainstorm season from July to September. Winter rain is rare. Yearly precipitation is around 16 centimeters as of late, quickly expanding populace and monetary and instructive advancements of the city brought an enormous weight on normal assets including ground water, arrive utilize, farmland and so on [6].

Because of low precipitation, generally between 5 and 10 inches, the chief source of fresh-water recharge in the Bahawalpur area is the Sutlej River. Ground water moves generally southward from the river toward the desert area of Cholistan and is commonly highly mineralized; maximum concentrations of 20,000 to 25,000 ppm have been measured in test holes at or near the southern boundary of the canal irrigated area, at a distance of 25 to 35 miles from the Sutlej River [7].

Methods and Materials

Provision of safe and clean drinking water to the masses should be the foremost priority of every government as it is the basic human right. In order to identify the potential areas for future environmental health problems, regular mapping of groundwater quality is a prerequisite for every city [8]. In a demand to study the ground water quality, forty samples of tap water were picked (Figure 2). They got admitted in Hydrology lab of College of Earth and Environmental Sciences, University of the Punjab and were treated in accordance with the instructions provided by PCRWR regional lab to find the quality status of physical and chemical parameters of the water. duly rinsed with distilled water after washing with acid water were used [9].

Latitude and Longitude of sampling site were allocated using GPS by Garmin at the spot (Table 1).

| Serial No | Sample Locations | Latitude (dd) | Longitude (dd) | Elevation (ft) |
|-----------|-----------------|---------------|----------------|---------------|
| 1         | BAKRI Hajji Aslam P/S, 9 BC Hsp Road, Bahawalpur | 29.37936 | 71.72883 | 261 |
| 2         | Rohi Model School Musa Colony NaseerAbad | 29.39161 | 71.74739 | 381 |
| 3         | Water Supply System Shahrah e Quaid e Azam Govt Employees Cooperative Housing Society Bwp | 29.39628 | 71.75894 | 376 |
| 4         | Rehman Auto Industry, 8 KM, Hasilpur Road, BWP | 29.39072 | 71.76972 | 373 |
| 5         | Arabian Petrol Pump, 5 BC, HSP | 29.40178 | 71.80961 | 383 |
| 6         | Quaid e Azam Hotel and Restaurant Solar Park By Pass (8 KM) | 29.39456 | 71.79931 | 367 |
| 7         | Quaid E Azam Solar Park, BWP | 29.33503 | 71.82064 | 372 |
| 8         | IUB, Farm Gate | 29.36894 | 71.76267 | 384 |
| 9         | Sheikh Rashid Airport | 29.35203 | 71.71083 | 395 |
| 10        | Dar E Arqam 13 Soling Campus | 29.31844 | 71.70858 | 356 |
| 11        | Model Avenue Housing Scheme | 29.33489 | 71.60828 | 345 |
| 12        | New Vegetable Market, Ahmad Pur road | 29.37153 | 71.64028 | 337 |
| No. | Location                                           | Longitude  | Latitude  | Distance |
|-----|---------------------------------------------------|------------|-----------|----------|
| 13  | Bahawal Victoria Hospital                         | 29.39119   | 71.68289  | 370      |
| 14  | General Bus Stand, Bahawalpur                     | 29.40625   | 71.67853  | 355      |
| 15  | One Unit Chowk                                    | 29.38881   | 71.70222  | 358      |
| 16  | Hussaini Chowk                                    | 29.38178   | 71.71739  | 350      |
| 17  | Forest Colony                                     | 29.38417   | 71.70983  | 358      |
| 18  | Residential Colony Department of Canals           | 29.38789   | 71.69325  | 360      |
| 19  | Islami Colony, Airport Main Road, BWP             | 29.37158   | 71.69425  | 363      |
| 20  | Cantt. Area                                       | 29.36383   | 71.69264  | 347      |
| 21  | Sadar Pulli                                       | 29.39225   | 71.69292  | 354      |
| 22  | GOVT Filter Plant, Sajid Awan colony              | 29.39283   | 71.70811  | 348      |
| 23  | 32 A- Al Majeed Paradise Qamar road               | 29.39906   | 71.71356  |          |
| 24  | SAMLA Basti, Rafi Qamar Road                      | 29.38523   | 71.72036  |          |
| 25  | Govt Filter Plant, One Unit Colony                | 29.38689   | 71.70147  | 343      |
| 26  | 37 Cheema House Block 3 K Satellite Town          | 29.38808   | 71.70392  | 351      |
| 27  | Civil Hospital Jhanghi Wala Road, Bwp             | 29.41261   | 71.72017  | 350      |
| 28  | Jhangi Wala, Main Boulevard, BWp                  | 29.42583   | 71.76392  | 377      |
| 29  | New Model Central Jail, BWP                       | 29.40639   | 71.69006  | 354      |
| 30  | Bahawalpur, Zoo                                   | 29.40217   | 71.68139  | 357      |
| 31  | Filter Plant, Model Bazar oppo Police Line Market | 29.39953   | 71.68436  | 345      |
| 32  | Abbassia Campus, IUB                              | 29.39822   | 71.69231  | 357      |
| 33  | Johar Town, Lane 4, Bwp                           | 29.39336   | 71.72017  | 350      |
| 34  | Akbar Colony, Street No.1, House 2, Satellite Town, BWP | 29.39133 | 71.71694  | 383      |
| 35  | Filter Plant, Model Town A                        | 29.39336   | 71.66197  | 356      |
| 36  | Filter Plant, Model Town C                        | 29.40503   | 71.66778  | 349      |
| 37  | Shahadra main Market Chowk, BWP                   | 29.40639   | 71.66217  | 343      |
| 38  | 76 A, Hashmi Garden, BWP                          | 29.37544   | 71.66886  | 359      |
| 39  | Agriculture and Research Institute, Bwp           | 29.38578   | 71.65442  | 405      |
| 40  | Railway Station                                   | 29.40275   | 71.65264  | 460      |

**Table 1:** location of sampling sites.

Total Dissolved Solids, Electrical Conductivity and pH were measured using TDS meter (model HI8314), Electrical conductivity meter (model HI98304) and pH meter (model HI8314) by Hanna [10]. Total Hardness, calcium and magnesium were determined titrimetrically using EDTA [11]. Chloride was estimated by performing argentometric titration [12]. Concentrations of carbonates and bicarbonates were calculated using titration method using methyl orange and phenolphthalein as an [13]. Lead, Copper, Chromium and Arsenic were measured using Atomic Absorption Spectrometer [14].

**Database creation and GIS analysis**

MS Excel program was used to enter and arrange data obtained from experimental analysis. Data was stored in xls format. Calculations were performed on the same sheet using basic formulas of mathematics. Excel data was easily transported to GIS in csv (comma delimited) format to create a shapefile. Another excel sheet was used to calculate the water quality index using Analytical Hierarchal Technique. Langelier Saturation Index was also calculated to some extent using MS Excel.
IDW interpolation technique

ArcGIS 10.3 was used to create thematic maps of the original data by applying IDW interpolation technique. A point shapefile was created using excel data. Shapefile for the boundary of the targeted area was extracted from Google earth. Its spatial references were adjusted accordingly when imported from Google earth to ArcMap. All the layers in GIS were assigned UTM coordinates. From interpolation methods, IDW was selected. This technique assigns values to the valueless points by considering neighboring values. Thematic maps were produced using this technique. These thematic maps create zonation of the whole area according to the assigned values.

Water quality index

Studies suggest WQI and GIS based overlay mapping techniques can be used to integrate multiple parameter values to a single index value and multiple layers into a single map respectively [15]. Water Quality Index shows a single value, obtained from many different parameters’ values, representing the overall quality of water at a place. For calculating water quality index, AHP technique was used. Analytical Hierarchy Process is a technique based on assumptions through reviewing and comparing with other weighting methods. The Analytic Hierarchy Process (AHP) was identified to be a suitable tool to establish the weights of water quality parameters [16]. It requires assigning values to different parameters between 1 and 9. On the basis of number of parameters, nth value for each parameter is calculated. Relative weight (W_i) is calculated from these nth values. A sensitivity analysis was performed to cross check the above process. A total of 10 parameters were used to assess the water quality of the area. When relative weights are calculated, their weightage is calculated out of 100 by multiplying each W_i with 100 (Table 2). WQI is a useful tool for providing a summary of the entire water environment system by integrating the information of various indicators [17].

| Parameter | TDS | Chloride | Calcium | Magnesium | Electrical conductivity | Ph | Lead | Copper | Chromium | Arsenic | Cadmium | Bicarbonate | Total Alkalinity | Iron | Caronate | Total Hardness | Product | nth value | weight (W_i) |
|-----------|-----|----------|---------|-----------|------------------------|---|------|--------|-----------|---------|---------|--------------|-----------------|------|----------|---------------|---------|-----------|-------------|
| TDS       | 1   | 2        | 3       | 3         | 3                      | 4 | 2    | 2      | 2         | 5       | 3       | 2            | 3               | 1    | 1        | 4             | 6220    | 80        | 3.79         |
| Chloride  | 0.5 | 1        | 2       | 4         | 4                      | 3 | 2    | 2      | 1         | 3       | 2       | 3            | 1               | 4    | 2        | 2             | 5529    | 6         | 2.98         |
| Calcium   | 0.33| 0.3333   | 0.5     | 1         | 3                      | 3 | 4    | 3      | 2         | 2       | 1       | 3            | 1               | 2    | 2        | 1             | 5184    | 3         | 2.35         |
| Magnesium | 0.33| 0.3333   | 0.25    | 0.3333    | 4                      | 1 | 3    | 2      | 2         | 2       | 1       | 1            | 2               | 3    | 1        | 2             | 64      | 1         | 1.51         |
| Electrical conductivity | 0.25 | 0.25    | 0.25    | 0.25      | 1                      | 4 | 1    | 1      | 2         | 2       | 1       | 3            | 3               | 2    | 3        | 4             | 8.1     | 2         | 1.23         |
| Ph        | 0.16| 0.1667   | 0.33    | 0.3333    | 0.2                    | 1 | 2    | 3      | 3         | 4       | 1       | 2            | 1               | 1    | 1        | 1             | 0.53    | 3         | 0.93         |
| Lead      | 0.5 | 0.5      | 0.25    | 0.5       | 0.5                    | 1 | 3    | 1      | 2         | 3       | 1       | 3            | 3               | 2    | 2        | 1             | 3.37    | 5         | 1.12         |
| Copper    | 0.5 | 0.5      | 0.3333  | 0.3333    | 0.3333                 | 1 | 0.5  | 0.33 | 0.3333    | 0.5     | 0.5     | 0.5          | 3               | 2    | 1        | 1             | 1.33    | 2         | 1.02         |
| Chromium  | 0.5 | 0.5      | 0.5     | 0.5       | 0.5                    | 1 | 0.5  | 0.5 | 0.3333    | 0.5     | 0.25    | 0.2          | 1               | 2    | 1        | 2             | 0.75     | 2         | 0.97         |
| Arsenic   | 0.2 | 0.3333   | 0.25    | 0.3333    | 0.25                   | 0.5 | 1    | 0.33 | 0.3333    | 0.25    | 0.25    | 0.2          | 1               | 1    | 2        | 2             | 0.01    | 3         | 0.63         |
| Cadmium   | 0.33| 0.3333   | 0.5     | 0.5       | 0.5                    | 0.25| 0.3333    | 0.33 | 0.3333    | 0.6     | 1       | 2            | 0.27            | 1    | 1        | 1             | 0.00    | 4         | 0.92         |
Table 2: AHP Technique to calculate water Quality Index.

| Parameter | Value 1 | Value 2 | Value 3 | Value 4 | Value 5 | Value 6 | Value 7 | Value 8 |
|-----------|---------|---------|---------|---------|---------|---------|---------|---------|
| Bicarbonate | 0.5 | 0.33 | 333 | 1 | 1 | 0.5 | 0.25 | 0.33 |
| Total | 0.33 | 333 | 0.5 | 0.333333 | 0.5 | 1 | 0.5 | 0.5 |
| Alkalinity | 333 | 0.5 | 1 | 2 | 2 | 2 | 2 |
| Iron | 0.00 | 1029 | 0.50 | 2613 | 0.00 | 1736 | 0.50 | 9612 |
| Carbonate | 0.00 | 1157 | 0.50 | 8568 | 0.00 | 1157 | 0.50 | 9612 |
| Total Hardness | 0.00 | 1157 | 0.50 | 8568 | 0.00 | 1157 | 0.50 | 9612 |

Table 3: Ranking of Water Quality Index.

| Quality | WQI |
|---------|-----|
| Excellent | WQI (95-100) |
| Very Good | WQI (89-94) |
| Good | WQI (80-88) |
| Fair | WQI (65-79) |
| Marginal | WQI (45-64) |
| Poor | WQI (0-44) |

Saturation index

Langelier Saturation Index is the measure of saturation of water with respect to concentration of calcium carbonate. It is the measure of corrosiveness and scale forming property of water. Usually this property is considered for brackish waters. Saturation index is based on approximation of the base 10 algorithm. It is calculated using concentrations of six parameters viz; pH, temperature, calcium, bicarbonate and TDS. It was calculated from the below given formulas for each sample, using MS Excel. Results include three types of saturation values which are:

- Negative, indicating that water is under saturated and of corrosive nature.
- Positive, showing that water is over saturated and scale forming by nature.
- Zero, indicating the neutral nature of water. It will neither be corrosive nor scale forming.

LSI is given by the formula:

$$LSI = pH - pH_s$$

Where:

- pH is the measured water pH.
- pHs is the pH at saturation in calcite or calcium carbonate and is defined as: $pH_s = (9.3 + A + B) - (C + D)$.
- $A = \log_{10} (\text{TDS} - 1) / 10$.
- $B = -13.12 \times \log_{10} (\text{ToC} + 273) + 34.55$.
- $C = \log_{10} [\text{Ca}^{2+} \text{as CaCO}_3] - 0.4$.
- $D = \log_{10} [\text{alkalinity as CaCO}_3]$.

Results and Discussion

Results of forty ground water samples from the study area for physical and chemical analyses demonstrate that concentrations of majority of parameters of the samples are high. The hardness of water is indicated by drinking and washing properties of water. This indicates high amounts of carbonates and bicarbonates in it. If so, associated cations normally calcium and magnesium should also be present which are confirmed by further experimentation.

Spatial distribution map of total hardness

Hard water is depicted with high mineral substance that are by and large not damaging for individuals.

**Figure 3:** Spatial Distribution of TH.
It interferes with for all intents and purposes each cleaning task from washing and dishwashing to showering and individual preparing. As demonstrated by World Health Organization (WHO) hardness of water should be 500 mg/L (Graph A). In study areas, hardness ranges from 93 mg/L of IUB, Homestead Door to 530 mg/L in Bakri oil station (Figure 3).

Graph A: Concentration comparison of TH.

Spatial distribution map of pH

As indicated by the University of Rhode Island, pH is "a standout amongst the most well-known examinations in water testing and is the standard measure of how acidic or soluble an answer is."

Graph B: Concentration comparison of pH.

The normal range given by WHO for pH of drinking water is 6.5 to 8.5, and water with a pH<6.5 is acidic while pH>8.5 is basic. It reaches from 6.6 to 7.4 in different territories of study area (Graph B). Subsequently, in study regions the pH qualities were not surpassed as far as possible however these were falling in fundamental or soluble range (Figure 4).

Spatial distribution map of TDS

TDS stands for Total Dissolved Solids. It effects the Electrical properties of water. It depicts amount of impurity present in water. The EPA and WHO sets a limit of 500 mg/liter for TDS. Right when TDS levels beat 1000 mg/L it is by and large observed as unfit for human utilize. TDS is extents from 264 mg/L to 1904 mg/L in different regions of the city (Graph C). Thus, it was observed to be unfit for drinking in many regions (Figure 5).

Graph C: Concentration comparison of TDS.

Spatial distribution map of EC

Electrical Conductivity is the ability of the water to conduct electricity. Pure water has an electrical conductivity in a much less decimal value. As shown by WHO measures EC regard should not outperformed 400 μS/cm (Graph D).

Graph D: Concentration comparison of EC.

Figure 5: Spatial Distribution of TDS.
Polished issues of water with an EC as high as 150 μS/cm, are that it tastes salty and water with an EC higher than 300 μS/cm, disregard to smother the thirst. The EC was found out to be in between 1 μS/cm and 1922 μS/cm (Figure 6).

Carbonate that takes after this way speaks to a linkage between the carbon cycle and the hydrologic cycle. The grouping of carbonates in characteristic waters is an element of broke up carbon dioxide, temperature, pH cations and other disintegrated salts concentration levels are shown in Graph E. Carbonate concentration ranges from 33 to 180 in various areas of the city (Figure 7).

Spatial distribution map of bicarbonates

The Bicarbonate (HCO₃⁻) particle is the central antacid constituent in all water supplies. Bicarbonate alkalinity is brought into the water by CO₂ dissolving carbonate-containing minerals. Bicarbonate is a characteristic part of every mineral water.

Figure 6: Spatial Distribution of EC.

Figure 7: Spatial Distribution of Carbonate.

Figure 8: Spatial Distribution of Bicarbonates.
Mineral waters that are sourced from limestone-rich regions commonly have a high bicarbonate content. WHO and EPA has not set ideal breaking points for bicarbonates independently. However, carbonates and bicarbonates adds to relative alkalinity of water. The limit for bicarbonates in water ranges from 62 mg/L to 711 mg/L in different zones of the city (Graph F). Bicarbonates concentration in water relies on upon pH and is for the most part under 500 mg/l in groundwater (Figure 8).

Both calcium and magnesium are fundamental minerals and gainful to human wellbeing in a few regards [18]. Lacking admission of either supplement can bring about unfavorable wellbeing results. Permissible limits given by PSQCA for calcium are 200 mg/L (Graph G). WHO and EPA have not any advisable limits for it. Calcium ranges from 46 mg/L to 386.3 mg/L in the targeted areas (Figure 9).

Appreciating water in which magnesium is accessible at high obsessions (above around 250 mg/l each) can have a diuretic affect, notwithstanding the way that data prescribe that purchasers acclimate to these levels as exposures continue. Permissible limits given by PSQCA for magnesium are 100 mg/L (Graph H). WHO and EPA have not any advisable limits for it. Magnesium ranges from 22 mg/L to 247.2 mg/L in the targeted areas (Figure 10).

With atomic number 17 on the periodic table, Chlorine is rich in nature in its chloride molecule shape found in countless salts that are in the earth. Chloride in surface and groundwater from both typical and anthropogenic sources, for example, keep running off containing street de-icing salts, the utilization of inorganic excrements, landfill leachates, septic tank effluents, creature encourages, mechanical
effluents, water structure spillage, and seawater impedance in shoreline front degrees [19]. Chloride develops the electrical conductivity of water and along these lines fabricates its harming inclination. WHO has set its permissible limits for chloride as 250 mg/L (Graph I). Chloride ranges from 54 mg/L to 659 mg/L (Figure 11).

Spatial distribution map of lead

Lead is the commonest of the brain boggling portions, addressing 13 mg/kg of Earth’s covering. Inorganic lead is not used as a piece of the body. Unabsorbed dietary lead is disposed of in the waste, and lead that is used however not held is discharged unaltered by techniques for the kidneys or through the biliary tract. WHO has set its permissible limits for lead as 0.01 mg/L while EPA, Pakistan has set its limits up to 0.05 mg/L (Graph J). Lead ranges from 0.03 mg/L to 0.21 mg/L in sampling zones (Figure 12).
Spatial distribution map of copper

In immaculate water, the copper (II) atom is the more common oxidation state. At lower estimations, copper particles can accomplish signs essential of nourishment harming (headache, nausea, regurgitating, the runs).

Spatial distribution map of arsenic

Arsenic is brought into water through the breaking of rocks, minerals and ores [20], from mechanical effluents, including mining squanders, and by strategies for climatic declaration [21]. WHO advised arsenic to be permissible at 0.01 mg/L (Graph M).

Not only in Southern Punjab, Arsenic contamination and its increasing contents in ground water are found throughout the Indus aquifer system starting from Punjab in Kashmir, extending to the remote areas of Asian plate. This situation needs a serious attention. Arsenic, which is the most important content to be highlighted among all the metallic and nonmetallic content of water samples, was found out to be in between 0.0003 mg/L to mg/L in observed areas (Figure 15).
Water quality index map

The WQI is a unitless number running from 1 to 100; a higher number is characteristic of better water quality. It includes the combined effects of many parameters. Thematic map of water quality index was developed using AHP. Thematic map shows poor water quality areas towards South East of the city while the Northern areas shows good water quality. Hence, to a general trend, it can be assumed that water quality is getting bad as we move from west to east of the city. Similarly, going from North to South a deteriorating trend in water quality is observed. North Western areas show good quality of water (Figure 16).

Corrosion and scale formation

Corrosive and scale forming nature of many samples has been identified using Langelier saturation index. According to the results, architectural structures in some of the sampling sites are subjected to serious threat of corrosion due to water possessing negative saturation index. The other areas are in a slight threat of corrosion in which some samples are scale forming while others are not. In such areas, hard water is responsible for damaging water supply structures from commercial level to domestic one. It is found to be corrosive in some areas and causes deterioration of internal structures of pipes. A perfect sample with zero saturation index was not found anywhere (Table 4).

| Serial No | GW   | Langelier Saturation Index (LSI) | Indication based on Langelier (1936)               |
|-----------|------|----------------------------------|--------------------------------------------------|
| 1         | GW-1 | 1                                | Scale forming but non corrosive.                  |
| 2         | GW-2 | -0.017                           | Slightly corrosive but non-scale forming.         |
| 3         | GW-3 | -0.22                            | Slightly corrosive but non-scale forming.         |
| 4         | GW-4 | -0.053                           | Slightly corrosive but non-scale forming.         |
| 5         | GW-5 | -0.019                           | Slightly corrosive but non-scale forming.         |
| 6         | GW-6 | -0.15                            | Slightly corrosive but non-scale forming.         |
| 7         | GW-7 | 0.44                             | Slightly scale forming and corrosive.             |
| 8         | GW-8 | -0.72                            | Serious corrosion.                                |
| 9         | GW-9 | -0.36                            | Slightly corrosive but non-scale forming.         |
| 10        | GW-10| -0.47                            | Slightly corrosive but non-scale forming.         |
| 11        | GW-11| -0.45                            | Slightly corrosive but non-scale forming.         |
| 12        | GW-12| -0.092                           | Slightly corrosive but non-scale forming.         |
| 13        | GW-13| -0.49                            | Slightly corrosive but non-scale forming.         |
| 14        | GW-14| -0.87                            | Serious corrosion.                                |
| 15        | GW-15| -0.17                            | Slightly corrosive but non-scale forming.         |
| 16        | GW-16| 0.7                              | Scale forming but non corrosive.                  |
| 17        | GW-17| -1.1                             | Serious corrosion.                                |
| 18        | GW-18| -0.28                            | Slightly corrosive but non-scale forming.         |
| 19        | GW-19| 0.019                            | Slightly scale forming and corrosive.             |
| 20        | GW-20| 0.025                            | Slightly scale forming and corrosive.             |
| 21        | GW-21| -0.72                            | Serious corrosion.                                |
| 22        | GW-22| -0.34                            | Slightly corrosive but non-scale forming.         |
| 23        | GW-23| -0.6                             | Serious corrosion.                                |
| 24        | GW-24| -0.78                            | Serious corrosion.                                |
| 25        | GW-25| -0.44                            | Slightly corrosive but non-scale forming.         |
| 26        | GW-26| -0.71                            | Serious corrosion.                                |
| 27        | GW-27| -0.24                            | Slightly corrosive but non-scale forming.         |
| 28        | GW-28| -0.61                            | Serious corrosion.                                |
| 29        | GW-29| 0.069                            | Slightly scale forming and corrosive.             |
| 30        | GW-30| -0.19                            | Slightly corrosive but non-scale forming.         |
| 31        | GW-31| -0.45                            | Slightly corrosive but non-scale forming.         |
| 32        | GW-32| -0.95                            | Serious corrosion.                                |
| 33        | GW-33| -0.85                            | Serious corrosion.                                |
| 34        | GW-34| -0.35                            | Slightly corrosive but non-scale forming.         |
Conclusion and Recommendations

Hardness of drinking water is significant for both aesthetic acceptability and operational considerations. Water for majority areas is found unfit for drinking purposes. Hardness in water prevails throughout. Water is found out to be brackish and unacceptable for drinking. High arsenic content is also found out to be dominating in the region which is the cause of stomach ulcer and even different types of cancer etc among the residents of that area who consume this brackish water. Further, the high hardness of water is the reason behind curd forming properties of soaps and detergents in that area. This causes dryness to skin. Skin pigmentation is prevailing. Skin cancer risk is enhanced. Nails become dry and hard. Hair problems are common due to washing with hard water which include split ends, dryness and loss of hair. Hair color is changed and it usually fades from the original one. Hair growth is retarded. As this hard water is affecting people externally, likewise, it causes severe ill effects internally. It is the cause of major chronic diseases like cancer and bone deformation.

All such conditions lead to many basic problems from dish washing to dryness of skin and is also responsible for causing many diseases associated with high metallic content in water such as stomach problems, dermatological issues, cardiovascular diseases, growth retardation and reproductive failure. Water softener series can be incorporated at both commercial and domestic level. Iron curtain Filter System can be installed at a commercial level. Reverse osmosis system can be used to remove hardness of water commercially.

Acknowledgements

This research was financially funded by College of Earth and Environmental Sciences, University of the Punjab, Lahore, Pakistan. We are grateful to our respected principal/supervisor Dr. Sajid Rashid Ahmad and Dr. Ihitkar Ahmad for their immense guidance and cooperation which they provided to us at every stage of research.

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