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PREDICTING LONG TERM TRENDS OF GROUNDWATER QUALITY IN FAISALABAD USING STOCHASTIC FRAMEWORK

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Water is a most important element for life. Water pollution is the most common threat concerning to public health in Pakistan. In order to check groundwater quality for drinking purpose, research was conducted in Lyallpur town which is an industrial area of District Faisalabad. The area was divided into four zones for sampling and groundwater quality evaluation. Sixty water samples from existing sources along with coordinates and four soil samples were taken to understand the mobility behavior of contaminants. Paharrang drain passing through research area was expected to be the main source of soil and groundwater contamination. Therefore sampling points for drinking water samples were selected keeping in consideration the relative position from the drain. The collected samples were analyzed for physio-chemical parameters such as pH, EC, TDS, Ca, Mg, Cl, bicarbonates. The results obtained from these samples were compared with WHO guidelines. The values of these results were represented by a mapping of quality parameters using ArcView GIS v9.3 and IDW was used for raster interpolation. The long term trends of all the groundwater quality parameters revealed that there is an increasing effect of contamination with respect to time. Soil analysis of the study area showed sandy loam soil texture overall consequently showing high rates of infiltration through soil. It was concluded that water is partially not fit for drinking specifically due to increased concentration of TDS, Chlorine, and hardness. Direct use of this groundwater for drinking purpose may cause health issues gastrointestinal illness, nausea, eye/nose irritation etc.
Keywords: Groundwater, water quality parameters, GIS, IDW, contamination

INTRODUCTION

Groundwater is widely used for domestic, industrial and irrigation purposes and over 91% of drinking water requirement is fulfilled by this. It is the renowned fact that contaminated environment has a harmful effect on human, animal and plant life (Saeed and Bruen, 2003).

The groundwater quality deterioration due to sewage and solid waste disposal is examined at different sources like bore wells and open wells by water quality analysis. One of the main sources of groundwater contamination is open drains that used as sewers. Water from open drains is often contaminated by bacteria from domestic sources. These infiltrate into the subsoil and reaches to groundwater bearing layers down to a depth of 15m beneath the surface (Hoencamp, 2007). Because of unique chemical properties of water due to its polarity and hydrogen bonding, it has the ability to dissolve, suspend, adsorb and absorb various compounds. Thus water is not pure in nature, as it gains contaminants from its contiguous and those arising from humans and animals as well as other biological activities (Khattak *et al.*, 2012).

In Pakistan, groundwater contamination is mainly due to byproducts of different industries such as sugar processing, textile, dying, Cement, leather, fertilizers, pesticides, food processing and others. These industrial effluents have leached down from the drain and pollute the groundwater (Rizwan and Riffat, 2009). It is estimated that in developing countries 60% of the population has no availability of pure drinking water. The health problem is mainly due to groundwater contamination. Worldwide, about 2.3 billion people suffered from different diseases due to contaminated water (UN World Water Development Report, 2003). In last two decades, patient's number has increased about 200% due to polluted water. About 20 to 40% patients admitted in the hospitals are suffering from water borne diseases (Rizwan *et al.*, 2009).

Faisalabad city has made rapid progress in the industry since independence. It is famous for its different industries such as paper, leather, textile, sugar, vegetable oil, soaps, detergents, and many other industries. As a result of industries, a large amount of organic and inorganic solid wastes and heavy metals are being disposed of into the natural streams and drains (Farah *et al.*, 2002). The groundwater is badly affected due to the haphazard construction of different industries which discharge their untreated polluted effluent into open fields around them (Nasir *et al.,* 2016).

GIS has great importance for use in solving environmental problems. It has permitted successful assimilation of water quality variables into a comprehensive format (Nas and Berktay, 2006). The assessment of groundwater quality through mapping has facilitated by using GIS. It offers great opportunities for the simulation of groundwater mapping (Dixon, 2005). There has great utilization of GIS based water quality map in the analysis of evaluating the spatial variability of groundwater quality and modeling of environmental change detection (Skidmore *et al.,* 1999). The risk associated with a contaminated groundwater system often refers to the chance of damaging a human's health through various exposure pathways. By using stochastic framework approach we can examine uncertainties associated with both source/media conditions and evaluation criteria in a groundwater quality assessment (Chen *et al.*, 2003).

There is a need to translate water quality modeling data into an understandable form so that user gets help to make related judgments and decisions (Song and Kim, 2009). Keeping this in view, GIS and field studies we have investigated for the assessment of groundwater quality of Lyallpur town Faisalabad and predict a future scenario of groundwater quality.

MATERIALS AND METHODS

Study area**:** The area of Lyallpur Town, Faisalabad City (Fig. 1) was selected for this study with the criteria that the area was thickly populated and Paharang drain passes through the area which is expected to be the main source of contamination. The major part of the study area is industrial and people using groundwater for domestic use.

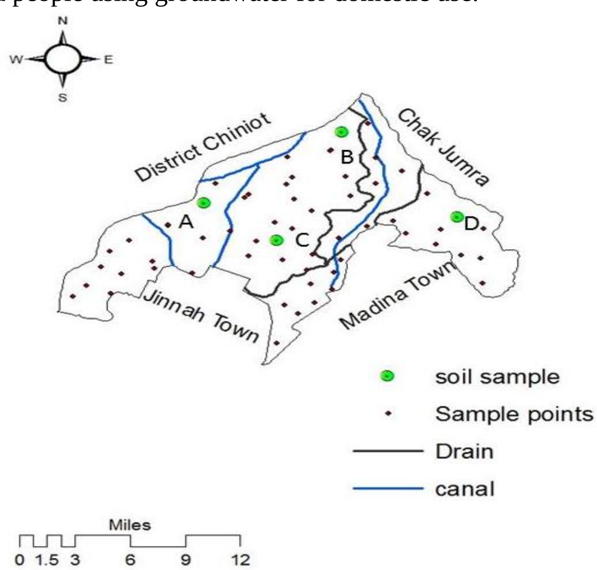

Figure 1. Map of Lyallpur town Faisalabad.

Sampling plan**:** As part of the study, groundwater samples were collected from different areas of Lyallpur Town, Faisalabad. Samples were randomly taken from the whole area from newly installed pumps to investigate the different water quality parameters in the groundwater. These pumps were installed at the average depth of 90 ft. Samples were collected from the area through taps. The pump was run for almost 5 minutes to get fresh water supply from the groundwater, the sample was taken from direct connection of the pump. The practice was done to avoid change in the groundwater properties due to deposits present in the pipes. The samples were taken in 500 ml bottles. The total 60 water samples and four soil samples were collected from the whole area. After collection of the samples, the samples were preserved and analyzed in the Environmental Engineering laboratory of Department of Structures & Environmental Engineering, University of Agriculture, Faisalabad.

Location of sample points**:** The location of sample points was found with the help of co-ordinates of points. The co-ordinates of the sample points were taken with the help of Global Positioning System receiver (GPS Receiver). For this purpose, Explorist 210 GPS receiver was used and coordinates were recorded in UTM projection (Asma *et al.,* 2012).

Determination of physio-chemical parameters**:** Water samples were analyzed for various physio-chemical parameters. pH was determined by using pH meter while EC and TDS by HACH CO 150 Conductivity meter directly (Tahir, 2003). Chloride, bicarbonates, Calcium was determined by titration method while magnesium and alkalinity by using mathematical formulas.

For the determination of bicarbonates methyl orange was used as an indicator in 10ml of the water sample. The color changed into light yellow that indicates the presence of bicarbonates. It was titrated against the 0.02N HCl solution until the color changed to orange. The used volume of HCl was multiplied by 100 to find number of bicarbonates in milligram per liter (Jain and Monika, 2007).

Meuroxide indicator is used to find calcium in the sample. The pink color appeared after adding an indicator. Then added 0.5ml NaOH (1Molar) buffer solution in the sample and titrated it against the 0.01Molar EDTA solution until the pink color changed into purple. The used volume of EDTA was multiplied by 40 which gave the amount of Ca^{+2} in milligrams per liter (Jain and Monika, 2007).

Magnesium value is found by using mathematical formula directly.

$$Mg(mg/L) = (\text{Hardness value} - 2.5 * \text{Ca value}) * 0.243$$

(DeZuane, 2007)

In a 20 ml water sample, added 2 to 3 drops of potassium chromate (indicator) which changed the water color to yellow. It was titrated against the 0.02Molar silver nitrate solution until the yellow color changed into pinkish yellow. The used volume of silver nitrate was multiplied by 35.45 which gave the amount of chloride in milligram per liter (Jain and Monika, 2007).

To find out the long term trend of groundwater quality in Lyallpur town, Faisalabad city, RStudio was used. Firstly, a probability distribution function of all the groundwater quality parameters was drawn by using RStudio and after that we developed an equation for long term trend (Hamid, 2011).

RESULTS AND DISCUSSION

pH**:** pH analysis of groundwater of Lyallpur Town varied from 6 to 12.4. The ranges are classified in spatial variation map shown in Figure 2. The low pH does not cause any harmful effect (Boominathan and Khan, 1994). Almost 80% of the samples of this area lie under the range for drinking water quality given by WHO. The long term trend of pH from 2008 to 2030 on the basis of probability distribution function has represented the basic behavior of water as shown in Fig.3.

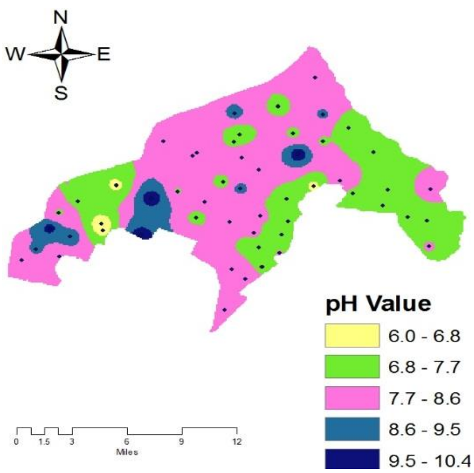

Figure 2. pH variation in Lyallpur town, Faisalabad.

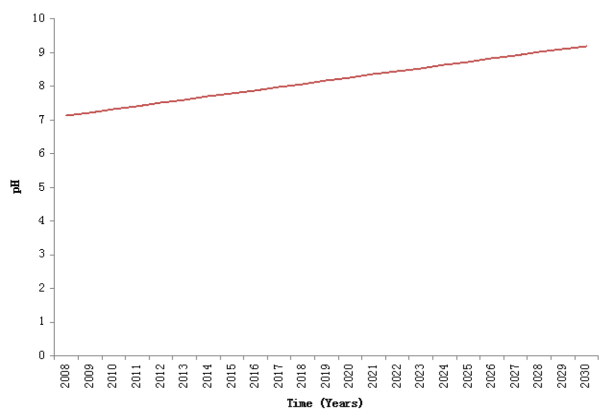

Figure 3. The future trend of pH variation in Lyallpur town, Faisalabad.

Electrical conductivity**:** Electrical Conductivity in groundwater sample of Lyallpur Town varied from 0.24 dS/m to 7.84 dS/m as shown in Figure 4. Yellow color in the map indicates that the samples in this area are somewhat near to permissible limit i.e. 2.50 µS/m given by WHO (2006). On the basis of probability distribution function long term trend of EC from 2008 to 2030 has been shown in Figure 5 that shows EC is more than 0.5 dS/m.

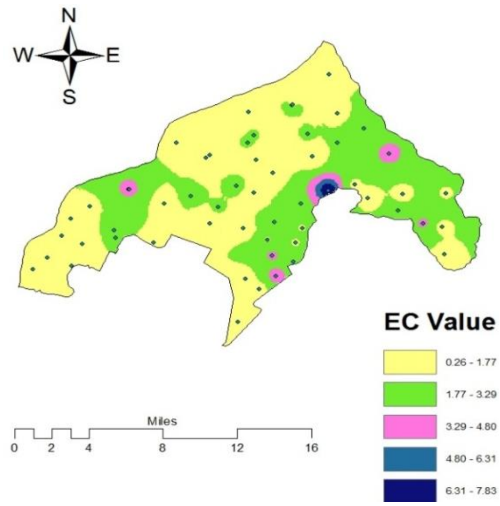

Figure 4. EC variation in Lyallpur town Faisalabad.

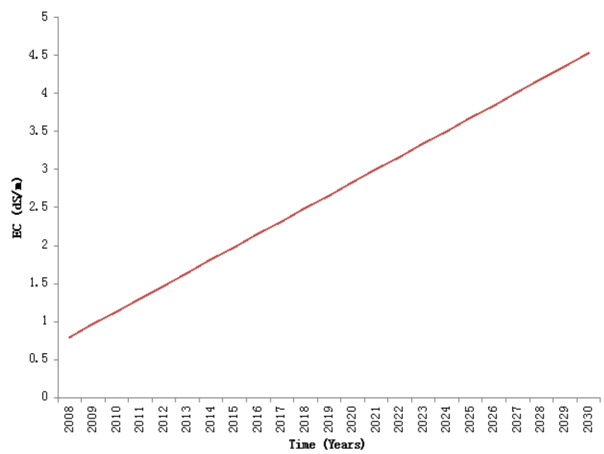

Figure 5. Future Trend of EC variation in Lyallpur town, Faisalabad.

Total dissolved solids**:** Total dissolved solids in the groundwater samples varied from 154 mg/l to 5018 mg/l. GIS analysis of the spatial variability in TDS indicates that major area has TDS value higher than the permissible limit as shown in Figure 6. The acceptable range of TDS is 500 mg/L (Rout and Sharma, 2011). Dark blue color represents the highest value of TDS that is found in the village 117 J.B. Dhanola (5018 mg/l). TDS of Ghulam Muhammadabad is varied from 309mg/L to 530mg/L (Asma *et al.*, 2012). Figure 7 represents long term trend of TDS from 2008 to 2030 on the basis of probability distribution function.

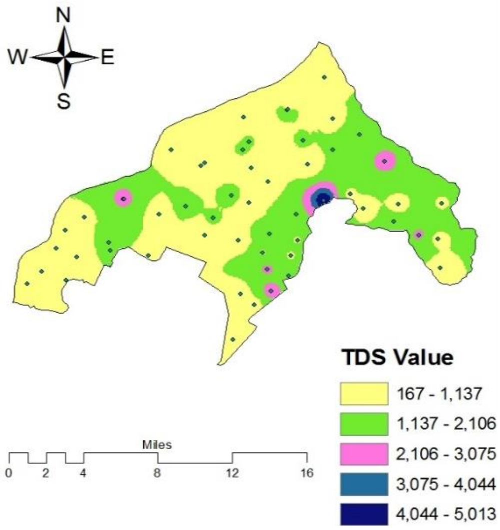

Figure 6. TDS variation in Lyallpur town, Faisalabad.

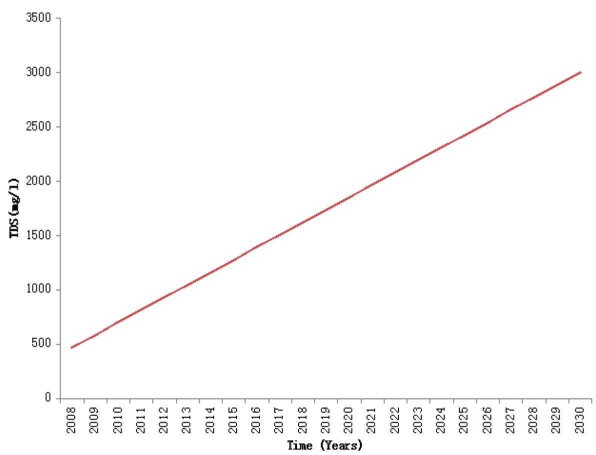

Figure 7. Future Trend of TDS variation in Lyallpur town, Faisalabad.

Bicarbonates**:** Bicarbonates in groundwater samples of Lyallpur town varied from 67 mg/l to 660 mg/l as shown in Figure 8. The high concentration of bicarbonates is indicated by purple color in the map. The R square value of the mean of these PDF is 0.7 which shows that the biasness is 30 %. The long term trend of bicarbonates from 2008 to 2030 on the basis of probability distribution function has been shown in Figure 9.

Calcium**:** Calcium is varied from 12 mg/l to 180 mg/l in this area which is illustrated in Figure 10. The R square value of the mean of these PDF is 0.6 which shows that the biasness is 40%. Figure 11 represents long term trend of calcium from 2008 to 2030 on the basis of probability distribution function that shows Ca is more than permissible limit (75ppm by KSA).

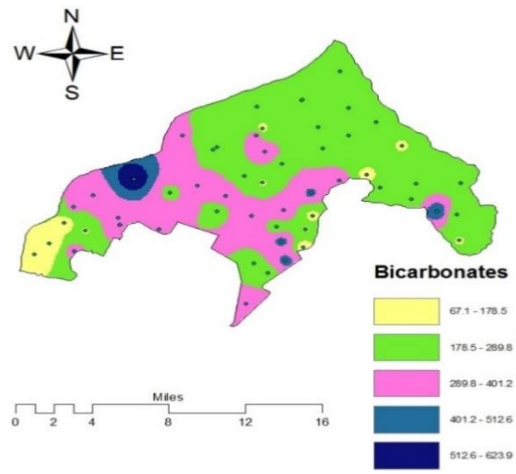

Figure 8. Bicarbonates variation in Lyallpur town, Faisalabad.

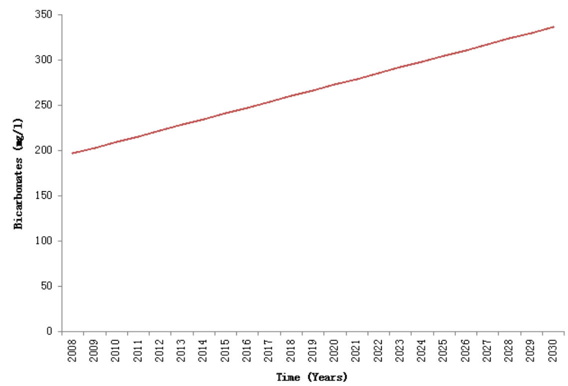

Figure 9. The future trend of bicarbonates variation in Lyallpur town, Faisalabad.

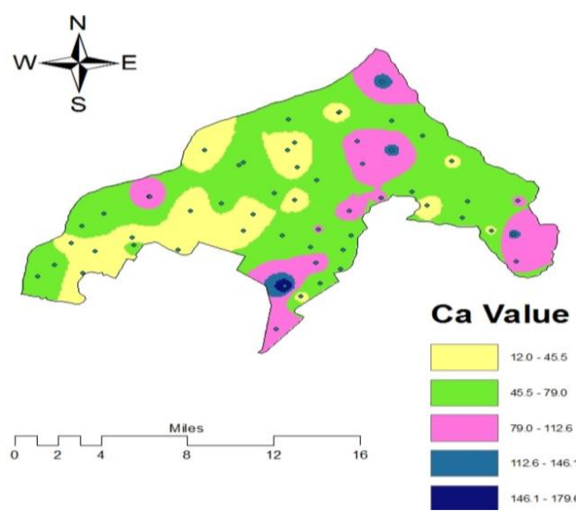

Figure 10. Calcium variation in Lyallpur town, Faisalabad.

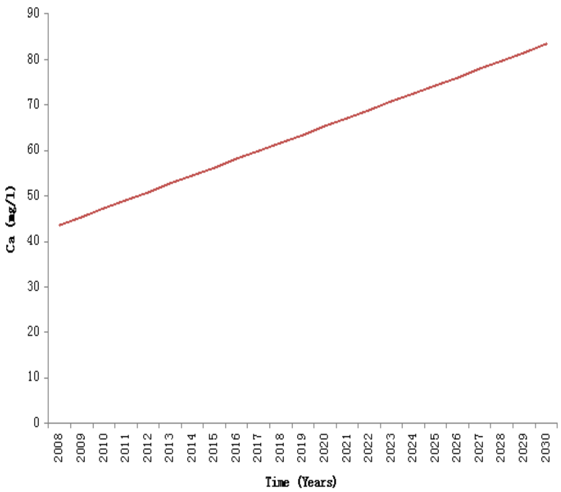

Figure 11. The future trend of calcium in Lyallpur town, Faisalabad.

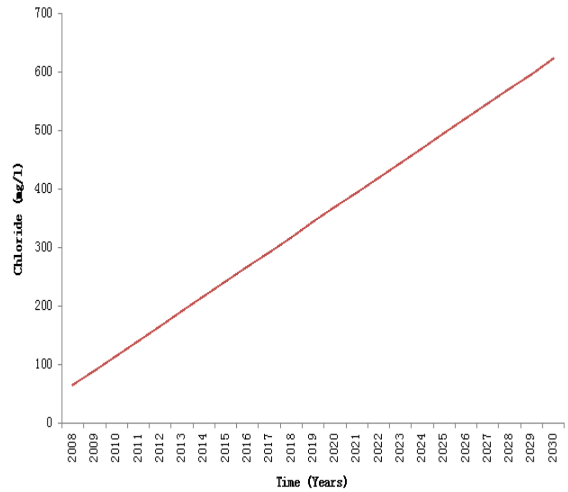

Figure 13. The future trend of chloride in Lyallpur town, Faisalabad.

Chloride**:** Chloride concentration is varied between 8 mg/l to 1319 mg/l. The spatial distribution of chloride concentration in groundwater is illustrated in Figure 12. The high concentration of chlorine varied 483 to 701 mg/l in village Gutwala, Baghian wala and khurd pur and is indicated as purple color. The increasing trend of chloride from 2008 to 2030 on the basis of probability distribution function is shown in Figure 13.

Magnesium**:** Magnesium concentration in groundwater is varied from 64.6 mg/l to 94.4 mg/l and its spatial variation is shown in Figure 14. The area covering the green color in map indicates that the magnesium value is much less than the permissible limits. Figure 15 represents long term trend of magnesium from 2008 to 2030 on the basis of probability distribution function.

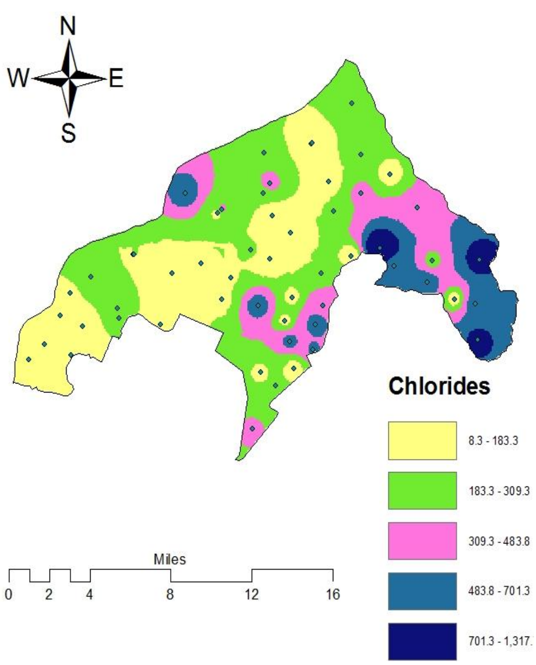

Figure 12. Chloride variation in Lyallpur town, Faisalabad.

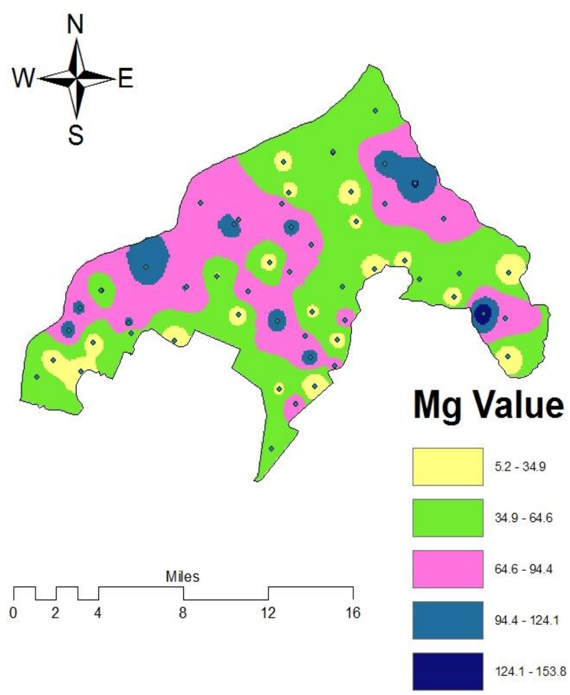

Figure 14. Magnesium variation in Lyallpur town, Faisalabad.

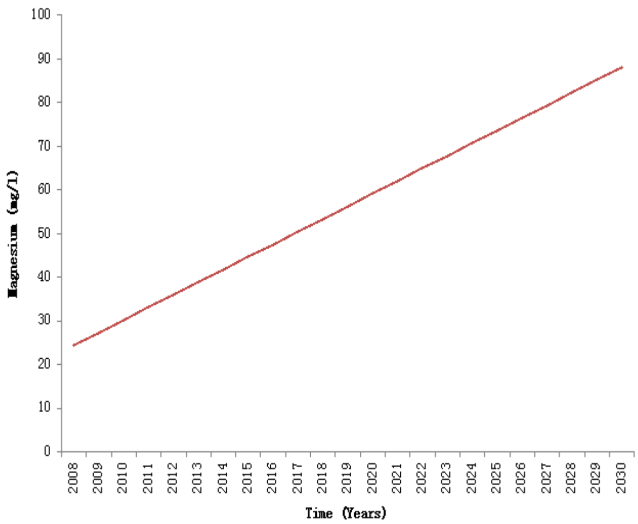

Figure 15. The future trend of Mg in Lyallpur town, Faisalabad.

Particle size analysis: For the particle size distribution of soil sample hydrometer was used and the results are given below.

Table 1. Particle size distribution of soil sample.

Soil primary particles	Sample A	Sample B	Sample C	Sample D
Sand %	52.5	75	62.5	65
Silt %	37.5	10	25	12.5
Clay %	10	15	12.5	22.5
Texture Class	Loam	Sandy Loam	Sandy Loam	Sandy Loam

From the results we have two types of texture classes. One is loam and second are sandy loam. The porosity of loam soil is 46.3% and for sandy loam is 45.3% (Miller and Donahoe, 1995). The results showed that infiltration rate is largely dependent on the relative proportion of sand, silt and clay.

Conclusion: The groundwater of Lyallpur town is partially not fit for drinking specifically due to increased concentration of chemicals. Direct use of this groundwater for drinking purpose may cause health issues such as Gastrointestinal illness, Nausea, eye/nose irritation etc. The zone A lies near the Jhang branch canal and having loamy soil so that groundwater is much better than other zones. The other three zones have sandy loam soil and most of the drainage is passing through these zones therefore percolation rate was high due to which groundwater quality is not good. The long term trends of all the groundwater quality parameters revealed that there is an increasing effect of contamination. Soil analysis of the study area shows that soil is a filter media that filter water if we apply biocides up to the certain limit in the field. The industry is playing a vital role in contaminating groundwater so further studies should be done to evaluate the role of industry in contaminating groundwater.

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