Research Article

Impact of Land Uses on Drinking Water Quality in Selected Areas of Lahore City

Sanwal Masood[1], Dildar Ahmed[2], Silvia Machado[1] and Sohaib Aslam[1*]

[1]Department of Environmental Sciences, Forman Christian College (A Chartered University), Lahore 54600, Pakistan; [2]Department of Chemistry, Forman Christian College (A Chartered University), Lahore 54600, Pakistan.

Abstract | The biggest threat to the quality of rapidly diminishing groundwater resources is the uncontrolled pollution by different human activities such as industries, sewage/wastewater drains, and agricultural practices. In the present study, water samples were collected and analyzed for selected physicochemical parameters including toxic metals for determining the impact of land uses on the ground water quality of Lahore, Pakistan. Our results showed that water of three sites namely Shadman, Samnabad and Township had the TDS above 300 mgL^{-1} and this value was comparatively greater than samples of other areas. Only one site named Ravi Town showed the extremely low concentration of DO i.e. 1.6 mgL^{-1}. All the heavy metals values were within the permissible limit as per world health organization (WHO) guidelines except for iron and silver. However, significant differences were present among the water samples of selected locations which indicated strong influence of type of land use on ground water quality. Monitoring of such activities by government departments is the deer need for conserving the quality of drinking water of this mega city.

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***Correspondence** | Sohaib Aslam, Department of Environmental Sciences, Forman Christian College (A Chartered University), Lahore 54600, Pakistan; **Email:** sohaibaslam@fccollege.edu.pk
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Introduction

Water resources of developing countries including India, Bangladesh and Pakistan are under great stress due to high population growth, industrialization and an ever-increasing use of agrochemicals (Khan *et al*., 2021). Both water quality and quantity has been affected by poor sanitation services, improper water consumption practices, untreated industrial effluents, agricultural discharge and unplanned solid waste management. In Pakistan, only 66% of total population has access to safe drinking water (Haydar *et al*., 2014). According to WHO survey, 80% of all diseases in developing countries including Pakistan are water-born (Akhtar and Zhonghua, 2013; Mazhar *et al*., 2019). Human land use activities including agricultural, commercial, industrial, municipal and industrial waste disposal are responsible for poor quality of water. The industrial effluents and sewage from residential urban areas are frequently discharged to land areas and surface water bodies without prior treatment. This uncontrolled activity leads to the contamination of groundwater with toxic metals and organic pollutants which is predominantly used for drinking purpose. The excessive intakes of heavy metals e.g., Cr, Cu, Ag, Fe, Zn etc. have adverse effects on human health. The ingestion of these heavy metals has carcinogenic effects (Khan *et al.*, 2021). The sewage water commonly contains both solid wastes and liquid wastes. It holds various trace metals and metal compounds. The constantly presence of such waters into unlined drains is permanent source of chemical leaching to groundwater. The toxic metals are also introduced into drinking water from these disposal sites and finally move down in hydrological cycle. As per an estimate, about 3,304 cusecs of wastewater is being disposed off into the Ravi River only in Lahore (Hussain and Sultan, 2013). Hussain and Sultan (2013) reported that untreated industrial effluents flowing through wastewater drains is contaminating the groundwater of the city. The Lahore drainage system consists of wastewater 14 drains collecting industrial wastes and household sewerage of the whole city (Hussain and Sultan, 2013). These drains have a great impact on groundwater quality. The values of many physical and chemical parameters such as pH, total dissolved solids and heavy metals are exceeding the acceptable limit. The industrial waste, municipal landfills and agricultural activities are considered serious dangers to adjacent urban environment.

Ashraf *et al.* (2010) conducted a study in Kasur, another city of Pakistan adjacent to Lahore, in order to determine the effects of polluted water coming from industries and sewerage used for irrigation purpose on groundwater quality. They reported that the pH of 35% of the samples was fit, of 47% samples was marginally fit and of 18% samples was unfit. The temperature of 67% samples was fit, 31% marginally fit and 2% unfit. The concentration of dissolved oxygen (DO) ranged from 5 to 8 mg/L. The 49% samples were fit, 37% marginally fit and 14% unfit. The turbidity of 28% samples was fit, 24.5% marginally fit and 47.5% unfit. The TDS of 6% samples was fit, 9.5% marginally fit and 84.5% unfit. They reported that condition of water of different sites was dependent upon the quantity of irrigation water applied, infiltration rate and soil drainage. The concentrations of Mn, Zn, Cu, Cr and Co were higher than the permissible level as set by Pakistan national environmental quality standards (NEQS). Akhtar and Zhonghua (2013) investigated the sources of groundwater contamination and reported improper disposal of solid waste, sewage, agricultural activities, urban runoff and polluted surface water as major contributors to groundwater contamination. Mazhar *et al.* (2019) assessed the physibility of groundwater for domestic use in Gujranwala city of Punjab and reported that 97.5% of water samples were bacteriologically contaminated and posed serious risk to public health. Moreover, certain metals in water samples were also found with following decreasing: Cr > Cu > Zn > As > Co > Ni > Cd. The study concluded that groundwater quality of study areas of Gujranwala has mostly deteriorated (Mazhar *et al.*, 2019). More recently, Khan *et al.* (2021) characterized various physicochemical parameters (pH, EC, TDS, DO, alkalinity, hardness, and chloride), and trace metals (such as Fe, Zn, Cu, Co, Mn, Cd, Cr, Ni, and Pb) in the groundwater of Lahore during multiple seasons. Their findings clearly demonstrated that majority of the metals had considerably higher concentrations in water samples during winter season than in summer season. Metals also exhibited spatial variability; comparatively higher metal levels in the old settlements and thickly populated areas of the city (Khan *et al.*, 2021). Moreover, Pb, Ni, Cd and Co levels in the water samples were greater than the permissible levels (Khan *et al.*, 2021).

The objective of this study was to determine the quality of ground water of selected areas of Lahore in order to see the effect of different land use activities. The groundwater samples from Gajjumatah, Mansoora, Raiwind road, Ravi Town, Samnabad, Shadman, Shahdara and Township areas based on different land uses (Table 1) were collected for water quality assessment and data was compared with Pakistan NEQS (national environmental quality standards) for drinking water quality.

Materials and Methods

Description of the study area

The city of Lahore is located north-east of the Punjab province of Pakistan between 31°-15` and 31°-42` north latitude, 74°-01` and 74°-39` east latitude. It has an approximated population of 10 million (Muhammad and Zhonghua, 2014). The altitude of Lahore city is ranging between 208 to 213 m above sea level and situated on the vast alluvial plain on bank of Ravi River. The agricultural land around Lahore city is predominantly cultivated for rice and wheat production.

Table 1: *Selected areas for water sampling and type of their use.*

Study area	Land use
GajjuMata, Shahdara, Raiwind Road	Industries e.g. Steel, Textiles, Paint
Shadman, Samnabad, Mansoora	Waste water drains (Municipal and industrial)
Ravi Town	River Ravi (sink of many drains)
Township	Wastewater drain (Used oils from Transport, Mechanical workshops)

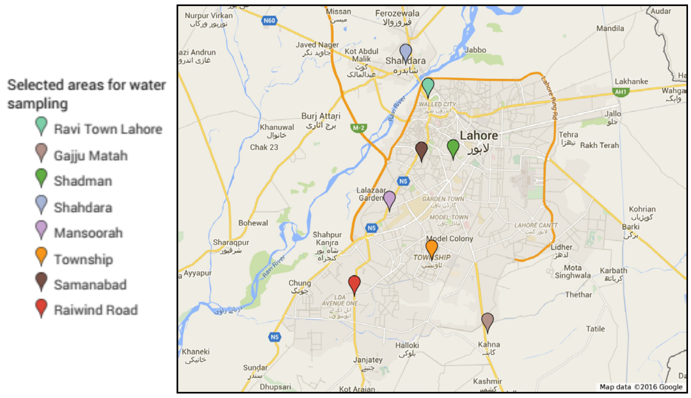

Figure 1: *Map of Lahore indicating selected areas where water sampling was carried out.*

Water sampling

Drinking water samples from taps connected to operational motor pumps were collected from selected areas of Lahore in 500-ml polystyrene bottles. Sampling bottles were first washed with distilled water to avoid contamination. All the glassware and apparatus used in this study was washed with ultrapure water and then oven-dried.

In order to study the effects of municipal, agricultural and industrial wastes on the ground water quality, water samples were collected in duplicate from eight selected locations of the Lahore city. The water samples were collected from Gajjumatah, Mansoora, Raiwind road, Ravi Town, Samnabad, Shadman, Shahdara and Township. The groundwater of these sites was supposed to be contaminated due respective land use activities. Table 1 shows the sampling areas and their respective land use. A number of industries including steel, electronics, textile, paint and leather tanneries were situated around areas of Shahdara, Gajjumata and Raiwind Road areas. All these industries present in the vicinity of these areas discharge their effluents in the surrounding land without prior treatment. A major wastewater drain (locally called as Ganda Nala) passes through Shadman, Samnabad and Mansoora areas. The wastewater in this Ganda Nala comes mainly from municipal and industrial sources without proper filtration. Organic and inorganic pollutants present in wastewater could infiltrate through soil and reach groundwater. So, ground water of these areas was supposed to be contaminated by Ganda Nala. Another Ganda Nala also passed through the Township area which contained mainly used vehicle oil and petroleum waste products originating from mechanical workshops and petrol pumps of that area. The Ravi Town was adjacent to Ravi River and all the industrial wastes of Lahore city came into it. A brief map of city Lahore along with sampling locations has been shown in Figure 1.

The samples were taken from operational ground water motor pumps which were being used by the local community for water extraction. All precautionary measures were adopted during the sampling. At each site, motor pump was run 3-5 minutes before the samples were collected. The tap was opened and water was let to flow for some time. The sampling bottles were then rinsed twice with running tap water before taking samples. Sampling was assured from the outlet of motor pump and not from the storage tank. After sampling, several drops of nitric acid were added to the bottles containing samples (decreasing pH to 2) to stop microbial activity. All samples were stored at 4°C in the laboratory until the analyses were made. The bottles were labeled correctly for identification and kept airtight.

Chemical analysis

The dissolve oxygen (DO) measurement was performed in the laboratory by using DO meter Hanna (Romania). After passing each sample, electrode of the DO meter was rinsed carefully with distilled water and then dipped into the next sample. The pH of water samples was measured in the laboratory by using WTW bench-top pH meter (Germany). Total dissolve solids (TDS) were measured in each water sample by using WTW bench-top TDS meter (Germany).

For toxic metal analysis in the water samples, atomic absorption spectrophotometer was used. For this, water samples were first filtered using Whatman filter paper in order to remove the impurities present in water samples. In addition, we pooled the two repetitions of each sample in order to get one single sample from each site. This was done to rescue the cost of analysis. The five metals namely zinc (Zn), copper (Cu), iron (Fe), silver (Ag) and chromium (Cr) were analyzed. All water analyses were done in duplicates except for metals. Means and standard deviations of all samples were determined by using XL software.

Table 2: *Comparison of WHO and Pakistan NEQS for drinking water quality.*

Parameter	Pakistan NEQS†	WHO guidelines
pH	6.5-8.5	No guidelines
TDS (mgL^{-1})	<1000	<1000
DO (mgL^{-1})	N/A	No guidelines
Copper (mgL^{-1})	2	2
Iron (mgL^{-1})	2	No guidelines
Silver (mgL^{-1})	1	No guidelines
Zinc (mgL^{-1})	5	3
Chromium (mgL^{-1})	<0.05	<0.05

† *Pakistan national environmental quality standards.*

Results and Discussion

pH

Our results showed pH range of 7.42-8.36 in all the water samples which lies within the permissible range of 6.5-8.5 as set by WHO guidelines and Pakistan NEQS (Table 3). However, there is great variation among different areas. The highest value 8.36 was in the water samples collected at Mansoora whereas the lowest value was in water samples collected at Ravi town. The pH value of Mansoora groundwater was high which can be attributed to factories located near this area. These factories were throwing their wastes into Wastewater drain (ganda nala) of Mansoora without filtration. Therefore, the high values of pH at this site is attributed to seepage of industrial waste into groundwater. The pH value of Gajjumata (surrounded by steel textile and paint industries) was also above 8 and is attributed due to discharge of industrial waste without filtration. The pH value of Samnabad (municipal and industrial wastewater drains) was 8.04. The value of pH of Township (wastewater drains and motor workshops) was 7.98 and Shahdara (industrial land use along with human settlements) was 7.86 respectively. The pH of Ravi town was lowest i.e., 7.42.

Total dissolved solids (TDS)

Total dissolve solid (TDS) in the drinking water originate from different sources including silt, sewage, wastewater, urban run-off, and chemicals used in the water treatment process. TDS data of the samples of water taken from different sites are presented in Table 3. The TDS values range from 60.5 mgL^{-1} to 371 mgL^{-1}. The results showed that TDS of Shadman was highest. The Shadman water contained 371 mgL^{-1} of TDS. This could be due to the presence of ganda nala in Shadman, because many industries and hospitals situated in Shadman throw their wastes into it without filtration. The domestic sewage is also thrown into it. It is possible that pollutants seep down in the ground water into Shadman area.

Table 3: *Chemical properties of drinking water samples from selected areas.*

Sampling area	pH	TDS (mgL^{-1})	DO (mgL^{-1})
Gajjumata	8.2±0.29	291±6.4	3.9±0.33
Mansoora	8.4±0.29	149±2.1	4.4±0.07
Raiwind road	7.8±0.15	241±16.3	4.3±0.28
Ravi Town	7.4±0.14	61±2.1	1.6±0.14
Samnabad	8.0±0.28	359±1.4	3.0±0.15
Shadman	7.7±0.28	371±9.9	2.9±0.10
Shahdara	7.9±0.12	66±2.8	3.4±0.19
Township	8.0±0.28	345±9.2	2.8±0.17
Pakistan NEQS†	6.5-8.5	<1000	n/a

† *Pakistan national environmental quality standards.*

The second highest value of TDS was at Samnabad lie 359 mgL^{-1}. The same condition is happening in Samnabad because this nala pass throw Samnabad. In Township the ganda nala is also located on college road. Many petrol pumps and workshops are located on this road. These workshops throw their waste into ganda nala. Therefore, the highest value of TDS at Township is 344.5 mgL^{-1}, could be attributed to this land use activity. The maximum contaminant level for TDS in drinking water is set as 1000 mgL^{-1} by WHO guidelines. Though TDS of all the samples were satisfactory as compared to WHO standard value 1000 mgL^{-1}, significant differences were present among them indicating impact of different land uses on groundwater quality.

Dissolved oxygen (DO)

In our study, it ranged from 1.62 mgL^{-1} to 4.35 mgL^{-1} (Table 3). The lowest dissolve oxygen level was 1.62 mg/L of Ravi Town. It has been mentioned in previous section that Ravi Town area lies adjacent to River Ravi where all the 12 wastewater drains fall collecting industrial and household waste from whole city. Lowest concentration can be attributed to contamination of organic wastes from river Ravi and these drains to the groundwater recharge. These organic wastes may go down and decrease the amount of dissolved oxygen. The dissolved oxygen value of Township area was 2.79 mgL^{-1}. This was the second lowest value of all samples. The ganda nala (wastewater drain) is present in township, which carries industrial organic effluents, domestic effluents as well as used motor-oil. They are released by surrounding industries, workshops and residential areas. The organic pollutants might have passed down into the ground water and decreased the availability of dissolved oxygen. The value of dissolved oxygen of Samnabad was 2.99 mg/L and Shadman was 2.87 mg/L respectively. These values were low because ganda nala passed throw both areas. The ganda nala which pass through Samnabad and Shadman contains organic effluents which, goes down into the groundwater and decrease the amount of dissolved oxygen. The value of Mansoora is 4.35 mgL^{-1}.

Toxic metals

Chromium has been reported to be present in waste effluents of steel, paint, and chemical industries including leather tanneries in Pakistan (Azeem, 2009). Although it is an essential micronutrient for animals and plants, its higher concentration in drinking water poses serious threat to human life. Chromium is toxic particularly in the hexavalent form. Chronic and sub chronic exposure can cause dermatitis and ulceration of the skin. The kidney, liver, circulatory and nerve tissues are damaged due to long term exposure of chromium (Mebrahtu and Zerabruk, 2011). According to WHO guidelines, chromium level of 0.05 mgL^{-1} in water is permissible for drinking purpose (Table 2). In our study, all the values of chromium were found within the limit (Figure 2).

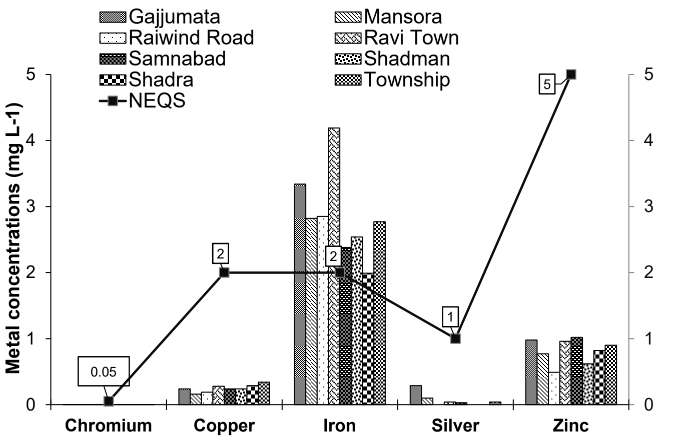

Figure 2: *Metal concentrations in drinking water samples collected from selected areas of Lahore city. Line plot along WITH data labels are the permissible limits as per Pakistan NEQS (national environmental quality standards).*

Copper is an essential element for living organisms including humans. Excessive intake of copper leads to a specific disease of the bone (Rajappa *et al*., 2010). In Pakistan, surface and ground water contamination with copper does not create any important problems. Most of the studies report copper concentration within WHO standard limits of 2 mgL^{-1} (Waseem *et al*., 2014). The values of copper concentrations in water samples of selected areas of Lahore city ranged from 0.16 mgL^{-1} to 0.34 mgL^{-1}. The highest value of copper observed in Township which was 0.34 mgL^{-1}. The second highest value was observed in Shahdara which is 0.28 mgL^{-1} and Ravi town is 0.27 mgL^{-1} respectively. Both the places are adjacent to each other and have the same source of groundwater recharge as well. The copper concentration in groundwater of Raiwind Road site was 0.18 mgL^{-1} and at Mansoora site, was 0.16 mgL^{-1}, which was the lowest of all the groundwater samples. Contamination of drinking water with copper in the studied areas arises mainly from industrial sources as well as agriculture activities.

Iron is necessary and required in human diet. The amount of iron dissolved in groundwater depends on the amount of oxygen in the water and to a lesser extent, upon its degree of acidity e.g., its pH. Iron, for example, can occur in two forms such as Fe^{2+} and as Fe^{3+}. The amount of iron in water samples ranged from 1.98 mgL^{-1} to 4.18 mgL^{-1}. The highest value of iron occurred in Ravi Town water samples, which was 4.18 mgL^{-1}. Most of the water recharge in Ravi Town area occurs by Ravi River. Wastewater coming in Ravi River originates from electrical, steel and chemical industries and may contain high quantity of iron metal. Comparatively greater concentration of Fe in groundwater of Ravi Town could be attributed to untreated industrial effluents falling in River Ravi.

The iron metal is found in exhaust, engine and breaks. High traffic rate is common in the Lahore city and motor vehicles are contributor to the pollutants on transport roads. These effluents collected on road surfaces and washed by storm or street cleansing as of road runoff. These effluents are finally collected into nearby storm water drainage. The second highest value of iron metal occurred in Gajjumata water sample which was 3.33 mgL^{-1}. There were many industries of electrical, steel and paint which throw their industrial waste without prior treatment. The high traffic rate is also a big contributor of high level of iron metal in groundwater. The iron metal concentration in groundwater of Township was 2.76 mgL^{-1}. Mechanical workshops and petrol pumps located on college road Township could be a factor og comparatively greater concentrations. The Iron contents in water samples could be associated to rust under carriage as well as iron present in the waste oil that is used to spray under carriage (Yasin *et al*., 2012). The lowest value of iron metal content was 1.98 mgL^{-1} in Shahdara.

Silver is used to make jewelry, silverware, electronic equipment, and dental fillings. The silver exposure for a long period may result in a condition called Arygyria, which is a blue gray discoloration of the skin as well as other body tissues. The silver contents ranged from 0.005 to 0.29 mgL^{-1} in water samples of present study. The highest value of silver was observed in Gajjumata groundwater which was 0.29 mgL^{-1}. The second highest value of silver was 0.10 mgL^{-1} in Mansoora groundwater. The value of silver in groundwater of Ravi Town was 0.04 mgL^{-1} followed by Township with 0.03 mgL^{-1} and Samnabad with 0.02 mgL^{-1}. In our study, differences in silver concentrations showed an effect of land uses in different areas of city Lahore.

Zinc is a necessary micronutrient and catalyzes enzyme activity. The deficiency of zinc has been known for many years but it can be toxic when the physiological limit exceeds. The severe effects related with chronic intake of zinc include acute gastrointestinal effects and headaches (Waseem *et al*., 2014). It is also associated with impaired immune function, cholesterol levels and changes in lipoprotein, reduced copper status and zinc iron interactions (Waseem *et al*., 2014). The zinc levels in collected water samples of study areas ranged from 0.49 mgL^{-1} to 1.01 mgL^{-1}. The highest value of zinc is 1.01 mgL^{-1} which was observed in Samnabad area. Zinc in water has been reported to come from wastes of steel, glass, chemical and drug industries in addition to medical and dental wastes (Azeem, 2009). The industries could have thrown their waste into Ganda Nala which pass near Samnabad and resulting in zinc seepage into groundwater. The concentration of zinc was 0.97 mgL^{-1} at Gajjumata site followed by 0.95 mgL^{-1} at Ravi Town area. There were many chemicals in glass industries located in Gajjumata which regularly throw their wastes and wastewater without proper treatment. Groundwater at Ravi Town gets recharged from River Ravi, which in turn *get all* wastes of Lahore city through different drains. The zinc at Township was 0.89 mgL^{-1} and 0.81 mgL^{-1} at Shahdara study site. Zinc can be a pollutant, especially in areas where the petroleum related activities are done. Township college road is related to petroleum activities since there many mechanical workshops including petrol pumps. The traffic rate is extremely high in Shahdara being on the Grand Trunk Road at the entry of city Lahore. In these areas, Zn concentration was supposed to be originating from alongside roads. Flowing water could seep down into groundwater after a rainfall event. The lowest zinc concentration was observed in Raiwind Road which was 0.48 mgL^{-1}. The permissible limit of zinc in drinking water is 3 mgL^{-1} according to WHO (World Health Organization).

Conclusions and Recommendations

This study assessed the impact of different land use activities on groundwater quality of Lahore city. Results indicated that type of land use had an influence on water quality parameters. Land used for industrial activities and wastewater drains can pose severe health risks because of poor monitoring by governmental and environmental agencies. Ravi Town, for example, is a densely populated area of Lahore city and lies besides the Ravi River. There are a couple of wastewater drains which pass through Ravi Town and fall in River Ravi. As many as 10 more drains discharge their industrial and domestic effluents in the river. Groundwater recharge has reduced the groundwater quality of Ravi Town as it was evident from our results. One limitation of our study was that we did not check the microbiological parameters. We suspect fecal contamination might degrade further the quality of groundwater and which is sole source of drinking water for people of these areas. In addition, we suggest the regular monitoring of ground water by governmental environmental departments to ensure the health of people which are greatly affected by water-borne diseases.

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Novelty Statement

Type of land use activity was one major reason of poor ground water quality in Lahore city.

Author's Contribution

Sanwal Masood: Conducted research work and manuscript writing
Dildar Ahmed: Assisted in lab analysis with atomic absorption spectrophotometer, editing the manuscript.
Silvia Machado: Data analysis, edited the manuscript
Sohaib Aslam: Planned and supervised the research work, proofreading and editing the manuscript.

Conflict of interest
The authors have declared no conflict of interest.

References

Akhtar, M.M., and T. Zhonghua. 2013. Identification of contamination sources and TDS concentration in groundwater of second biggest city of Pakistan. Int. J. Environ. Sci. Dev., 4(3). https://doi.org/10.7763/IJESD.2013.V4.367

Ananias, N.N., M.K. Japhet, O. Mayabi, K. Jacob and N. Taratistio. 2012. Groundwater pollution risk from incinerated health care waste bottom-Ash at a National Teaching and Referral Hospital in Kenya. Greener J. Med. Sci., 2(6): 157-162. https://doi.org/10.15580/GJMS.2012.5.110512223

Ashraf, M.A., M.J. Maah, I. Yusoff and K. Mehmood. 2010. Effects of polluted water irrigation on environment and health of people in jamber, District Kasur, Pakistan. Int. J. Basic Appl. Sci., 10(3).

Azeem, H.A., 2009. Analysis of industrial waste water from Kot Lakhpat area (Lahore, Pakistan) by atomic absorption spectrometer. Biol. J. Pak., pp. 35-41. PK ISSN 0006-3096.

Hamid, A., G. Yaqub, Z. Sadiq, A. Tahir and Noor-ul-Ain. 2013. Intensive report on total analysis of drinking water quality in Lahore. Int. J. Environ. Sci. 3(6), ISSN 0976–4402.

Haydar, S., H. Haider, O. Nadeem, G. Hussain, I. Jalees and A. Qadeer. 2014. Effect of Hudiara Drain on the quality of groundwater in the housing schemes of Lahore, Pakistan. Pak. J. Eng. Technol., 21(2): 119-134.

Hussain, F., and A. Sultan. 2013. Existing situation of sewerage in Lahore city and its impacts on River Ravi, Pakistan Water Operators Partnership (The Urban Gazette).

Khan, Y.K., M. Toqeer and M.H. Shah. 2021. Spatial distribution, pollution characterization and health risk assessment of selected metals in groundwater of Lahore, Pakistan. Geochemistry, 81(1): 125692. https://doi.org/10.1016/j.chemer.2020.125692

Khattak, M.A., N. Ahmed, MA. Qazi, A. Izhar, S. Ilyas, M.N. Chaudhary, M.A.S. Khan, N. Iqbal and T. Waheed. 2012. Evaluation of groundwater quality for irrigation and drinking purpose of the areas adjacent to Hudiara Industrial Drain, Lahore, Pakistan. Pak. J. Agric. Sci., 49(4): 549-556.

Mazhar, I., A. Hamid and S. Afzal. 2019. Groundwater quality assessment and human health risks in Gujranwala District, Pakistan. Environ. Earth Sci., 78(22): 1-12. https://doi.org/10.1007/s12665-019-8644-y

Mebrahtu, G., and S. Zerabruk. 2011. Concentration of heavy metals in drinking water from urban areas of the Tigray Region, North Ethiopia, CNCS. Mekelle Univ., 3(1): 105-121. https://doi.org/10.4314/mejs.v3i1.63689

Muhammad, A.M., and T. Zhonghua. 2014. Municipal solid waste and its relation with groundwater contamination in Lahore, Pakistan. Res. J. Appl. Sci. Eng. Technol., 7(8): 1551-1560. https://doi.org/10.19026/rjaset.7.431

Panday, R., and S.K. Panday. 2012. Investigations of physico-chemical status of groundwater of Singrauli District, Madhya Pradesh, India. J. Qual. Manag., 3(10).

Rajappa, B., S. Manjappa and E.T. Puttaiah. 2010. Monitoring of heavy metal concentration in groundwater of Hakinaka Taluk, India, Contemp. Engin. Sci., 3: 183-190.

WHO, 1996. Total dissolved solids in drinking water. Guidelines for drinking water quality, 2nd ed. Vol. 2. Health criteria and other supporting information. World Health Organization, Geneva.

Waseem, A., J. Arshad, F. Iqbal, A. Sajjad, Z. Mehmood and G. Murtaza. 2014. Pollution status of Pakistan: A retrospective review on heavy metal contamination of water, soil and vegetable. Biol. Med. Res. Int., Volume 2014, Article ID 813206, 29 pages. https://doi.org/10.1155/2014/813206

Yasin, N., N. Shah, J. Khan, N. Saba and Z. Islam. 2012, Bacteriological status of drinking water in the peri-urban areas of Rawalpindi and Islamabad-Pakistan. Afr. J. Microbiol. Res., 6(1): 169-175.