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Patterns of Groundwater Pollution along Industrial Zones of Lahore, Kasur and Kala Shah Kaku: A Comparative Analysis

Abstract

The present study is an in depth analysis of groundwater pollution along the industrial zones of Lahore, Kasur and Kala Shah Kaku. A total of forty (40) ground water samples were collected randomly from study area out of which twenty(20) were taken from Lahore, ten (10) were gathered from Kasur while ten(10) from Kala Shah Kaku. In order to evaluate the groundwater quality, different physical parameters (pH, TDS and Electric Conductivity) chemical (Calcium-magnesium, Sodium, Bicarbonates, Chloride) and metals (Cr, Cd, Zn, Pb, Mg and Ni) were analyzed and were compared with the prescribed limits of (WHO, 2011). The deduced results revealed that all the physio-chemical parameters were within the prescribed range of WHO, except EC that exceeded the permissible range of WHO. Based on mean values heavy metals in ground water samples followed the declining concentration (Mn> Zn>Cu>Cd>Cr>Pb>Ni). Manganese and Zinc were found to be in magnified concentrations. The results demonstrated that effluents discharged from various industries without treatment are a potential threat to underground water contamination. Thus, it is recommended that waste water treatment plants should be installed by these industries. Furthermore, strict government actions, effective environmental laws and social awareness programs must be undertaken.

1. Introduction:

Groundwater pollution from municipal, domestic, human and animal waste has been a serious problem in Latin America, Asia and Africa. In Asia, groundwater condition is worst, 70 % people live without proper sanitation. Exceeding amount of toxic metals and fecal coliform bacteria has been found in Rivers of Asia that exceed the WHO guidelines [1]. Many of the developing countries like Kenya, Nigeria and Sudan have suffered from severe groundwater contamination because of the untreated discharge of the effluents from the industries nearby into the water bodies that has resulted due to the rapid growth of industrialization [2].Large numbers of industries are mainly situated along the banks of the canals and the rivers due to which their waste material is directly disposed of into water bodies without proper monitoring. These pollutants when

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enter into water bodies contaminate the groundwater due to seepage and thus becomes unfit for human and agricultural use [3].

Water quality of the major cities of Pakistan such as Karachi, Faisalabad, Kasur, Sialkot, Gujrat, Lahore, Sheikupura and Peshawar is deteriorating due to unchecked disposal of industrial effluents into the water bodies [4]. Important Industrial activity known as leather processing is concentrated in three major cities (Sialkot, Kasur and Karachi) where 600 tanneries are working. Waste water discharge from leather production industries pollute air, soil and water leading to chronic water borne diseases [5]. Kasur is Industrial city in central Punjab Province and is characterized to be one of the most severely affected regions in terms of groundwater contamination as it contains highest number of tanneries that discharge about 9 million liter of contaminated water daily. Kasur is famous for its Industrial activity especially the Leather Industry. Frequently reported diseases observed in people of Kasur due to water contamination include diarrhea, dysentery, respiratory disorders, lung infection and typhoid [6]. Kala Shah Kaku that is an industrial Complex is surrounded by large number of industries that deals with production of paper, leather, textile, ceramics and other industrial activities. Kala Shah Kaku also face serious problem of groundwater pollution due to seepage of untreated effluents that are discharged from the industries [7].

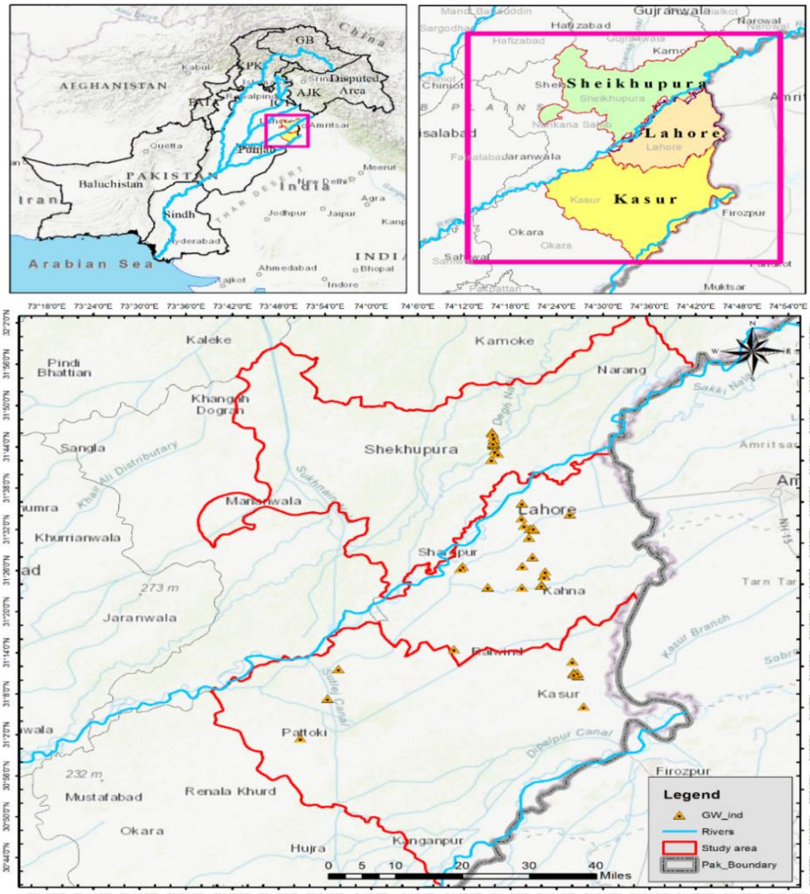
In order to determine the water quality in connectivity to contamination of the heavy metals and its impact on human health [5] examined the groundwater pollution of an industrial city Sialkot, Pakistan. During the month of October-November, water samples were collected from 25 locations. Ten physical and chemical parameters including (Total Hardness, nitrate, Zinc, manganese, Lead, chromium and nickel) were analyzed. The gathered results were compared with WHO and (PSQCA) standards. Ecological status of groundwater was determined through spatial distribution maps. The results revealed that the water quality of the industrial city had been severely deteriorated because of the exceeding values of the parameters that were above the standard guidelines of WHO. It was concluded that water was polluted due to increase influx of industrial waste into the water bodies.

2. Materials and Methods

2.1 Study Area

The present research study is based upon three areas including Lahore, Kasur and Kala Shah Kaku. Kasur is an industrial city located along (31º.7N. 74º.27′E) [6] in the central Punjab, Pakistan. The area of Kasur is 3996km^2 and the population is more than 3 million. For daily use many inhabitants use groundwater from tube wells. Leather Industry of Kasur was selected as the main target point for the selection of samples. Lahore lies between 31º15′-31º45′N and 74º01′-74º39′E [8] in Punjab Province. Pakistan. The population of Lahore is over 10 million [8]. Lahore has an area of about 1, 772km^2 .Quaid-e-Azam Industrial Complex was selected as target point from Lahore. Kala Shah Kaku is known as an Industrial Complex that is located at a distance of about 17 km from Lahore. It surrounds large manufacturing Industries of paper, leather, textile, printing, ceramics and chemicals. The area was selected as Industrial complex because of the availability of raw material and good transportation system.

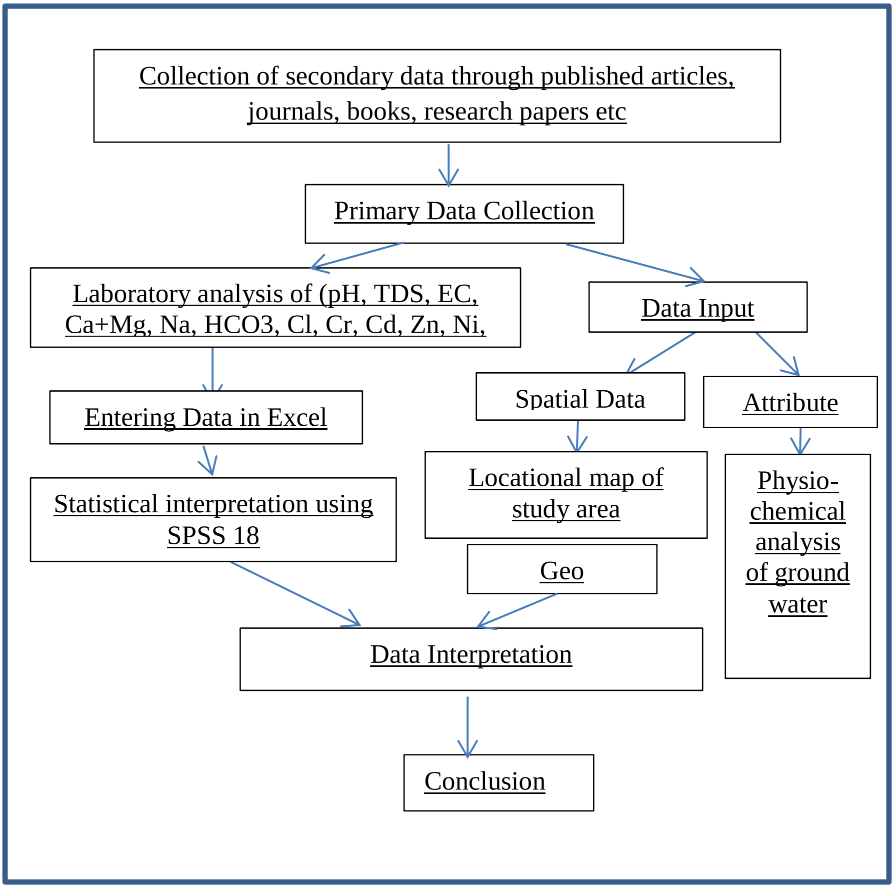
Fig 1 Showing Study Area



2.2 Sampling Procedure

For this research study groundwater samples were collected to test the physio-chemical parameters and the presence of heavy metals. Random sampling procedure was adopted in order to gather the groundwater samples. A total of forty (40) groundwater samples were collected out of which twenty (20) groundwater samples were selected from Lahore and they were marked as (L1…..L20), ten (10) groundwater samples were selected from Kasur marked with (S1…..S10), and ten (10) groundwater samples were selected from Kala Shah Kaku marked with (K1……K10). All groundwater samples were taken in polythene bottles of size of 500 ml. All the sample bottles were properly sealed and proper labels were pasted on each bottle.

Fig 2 Showing Flowchart of Methodology



2.3 Laboratory Analysis

The Chemical parameters (Calcium-magnesium, Sodium, Bicarbonates and Chloride) were tested from Soil and water testing Laboratory, Agriculture Department, Thokar Niaz Beig, Lahore. Metals analysis including (Chromium, cadmium, zinc, Nickel, manganese, copper) and physical parameters (pH, TDS and Electric Conductivity) were tested from Environmental Science Laboratory, Kinnaird College For Women. Lead testing was done through C.E.E.S Laboratory, University of Punjab.

Table 1 Laboratory analysis of the collected groundwater samples along the study area

Sample#	pH	TDS (mg/l)	EC (µs/cm)	Na (mg/l)	HCO_3 (mg/l)	Cl^- (m,g/l)	Cal_Mag (mg/l)	Cr (mg/l)	Zn (mg/l)	Mn (mg/l)	Cu (mg/l)	Cd (mg/l)	Pb (mg/l)	Ni (mg/l)
L1	7.71	660	1245	7.3	10.6	3.1	5.15	0.02	1	0.06	0.51	0.002	0.447	0.003
L2	7.3	706	1432	9.51	11.1	1.4	4.81	0.02	0.24	0.04	0.33	0.013	0.526	0.069
L3	7.17	720	1073	7.35	7.8	1.9	3.38	0.1	1.48	0.06	0.46	0.019	0.451	0.003
L4	6.02	999	1272	7.33	10.8	1.6	5.39	0.02	0.27	0.05	0.2	0.011	0.194	0.135
L5	7.1	660	2280	15.96	16.1	5.3	6.84	0.4	0.33	0.05	0.4	0.132	0.056	0.045
L6	7.36	715	1492	10.6	11.1	2.1	4.24	0.04	0.37	0.04	0.5	0.002	0.451	0.075
L7	7.1	941	1527	9.98	10.8	1.8	5.29	0.6	0.25	0.02	0.3	0.002	0.564	0.069
L8	7.05	758	1979	13.89	14.3	3.1	5.9	0.01	0.66	0.22	0.22	0.03	0.571	0.012
L9	6.82	826	1648	10.38	12.1	2.4	6.1	0.01	0.27	1.08	0.36	0.002	0.004	0.045
L10	7.06	999	1624	11.92	10.8	2.2	4.32	0.03	0.37	0.04	0.34	0.001	0.023	0.159
L11	7.12	472	1620	10	12.2	5.21	6.2	0.06	0.58	0.07	4.3	0.001	0.017	1.32
L12	7.43	675	1125	8.32	12.2	1.92	2.93	1.3	0.45	0.02	0.23	0.001	0.004	0.102
L13	7.12	931	1422	10.79	6.2	2.4	3.43	0.01	1.78	0.41	0.61	0.001	0.005	0.03
L14	7.18	690	1923	16.9	10.4	3.9	2.73	0.03	0.39	0.68	0.14	0.002	0.013	0.096
L15	7.31	725	1994	17.49	12.2	3.7	2.45	0.01	0.58	0.25	0.28	0.003	0.018	0.066
L16	7.37	720	1510	12	12.4	2.3	3.1	0.05	2.13	0.41	0.13	0.001	0.025	0.012
L17	6.23	820	1547	10.77	8.8	2.81	4.2	0.07	0.45	0.44	0.91	0.031	0.033	0.015
L18	7.45	920	1552	11.26	10.9	2.2	4.26	0.5	2.21	0.32	0.23	0.003	0.015	0.336

L19	7.29	523	1555	10.42	11.1	1.9	5.13	0.32	2.95	0.22	4.1	0.002	0.126	0.093
L20	6.03	872	1547	11.54	11.2	2.07	3.93	0.36	3.51	0.3	4.8	0.002	0.688	0.072
KSK1	7.22	632	989	4.41	8.1	1.63	5.48	0.08	0.04	0.26	5.1	0.003	0.014	0.033
KSK2	7.1	943	1034	7.11	7.2	2.08	3.23	0.01	0.51	0.37	0.26	0.005	0.053	0.126
KSK3	7.34	598	926	5.94	7.1	1.9	3.32	0.03	0.06	1.44	0.12	0.002	0.013	0.063
KSK4	7.4	732	867	6.19	6.1	1.7	2.48	0.06	0.08	0.37	0.42	0.013	0.001	0.033
KSK5	7.03	842	912	6.7	6.4	1.84	2.42	0.3	0.45	1.74	0.34	0.034	0.007	0.54
KSK6	7.22	639	885	6.22	6.7	1.7	2.63	0.05	0.03	5.23	0.42	0.052	0.006	0.063
KSK7	6.23	803	996	6.15	7.1	1.15	3.81	0.01	0.02	4.06	0.21	0.063	0.052	0.039
KSK8	6.95	795	982	6.31	7.1	1.2	3.51	0.7	0.05	2.88	0.56	0.003	0.039	0.096
KSK9	7.71	812	1032	5.69	7.2	1.08	4.63	0.09	0.55	0.67	0.24	0.001	0.057	0.045
KSK10	7.02	408	1054	6.53	7.4	0.8	4.01	0.02	0.04	0.49	0.33	0.032	0.062	0.033
K1	7.01	512	784	4.68	5.2	2.22	3.16	0.05	1.12	3.88	0.35	0.003	0.065	0.069
K2	7.47	580	817	5.21	5.1	1.6	2.96	0.02	1.33	2.45	0.23	0.001	0.093	0.063
K3	7.01	612	823	5.3	4.8	1.68	3.46	0.04	2.27	0.67	0.32	0.1	0.078	0.366
K4	7.5	670	1305	9.59	8.8	2.9	3.57	0.01	3.55	0.53	0.63	0.031	0.011	0.042
K5	7.03	498	1411	10.54	8.4	2.9	3.43	0.01	2.85	0.8	0.55	0.13	0.025	0.045
K6	6.91	512	1335	9.92	8	2.7	3.72	0.06	3.9	0.25	0.47	0.002	0.058	0.183
K7	7.71	540	1322	9.5	8.1	2.9	3.05	0.05	3.2	2.87	0.52	0.003	0.018	0.063
K8	6.82	880	1889	15.84	12.4	3.8	2.48	0.7	4.5	7.5	0.6	0.004	0.007	0.096
K9	7.61	712	1970	17.22	12.7	3.5	3.25	0.06	2.91	6.5	0.42	0.001	0.022	0.135

4 Discussion

Table 2 Descriptive statistical data of groundwater samples along industrial zones

	PH	TDS (mg/l)	EC (mg/l)	Na (mg/l)	HCO_3 (mg/l)	Cl (mg/l)	Ca + Mg (mg/l)	Cr (mg/l)	Zn (mg/l)	Mn (mg/l)	Cu (mg/l)	Cd (mg/l)	Pb (mg/l)	Ni (mg/l)
Mean	7.16	738.59	1367.08	9.73	9.48	2.40	3.94	0.18	1.25	1.28	0.799	0.018	0.12	0.12
Std Dev	0.461	183.42	395.09	3.74	2.749	1.020	1.154	0.299	1.305	1.875	1.290	0.032	0.194	0.220
Min	6.02	408	784	4.41	4.8	0.80	2.42	0.01	0.02	0.02	.12	0.001	0.001	0.003
Max	7.71	999	2280	17.49	16.1	5.30	6.84	1.30	4.50	7.50	5.10	0.132	0.688	1.320
WHO	6.5-8.5	1400	1000	200	350	250		0.05	3	0.5	1-2	0.003	0.01	0.07

Fig 3 Physiochemical Parameters

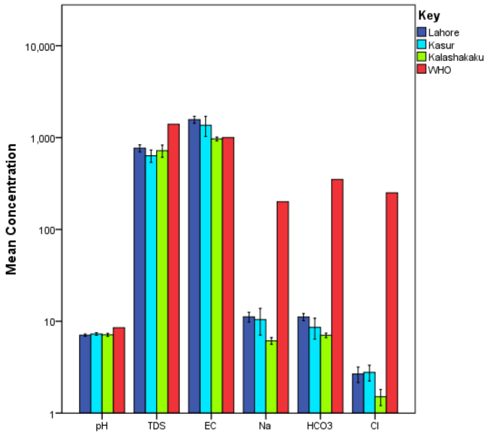
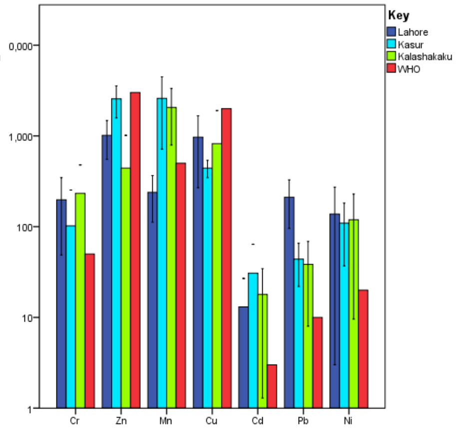


Fig 4 Showing Metal Concentration



The EC values varied from 784-2280 µs/cm with the mean value of 1367.08µs/cm with standard deviation of 395.09 (Table 2). The values of groundwater EC exceeded the prescribed limits of WHO (1000 µs/cm) (Fig 3) .The maximum EC was found in (L5) EMCO Industry of Lahore which is one of the most popular trading industry of electrical goods such as fuses and is best known for ceramic manufacturer. While all the other physio-chemical parameters including (pH, EC, TDS, Na, HCO_3 were within the range of WHO (Fig 3).

The Cr values ranged from .01-1.30 mg/l with mean value of .18 with the standard deviation of .299 (Table 2). The values of groundwater Cr exceeded the prescribed range of WHO (0.050 mg/l) (Fig 4). The maximum value was found along the (L12) Permair Leather Tannery Industry of Lahore due to the effect of the industrial effluent into water. Similar study demonstrated by [9] in Ludhiana, India also revealed exceeding concentration of Chromium in groundwater samples due to location of tannery industry adjacent and its discharge into water bodies without treatment. The minimum Cr value was found along many locations along study area (L8, L9, L13, L15, S3, S8, K5 and K6). The Zn values ranged from .02-4.50 mg/l with mean value of 1.2590 with the standard deviation of 1.30562 (Table 2). Some of the values exceeded the prescribed range of WHO (3mg/l) These sites were (L20) City steel Industry, (K5) Ravi Chemical Complex (K7) Ittehad Chemical, (K8) Shan Steel industry and the highest value was found along (K9) mono textile industry of Kala shah Kaku. The results revealed that Steel production industries are mainly an important source of Zinc presence in groundwater.

The Mn values varied from .02-7.5 mg/l with mean value of 1.28 with standard deviation of 1.87516 (Table 2). The values of groundwater Mg exceeded the prescribed range of WHO (0.5 mg/l) (Fig 4), The exceeding Mg values were found along industrial zones of (L9, S1, S4, S6 ,S7,S8,S9,S10,K2,K3) with the max value at (K9) Mono Textile Industry with the main source of manganese in water appeared to be the industrial discharge from the aluminum industries. The Cu values ranged from .12-5.10mg/l with the mean value of Cu .7998 with the standard deviation of 1.29083 (Table 2). Some of the values exceeded the prescribed range of WHO (1-2 mg/l) while the rest values were within the range (Fig 4) . The maximum value was found along (S2) Leather Pak tannery at Kasur .The results revealed that the main source of copper was industrial waste discharge without treatment, corrosion of household plumbing and use of agrochemicals.

The Cd values varied from .001-.132mg/l with mean value of .01868 with the standard deviation of .033211 (Table 2, Fig 4)).The values of groundwater cadmium exceeded the prescribed range of WHO (0.003 mg/l) (Fig 4). The maximum value was determined at (L5) EMCO industry of Lahore due to the discharge of the untreated material from industry and from metal plating activity. Similar findings were determined by [10] in which he demonstrated that high cadmium mainly occurs due to untreated industrial waste coming from iron and steel production industries. The lead values varied from .001-.688 with mean value of .12637 with the standard deviation of .194860 (Table 2). The values of groundwater Pb exceeded the prescribed range of WHO (0.01 mg/l) (Fig 4). The maximum value was .688 mg/l found along (L20) City steel industry, Lahore while the minimum Pb value was .001 mg/l determined at (S5) Cure Inn Phytogeuticals (Pvt ,Ltd), Kasur. The results revealed that main sources of lead are the steel industries production. Similar findings were conducted by [4] where high values of lead (0.81mg/l) were determined along the steel industry at Sialkot

The Ni groundwater values varied from .003-1.320mg/l. with the mean value of .12615 with the standard deviation of .220 that exceeded the prescribed range of WHO (0.07 mg/l) (Table 2, Fig 4) . The maximum value was 1.320mg/l determined at (L11) City textile industry while the minimum value was 0.003 mg/l found at (L3) Pak Electron Ltd. Similar findings were revealed by (Tariq, Ali &Shah,2006) where they determined high values of nickel along the textile industries of Peshawar. The main sources of nickel include stainless steel industries, batteries, metal factories, power plants etc.

Table 3 Correlation matrix for different water quality parameters along study area

	pH	TDS	EC	Na	HCO3	Cl	Cal+Mag	Cr	Zn	Mn	Cu	Cd	pb	Ni
pH	1													
TDS	-0.312	1												
EC	0.008	0.208	1											
Na	0.07	0.205	**.954****	1										
HCO3	0.021	0.187	**.872****	**.769****	1									
Cl	0.133	-0.123	**.748****	**.727****	**.613****	1								
Cal+Mag	-0.165	0.03	.332*	0.041	.490**	0.202	1							
Cr	0.083	0.223	0.177	0.208	.323*	0.071	-0.086	1						
Zn	0.081	-0.121	0.255	.348*	0.101	0.275	-0.258	0.146	1					
Mn	0.028	-0.01	-0.002	0.129	-0.103	0.084	-.433**	0.175	0.295	1				
Cu	-0.194	-0.197	0.051	-0.056	0.12	0.107	.346*	0.031	0.162	-0.168	1			
Cd	-0.201	-0.238	0.02	-0.014	-0.037	0.154	0.122	-0.113	-0.009	-0.017	-0.152	1		
Pb	-0.154	0.176	0.142	0.046	0.271	-0.122	.339*	0.016	-0.013	-0.291	0.15	-0.111	1	
Ni	-0.012	-0.145	0.032	-0.012	0.064	.358*	0.176	0.04	-0.013	-0.064	.341*	-0.031	-0.175	1

From the correlation analysis of water quality parameters, it is observed that significant high positive correlation exists between the Na and EC (+0.954) and HCO_3 and EC (0.872). The sodium showed a very strong positive correlation with EC groundwater , similar findings were done by [11]. Positive correlation exist between the pairs of EC and Cl (+0.748), Na and HCO_3 (+0.769), Na and Cl (+0.727) and marginal correlation exist between $HCO_3$and Cl (+0.613) [11]. Since EC correlates with most of the parameters the quality of groundwater can be predicted with sufficient accuracy just by the measurement of Electric Conductivity alone

5 Conclusions

Groundwater is significant source of drinking water and irrigation in Lahore, Kasur and Kala Shah Kaku. Quality of groundwater is being contaminated because of the discharge of the untreated effluents from the industries into water bodies. The population mainly relies on bore wells, dug wells and hand pumps for their water requirements. The untreated disposal of industrial waste without proper treatment is the primary source of groundwater contamination. The results revealed high metal contamination in industrial zones of Lahore, Kasur and Kala Shah kaku. All the metals were found to be in magnified concentrations. The mean trend of the metals in groundwater samples followed the descending concentration (Mn> Zn>Cu>Cd>Cr>Pb>Ni).

6 Recommendations:

There is a dire need to address the water quality challenges by adopting preventive strategies. The most basic way to protect water from pollution is by eliminating the contaminants at source because it is a cost effective solution. It involves reducing the hazardous substances, leaks and fugitive releases and completely eliminating them.

- Waste water treatment plants should be installed in industries. Increased administrative, technical and financial assistance should be provided to check and monitor the wastewater treatment plants.
- Industries should treat their wastewater at point source and then reuse it. This would help in preventing water from pollution and also would avoid future water crisis.
- Awareness Campaigns about the significance of water should be launched. In these campaigns non- governmental organizations (NGOs) and Media can play a very vital role as they are an important source of sharing awareness programs on large scale.
- There is a need to develop common understanding among all stake holders (Business, Government and civil society) so that an integrated water resource management strategy should be adopted and implemented for protection of water quality.
- In order to assess the effect of polluted water on consumer’s health; epidemiological studies should be conducted along those areas which are near to contaminated water bodies.

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