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QUALITY MODELING OF DRINKING GROUNDWATER USING GIS IN URBAN COMMUNITIES OF PAKPATTAN, PAKISTAN

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Water is driving force of all nature but constant deterioration of water quality here in Pakistan is predicting unprecedented impacts country might have to face, as water quality is declining by every passing day. For the very first time quality modelling of drinking groundwater was done in one of the most health hazards stricken district of Pakistan i.e., Pakpattan. For the purpose 20 samples from random water outlets were collected and to gauge the quality of water, water Quality Index (WQI)was calculated along with the application of GIS and IDW technique in order to create a 3D raster maps regarding 11 predefined parameters. The overall findings projected that all the selected parameters were aligned with the safe range defined by WHO standards except for the Cadmium, Lead and Electrical Conductivity. As per Water Quality Index more than 40% of the samples were not found safe for drinking purpose. The results revealed that water quality of Pakpattan is just below being satisfactory but with the occurrence of increment in gradual and consistent addition of contamination due to several unwatched anthropogenic activities situation is not far away from being acclaimed detrimental.
Keywords: Groundwater, Water quality index (WQI), Inverse Distance Weight (IDW), Geographical Information System (GIS), Ground Water Modelling.

INTRODUCTION

Water is essential source of life which is crucial for existence of all living creatures. It is main constituent of all living organisms, so the availability of water ensures the survival of human race on this planet (Balakrishnan and Ramu, 2016). Ground water disaster is not the consequence of ordinary reasons. Persistent release of factory runoffs, household manure and municipal disposal polluted the groundwater and caused health risks (Desai, 2012; Shrivastava*et al.*, 2013; Ali *et al.*, 2018; Shakoor *et al*., 2018). Existence of man depends on availability of safe drinking water (Rani *et al.*, 2012). From total amount of water available on earth only1% is used for drinking, farming, local power generation, manufacturing consumption, transport and waste dumping. Pakistan is a country where due to population increase water quality is deteriorating, another reason is water is supplied through pipes which are not well maintained and these supply lines are not properly managed (Haydar *et al.*, 2016). The areas which are not available with safe drinking water for the consumers can be called a hell for the residents because of certain diseases. About 2.5 million of people die after drinking unsafe water every year. Diarrhea is a common disease in developing countries and affects children younger than 5 years. Kosek *et al.* (2003) A case study was conducted by Zahir *et al.* (2015) under which a conduction of water analysis was undertaken on 20 samples collected randomly from district Sahiwal, Punjab, Pakistan for the evaluation of concentrations of arsenic (As), chromium (Cr)and lead (Pb). The levels of arsenic and lead were lower than Pak EPA guided values while chromium had crossed the standard limit of Pak EPA in all the water samples.

The goal of this research was to examine water quality by assessing water quality Index (WQI)through GIS application and IDW technique, and comparing it with WHO Standards in urban area of Pakpattan.

MATERIALS AND METHODS

***Study area*:** District Pakpattan is situated at 30°21'26.25"N and 73°22'57.16"E. It has two main tehsils "Arif wala" and "Pakpattan" covering an area of more than 0.674 million acres. Pakpattan city is famous because of the shrine of Hazrat Baba Farid Ganj Shakar. May and June are the hottest whereas the coolest months are December and January. Annual average rainfall varies from 300-400 mm (Masood*et al.*, 2016). Pakpattan tehsil consists of 33 union councils (UC). In this study the main focus was UC no 1-5 (areas of Green town, Fareed Nagar) and UC no 17 (Chak No16/SP, Chak No 19/ SP) (Fig. 1).

***Water sampling*:** Sampling was done in the month of March, 2018 at twenty random locations (Hassan Town, Tiba Sher Kot, Sofia Abad, Fareed Abad, Canal Road, Circular Road, Ali block, Khan Pura, Railway Colony, Green Town, Fareed Nagar, Officers Colony, Rakh Pull, Jamal Chowk, Bhatta

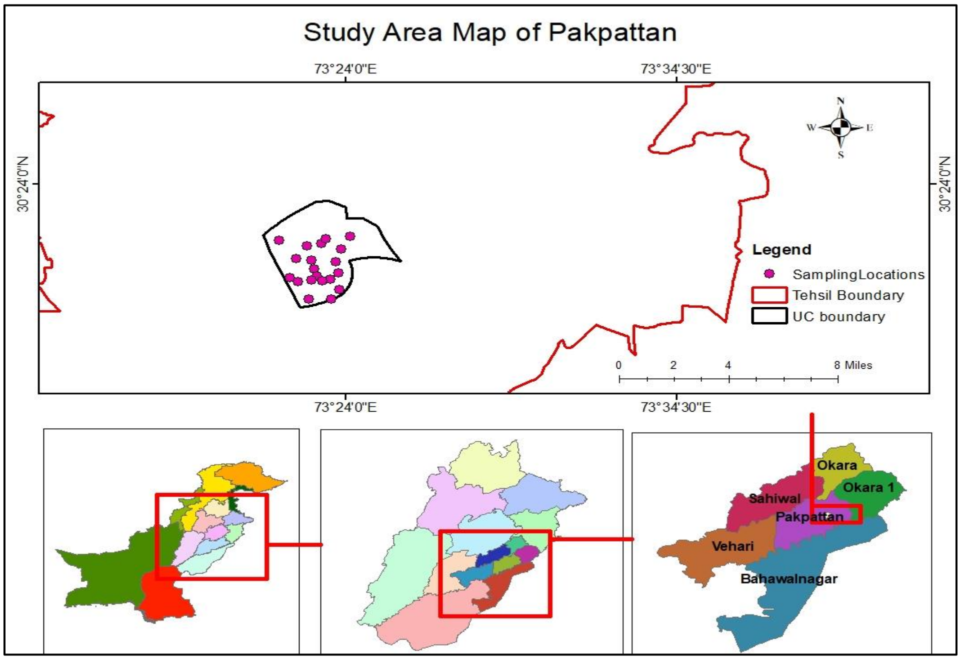

Figure 1. Map showing study area of Pakpattan

Chowk, Aziz Abad, DHQ hospital, Nagina Chowk, Chowk Arayian, Baba Fareed tube well).Some of the samples were collected from houses and some from parks and mosques. Global positioning system (GPS)was used to obtain localities (latitude, longitude) for each sampling site. These samples were collected and stored in accordance with the standard procedures and brought to the laboratory for analysis.

***Chemical analysis*:** Each sample was tested for seven physicochemical parameters (pH, Total dissolved solids (TDS), electrical conductivity (EC), sulphate (SO_4^{-2}), alkalinity, Chloride (Cl-), hardness and four heavy metals (Pb, Cr, Cd, Fe) by following standard processes (APHA, 2012). For all locations three samples were tested and the mean value was taken.

***Statistical and Spatial analysis*:** A Geo-database was created and incorporated into Arc Map 10.5 to perform spatial analysis of all parameters. Inverse Distance Weight (IDW)was used as an interpolation technique.

***Calculation of Water quality Index*:** The water quality index (WQI)assists to find whether physic-chemical condition of water is acceptable for drinking purpose or whether the particular sample is meeting some standards or not (Vasanthavigar *et al.*, 2010). Some researchers said that WQI determines the quality of water and described following method to estimate water quality. (Avvannavar and Shrihari, 2008; Mishra and Patel, 2001)

WQI was obtained from the equation given below

WQI = ΣQiWi/ Σ Wi

Where, Qi = Quality rating; Wi = Relative weight

Wiis relative Unit Weight that was estimated by the given formulae:

Wi = I/Si

Where, I = constant of proportionality

I= 1Σ1/Si

Qi = {[(Vobserved– Videal)/ (Si – Videal)] * 100}

Where, Qi = Quality rating of ith parameter for a total of n water quality parameters; V Observed= value got from research laboratory examination of certain parameter; V ideal = Ideal value of the tested parameter that we get from standard Tables.

Basically WQI was defined according to use of water. For drinking we get different values and for irrigation purpose we have different ranges (Khan *et al.*, 2013; Khwakaram *et al.*, 2015).

RESULTS AND DISCUSSION

pH indicates the degree up to which hydrogen ion is present; it shows acidity or alkalinity of water sample (Patil and Patil, 2010). In this study pH varies between 7and 7.8 with an average of 7.5 (Table 1 and Fig. 2). All samples are within safe limits as per WHO standards.

The flow of electric current through water determines its electrical conductivity (EC). It indicates occurrence of various salts (cations, anions).EC in study area varied between 514 µS/cm and 1806 µS/cm with sample mean value of 904 µS/cm (Table 1 and Fig. 3). The permissible value of EC by WHO is 500 µS/cm (WHO, 2011). Only few samples were within the safe range. It is clear from Fig. that values were gradually increasing towards south that was might be due to some salty geographical area.

Table 1. Descriptive Statistics along with standard values

Parameters	Mean	Min	Max	SD	Variance	WHO (2011)
PH	7.585	7.000	7.800	0.174	0.030	6.5-8.5
TDS	461.850	257.000	937.000	184.655	34097.530	500
EC	904.750	514.000	1806.000	353.620	125047.200	500
SO_4^{-2}	0.529	0.011	2.881	0.901	0.811	250
Alkalinity	152.120	100.080	250.200	43.349	1879.113	n/a
Cl^-	44.311	21.270	63.810	11.461	131.352	250
Hardness	530.000	250.000	900.000	174.929	30600.000	n/a
Pb	0.0231	-0.010	0.170	0.041	0.00170	0.01
Cr	0.0077	-0.012	0.051	0.018	0.00034	0.05
Cd	0.0004	-0.005	0.007	0.003	8.25E-6	0.003
Fe	-0.0156	-0.062	0.042	0.026	0.00068	0.3

n/a: not available, all units are in ppm except for Ec (µS/cm) and pH

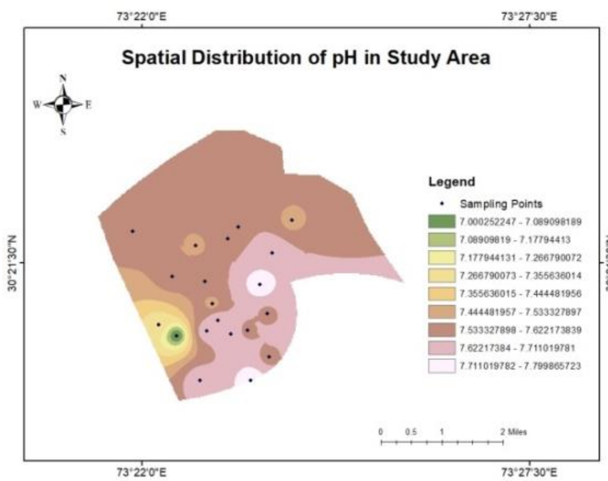

Figure 2. PH variability in Study Area

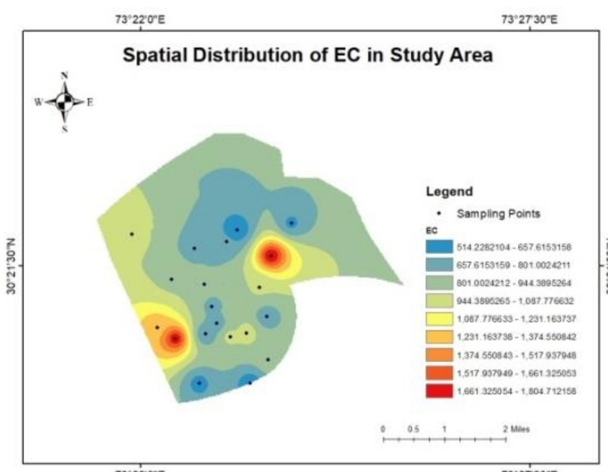

Figure 3. EC variability in Study Area

Total Dissolved Solids (TDS)is the quantity of all mixed material like mineral deposits, salts or metals, with high value of TDS is expected to create problems like laxative, taste (Haydar*et al.*, 2016). TDS varied between 257 and 937 with a mean of 461 (Table 1 and Fig. 4). According to the WHO all samples were with in safe limits. From Table 2, it is clear that TDS had a strong positive association (r>0.7, p=0.001) with EC that indicated large amounts of salt.

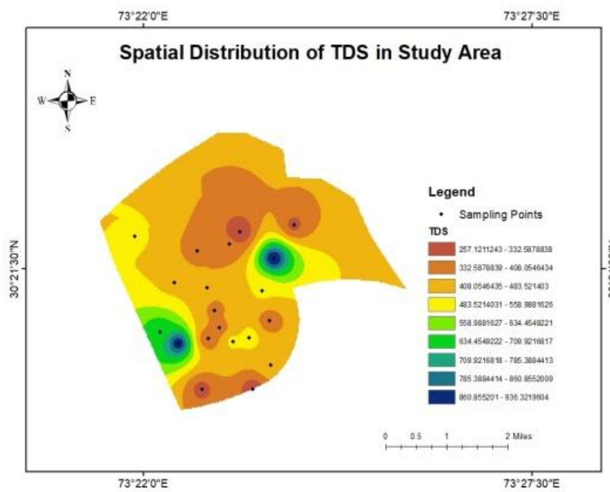

Figure 4. TDS variability in the study Area

Water hardness is the result of excessive cations and anions (Reda, 2016). Total hardness in selected water samples varied from 250 ppm to 900 ppm with an average value of 900 ppm (Table 1 and Fig. 5). WHO has not defined any standard value for hardness.

The ability of water to neutralize acid is called total alkalinity. The sums of alkalis present in water in form of bicarbonate, carbonates and hydroxides. High alkalinity causes cloudiness in water (Haydar *et al.,* 2016). Total alkalinity among different areas of Pakpattan. varies between 100 ppm to 250 ppm (Table 1 and Fig. 6). There are no drinking water standards which are defined by WHO for Alkalinity.

Chlorides occur in all natural water in different concentrations. Due to increase in mineral content chloride content normally increase. Chloride ions in selected water samples ranged between 21ppm to 63ppm (Table 1 and

Table 2. Correlation among different Physicochemical Parameters

	PH	TDS	EC	SO_4^{-2}	Alkalinity	Cl^-	Hardness	Pb	Cr	Cd	Fe
PH	1.000										
TDS	-0.507	1.000									
EC	-0.510	1.000**	1.000								
SO_4^{-2}	-0.497	0.463	0.460	1.000							
Alkalinity	-0.421	0.669	0.666	0.190	1.000						
Cl^-	-0.093	-0.028	0.037	-0.073	-0.193	1.000					
Hardness	-0.067	-0.074	0.080	-0.117	0.005	0.027	1.000				
Pb	-0.367	0.270	0.282	-0.104	0.066	0.067	-0.129	1.000			
Cr	0.125	0.125	0.136	-0.066	0.352	-0.460	-0.128	0.200	1.000		
Cd	-0.047	0.370	0.376	0.123	0.620	-0.385	-0.022	0.197	0.858*	1.000	
Fe	-0.188	0.209	0.222	0.203	0.116	0.080	0.090	0.201	0.337	0.444	1.000

**Correlation is significant at the 0.01 level (2-tailed); *Correlation is significant at the 0.05 level (2-tailed); TDS (Total dissolved solids), EC (Electrical Conductivity), Cl- (chloride), Cr^- (chromium), Pb (lead), Cd (cadmium) and Fe (Iron).

Fig. 7). The highest value of chloride ions was observed in water sample of Fareed Abad, Officers colony and Aziz Abad. According to WHO the permissible limit for chloride was equal to 250. In this study even the highest value of chloride was under permissible limit.

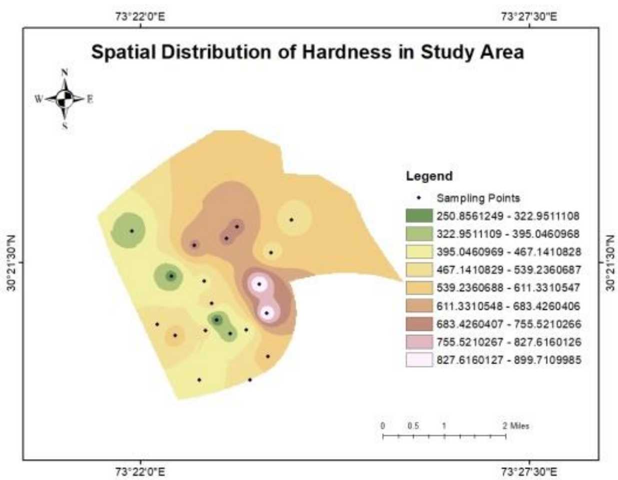

Figure 5. Hardness variability in Study Area

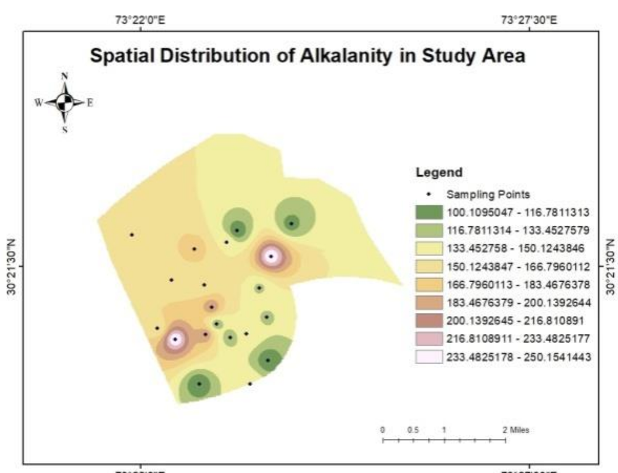

Figure 6. Alkalinity Variability in Study Area

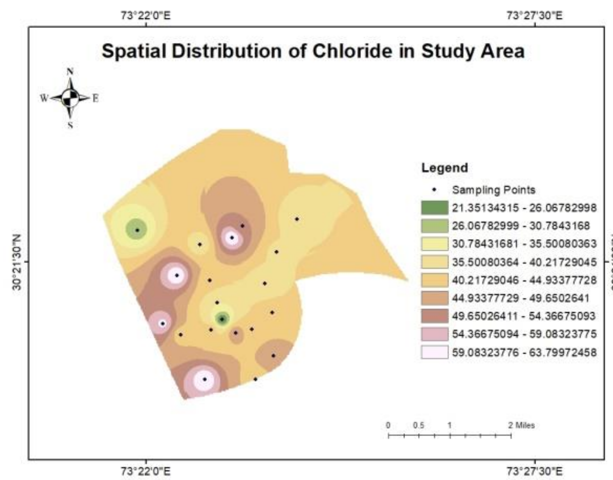

Figure 7. Chloride Variability in Study Area

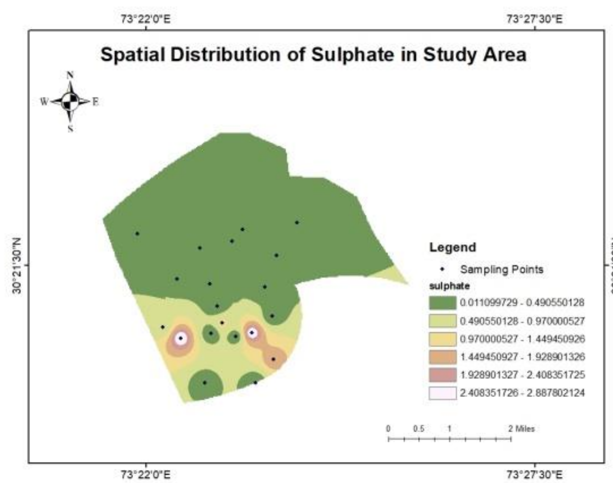

Figure 8. Sulphate variability in study area

Sulphate is found in almost all water bodies due to dissolution of salts of sulfuric acid. The permitted value for sulfate in drinking water set by WHO is 250 mg/L (Mohsin *et al.*, 2013). In this study sulphate varied between 0.01ppm to 2.8ppm

(Table 1 and Fig. 8), all results were under permissible limit with standard of WHO.

Iron is one of the earth's most abundant resources. Iron reach to groundwater through the phenomena of rainfall as it is present in soil so rain water takes it away to natural water. The measure of iron found in water was mostly under 10 milligram for every liter (mg/L) (Giri and Singh, 2015). The standard value for iron in water is 0.3mg/l (ppm). Iron concentration in 20 water samples of Pakpattan ranged from -0.06 ppm to 0.04 ppm (Table 1 and Fig. 9). So, all samples were with in safe limit.

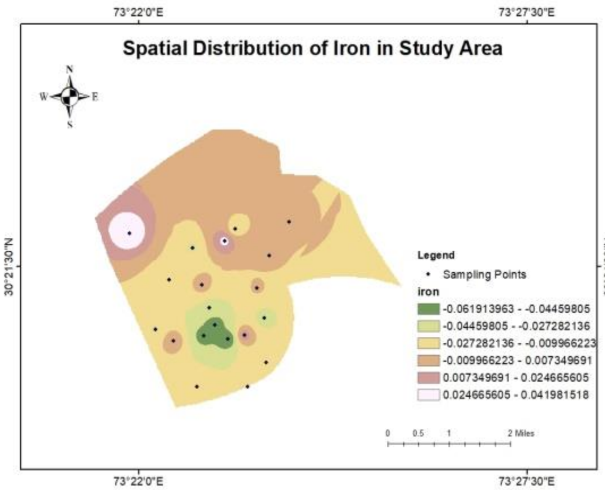

Figure 9. Iron variability of Study Area

Lead move into water by means of water. It filters into water due to corrosion of metal triggered by an organic reaction between water and drainage system. Lead can percolate into water from plumbing, joints, fittings and fixtures *(*Hanna-Attisha *et al.*, 2016). Its amount in water samples in this study ranged from -0.001 to 0.17 (Table 1 and Fig. 10). That shows some of the samples surpassed permissible limit.

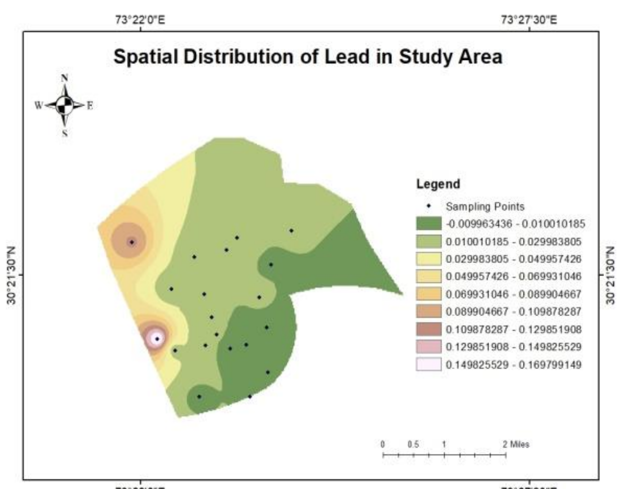

Figure10. Lead variation in Study Area

Cadmium concentration in 20 water samples of Pakpattan was observed by active Absorption Spectroscopy with flame detection and the values ranged from -0.005 to 0.007 (Table 1 and Fig. 11). That means some samples exceeded WHO limits.

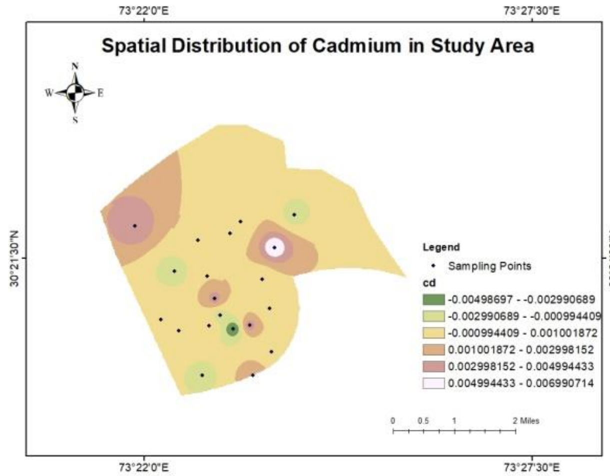

Figure 11. Cadmium Variation in Study Area

Chromium existsin natural waters as its trivalent and hexavalent form. Chromium concentration in water samples of Pakpattan ranged from -0.012 ppm to 0.051 ppm (Table 1 and Fig. 12). All the samples were within permissible limits. From Table 2, it is clear that Cr had a strong positive association ($r>0.7$, p=0.001)with Cd that indicate they had some common source or linkage.

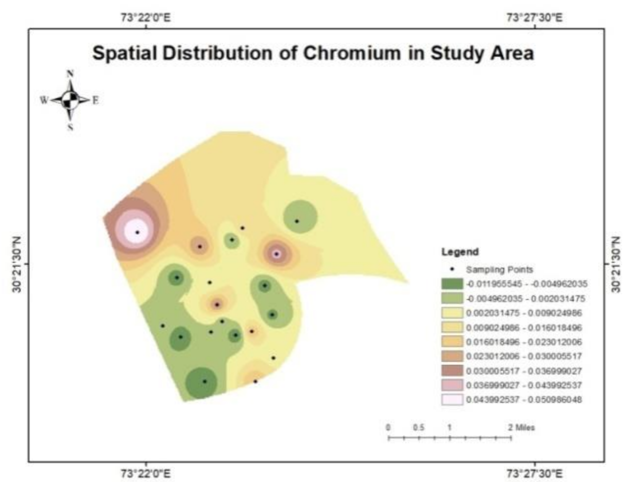

Figure 12. Chromium variability in Study Area

Water Quality Index: In this study there was huge variability in WQI of different samples as shown in Fig. 13. The Water quality Index of majority of the samples was good while some had excellent and some have poor WQI. This classification is made according to Table 3. Overall 5% samples were very poor, 10% were poor, 70 % were good and 15% were excellent.

Table 3. Classification of water quality.

WQI range	Type of water
<50	Excellent water
50-100	Good water
100-200	Poor water
200-300	Very poor water
>300	Water unsuitable for drinking purpose

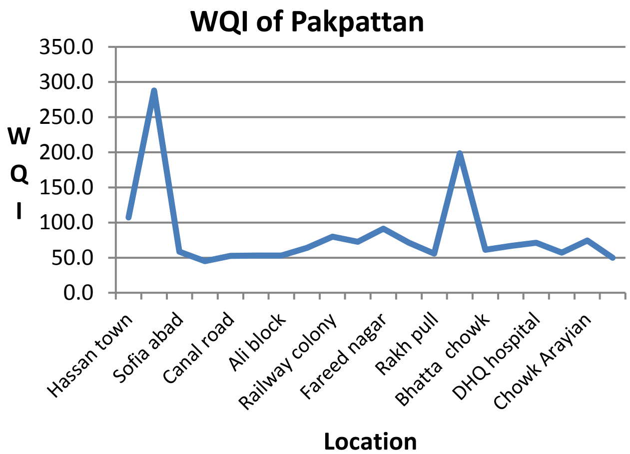

Figure 13. WQI of study Area

***Conclusions*:** Physio-chemical characteristics of twenty sites in Urban area of Pakpattan were examined to determine ground water quality. The examination showed that all the parameters were within safe range with WHO standards except for cadmium, lead and electrical conductivity that indicated some contamination in some water samples due to anthropogenic activities. Moreover, WQI for all samples was also calculated, and the results showed 5% samples were very poor, 10% were poor, 70 % were good and 15% were excellent. There is a necessity of the existence and implementation of strict law with no compromise on quality of public drinkable. Instead of high risks of health hazards the area of Pakpattan was not studied before so these findings will help in the assessment of the issue and in developing guidelines to develop remedial actions/measures

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