



Characterizing spatial distribution of chemical properties and heavy metal contamination in ground-water using GIS

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Abstract

Heavy metal contamination poses a significant threat to peri-urban environments, exacerbated by the use of raw sewage and industrial runoff for irrigation. A survey in Lyallpur Town, Faisalabad, utilized ArcGIS 9.1 to assess ground, canal, and wastewater quality. Sixty sites were sampled, with data analyzed for chemical parameters (EC, SAR, RSC) and heavy metal concentrations (Ni, Pb, Cd), highlighting spatial variations in contamination levels. The concentration of Ni, Pb, and Cd were measured using an atomic absorption spectrophotometer. Almost all collected samples were found to be unfit for irrigation due to their high EC, SAR and RSC. Wastewater was highly unfit because of higher values of EC (5.45 dS m^{-1}), SAR ($7.86 \text{ mmolc L}^{-1/2}$) and RSC ($18.95 \text{ mmolc L}^{-1}$) than permissible limits. In contrast to groundwater and wastewater, canal water was chemically fit for irrigation due to lesser EC (0.72 dS m^{-1}), SAR ($2.98 \text{ mmol L}^{-1/2}$), and RSC (1.40 mmol L^{-1}) values. The Cd concentrations (0.04 mg L^{-1} , 0.03 mg L^{-1} , and 0.11 mg L^{-1}) in ground, canal and wastewater, correspondingly, were above the acceptable limit of 0.01 mg L^{-1} , while Ni and Pb concentrations in all water sources (ground, canal, and waste) found near the permissible limit 0.20 mg L^{-1} and 5 mg L^{-1} , respectively. The irrigation by wastewater results in the increase of heavy metals in the soils, eventually contaminating the groundwater quality. However, it is strongly recommended that wastewater be detoxified and mixed with fresh water before being utilized for the production of crops.

Introduction

Heavy metal pollution of surface and ground water has limited its use. Ground water contamination is sourced in two ways: direct and indirect.

The direct source of contamination is normally abandoned wells, while the indirect source is groundwater passing through areas of the tailings' solids (municipal and industrial), oil spills, or mining wastes (Navarro Ferronato and Vincenzo Torretta, 2019).

Heavy metals of different origins ultimately contaminate soil, water, plants, and even the atmosphere, which are later hazardous for human health (Demkova *et al.*,

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2017). In Pakistan, the induction of an untreated sewerage system in the surface water flows is a common practice that causes pollution of water channels (Iqbal *et al.*, 2018). Apart from the natural sources, anthropogenic activities such as the use of chemical fertilizers and pesticides, the use of urban and industrial discharges for irrigation of agricultural land, and mining and metallurgical industries are said to be crucial to increasing the concentration of heavy metals in soils (Yan *et al.*, 2018).

Perhaps the risk assessment of contamination is based upon its transport processes. The study of groundwater flow needs intensive studies in its following aspects: the rapid flow pathways, pollution sources, and the potential of contaminating or reclaiming the already contaminated soils (Somaratne *et al.*, 2013). It was reported that the water quality in major cities of Pakistan such as Faisalabad, Sialkot, Qasur, Gujarat, Lahore, Karachi, Shekhupura, Peshawar, and Rawalpindi is fading by uncontrolled disposal of untreated municipal and industrial effluents and extreme use of inorganic chemicals (Bhutta *et al.*, 2002). Industry development in the past decades depleted water resources by over-pumping and discharging untreated wastewater into nearby farming areas, lakes, open ditches, and water streams. Toxic waste effluents percolate down into the ground leading to aquifer pollution, damaging safe and clean water supplies. Risk of transmission of heavy metals in the other, especially shallow groundwater system is induced by infiltration-induced draining (Tchounwou *et al.*, 2012).

For identification of heavy metal contaminated areas, the assessment of pollution trends, and the possible risks of heavy metals GIS and geo statistics are useful tools (Kowalska *et al.*, 2018). Due to advancement in computer science and development of new statistical tools for analysis, geostatistic (Burgos *et al.*, 2008), and geographical information system (GIS) are becoming most important tools for addressing problems related to environmental geochemistry (Naves *et al.*, 2015). GIS provides powerful tools for spatial analysis (Wieczorek W.F. and Delmerico A.M., 2009). This is due to the spatial heterogeneity of the soil and the wastes, in terms of GIS covariates (variables) which explaining the contamination process.

Due to the non-biodegradable nature and long persistency of heavy metals within the different environmental media, it has become an important environmental issue in many parts of the world. Therefore, this study was planned, in view to inspect the heavy metal contamination in ground water and to give a primary risk assessment through GIS based study.

2. Materials and Methods

2.1. Study area

This study was conducted in Lyallpur town, city Faisalabad, Pakistan (Figure. 1). The sixty-ground water, four canal water and eight wastewater samples from Lyallpur town Faisalabad (34°30' N and 43°31' E with an elevation of 580 ft), approximately from every grid 4×4 km were taken. High concentration of heavy metals (Ni, Cd, Pb) was determined around the Lyallpur town due to presence of leather tanning and detergent industries. The area is within the arid climate due to high evapo-transpiration. Where, ambient temperature is from 30 to 45°C and sometimes reaches to 48°C. Humidity reported is 45.38 ± 13.11% in hot summer; hot-humid period starts from mid-July and ends in mid-September (Fiaz *et al.*, 2010).

2.2. Collection and preparation of samples

The following types of water samples were collected, as per availability, from each grid: Tube well water, hand pump water as groundwater, canal water as surface water, and sewerage/industrial discharged as wastewater. A total of 60 water samples were collected and transported to laboratory, where filtered through Whatman filter paper No. 40, and analyzed for electrical conductivity (EC), sodium adsorption ratio (SAR) and residual sodium carbonates (RSC) (Richard, 1954). After the basic analysis (EC, SAR and RSC) of water samples a drop of concentrated HCl and 1-2 drops of Sodium Hexametaphosphate were added to water samples to check the metal and salt precipitation. The concentrations of heavy metals were estimated by atomic absorption spectrophotometer (Model Thermoelectron S-Series). Global Positioning System (GPS) reading of coordinates were recorded with Etrex Gemin. Base map was constructed using software ArcMap v.9.1.

2.3. Chemical analysis

With the help of Senso Direct 200 conductivity meter, EC was noted after standardizing it with 0.01 N KCl solution. Cell constant (K) was calculated as:

$$K = 1.4118 \text{ dS m}^{-1} / \text{Observed EC of } 0.01 \text{ N KCl (dS m}^{-1})$$

The EC was converted into Total Soluble Salts (TSS) (mmol_c L⁻¹) by graph as elaborated in USDA Handbook No.60. Ca²⁺ + Mg²⁺ were determined by titrating the saturation extract against 0.01 N EDTA (disodium) solution to a purple end point using Erichrome black T (EBT) indicator in the presence of NH₄OH + NH₄Cl buffer solution. Calcium plus magnesium was calculated as:

$$\text{Ca}^{2+} + \text{Mg}^{2+} (\text{mmol}_c \text{ L}^{-1}) = \text{mL of EDTA used} \times 0.01 / \text{mL of extract taken} \times 100$$

For Na⁺ concentration, series of NaCl solutions (2, 4, 6, 8, 10, 12, and 16 ppm Na⁺) were used to standardize the

Sherwood flame photometer. Sample readings were recorded, and concentrations (ppm) were calculated from regression equation absorbance obtained by plotting concentration of standards against their readings from flame photometer. The actual concentration of Na^+ $\text{mmol}_c \text{L}^{-1}$ was measured as:

$$\text{Na}^+ (\text{mmol}_c \text{L}^{-1}) = \text{ppm concentration} \times \text{dilution factor} / \text{Equivalent weight of Na}^+$$

Carbonates (CO_3^{2-}) were determined by titrating the sample against 0.01 N H_2SO_4 to a colorless end point using phenolphthalein as indicator. Concentration of carbonates was calculated using the formula:

$$\text{CO}_3^{2-} (\text{mmol}_c \text{L}^{-1}) = (2 \times \text{mL of H}_2\text{SO}_4 \text{ used}) \times 0.01 \times 1000 / \text{mL of sample taken}$$

Bicarbonates (HCO_3^-) were determined by titrating the aliquot after CO_3^{2-} determination against 0.01 N H_2SO_4 to a pinkish yellow endpoint using methyl orange as an indicator.

$$\text{HCO}_3^- (\text{mmol}_c \text{L}^{-1}) = (\text{mL of H}_2\text{SO}_4 \text{ for HCO}_3^-) - (\text{mL of H}_2\text{SO}_4 \text{ for CO}_3^{2-}) \times 0.01 \times 1000 / \text{mL of sample taken}$$

Chlorides (Cl^-) were determined by titrating the aliquot after CO_3^{2-} and HCO_3^- determinations with 0.01 N AgNO_3 solution to a brick red end point using potassium chromate (K_2CrO_4) as indicator.

$$\text{Cl} (\text{mmol}_c \text{L}^{-1}) = \text{mL of AgNO}_3 \text{ used} \times 0.01 \times 1000 / \text{mL of sample taken}$$

Finally, SAR was calculated as:

$$\text{SAR} = \text{Na}^+ / [(\text{Ca}^{2+} + \text{Mg}^{2+})/2]^{1/2}$$

$$\text{RSC} = (\text{CO}_3^{2-} + \text{HCO}_3^-) - (\text{Ca}^{2+} + \text{Mg}^{2+})$$

2.4. Data analysis

Data from the whole experiment were tabulated in Microsoft Office Excel 2016. Software package MSTATC was used for the calculation of standard error. X and Y coordinates of each sampling sites were collected using Garmin eTrex H-iking global positioning system (GPS). The base map of Lyallpur town was digitized from the map obtained from the water and sanitation agency (WASA) Faisalabad after geo-referencing it is using Arc Map v. 9.1 Software. The heavy metal concentrations were used as the input data (attribute data) for a grid-based contouring map, to study the distribution of metals in the water and vegetation of Lyallpur town. The Inverse Distanced Weighted (IDW) method was adopted for the interpolation of geographical data. In the IDW method, the closer a point is to the center of the cell being estimated, the more weight it has in the averaging process. The geochemical maps that

were obtained then overlaid using Arc Map software with other geographical features such as roads, landscapes and buildings.

3. Results and Discussion

3.1. Chemical properties in Lyallpur town

3.1.1 The EC of ground, canal and wastewater

The EC was found higher in wastewater than ground and canal water. The maximum unfit samples were found for wastewater with respect of EC. Maximum EC (8.25 dS m^{-1}) was recorded at Chak No. 56 JB (Giyala Khurd) while, it was minimum 2.01 dS m^{-1} at Chak No. 47 JB (Mansooran). All the wastewater samples had EC above the permissible limit of 1.25 dS m^{-1} . Groundwater has much higher EC contrast to canal water as it ranged from 0.27 – 12.71 dS m^{-1} with mean value 3.07 dS m^{-1} in Chak No. 118 JB (Bathan) and Rashidabad, respectively. Out of 60 water samples, only 21 have the EC less than 1.25 dS m^{-1} . Among the sample sites, Chak No. 42 JB contained superior EC range (1.40 dS m^{-1}) of canal water comparable to Chak No. 42 JB location with least EC value (0.29 dS m^{-1}) (Table 1). The total soluble salts were interpolated with the Inverse Distanced Weighted (IDW) method using ARCGIS v 9.1 software. (Figure. 2). Several points of high TSS were identified in the TSS map. The area under green color indicated the groundwater with TSS value of less than 800 mg L^{-1} was fit for irrigation, area under sky blue color with values ranging from 800 – 1000 mg L^{-1} falls under the category of marginally fit water, while the area with pink color indicated that groundwater with TSS values greater than 1000 mg L^{-1} was unfit for irrigation. The whole Lyallpur town area was highly urbanized, with extensive infrastructures of roads and towns. The statistical results presented that ground and wastewater is unfit for irrigation because of much higher mean EC values for ground (2.04 dS m^{-1}) and wastewater (5.45 dS m^{-1}) than 1.50 dS m^{-1} according to the criteria as suggested by Richard (1954). Similar results were reported by Mehdi *et al.*, (2003).

3.1.2. Sar in ground, canal and wastewater

Statistical results of Sodium adsorption ratio (SAR) are given in Table 1, and graphically elaborated in Figure 3. Maximum SAR value $11.15 (\text{mmol}_c \text{L}^{-1})^{1/2}$ was recorded Chak No. 112 JB while minimum SAR $0.01 (\text{mmol}_c \text{L}^{-1})^{1/2}$ was observed at New Civil Line along with standard deviation and mean values $(0.044, 3.36 \text{ mmol}_c \text{L}^{-1})^{1/2}$, respectively. From 60 groundwater samples 53 have SAR values less than the permissible limits $8 (\text{mmol}_c \text{L}^{-1})^{1/2}$ while other samples have SAR value $> 8 (\text{mmol}_c \text{L}^{-1})^{1/2}$. According to irrigation water quality guidelines of Water

and Power Development Authority (WAPDA), irrigation water having SAR below 10 (meq/l) 0.5 are useable for irrigation (Table 3). With respect to SAR, canal water was fit as all the samples had SAR less than the permissible limit of $8.0 \text{ mmol}_c \text{ L}^{-1}$ (Richard, 1954) as SAR value for canal water ranged from $1.92\text{--}3.80 \text{ mmol}_c \text{ L}^{-1}$ with mean and standard deviation values of $2.98 \text{ mmol}_c \text{ L}^{-1}$, 0.87, accordingly. Chak No. 112 JB as maximum and Chak No. 116 JB as least cited locations for SAR. The SAR of wastewater ranged from $2.83\text{--}26.96 \text{ mmol}_c \text{ L}^{-1/2}$ with mean value of $17.42 (\text{mmol}_c \text{ L}^{-1})^{1/2}$. All waste samples had SAR value above the permissible limit of 8 $(\text{mmol}_c \text{ L}^{-1})^{1/2}$ (Richard, 1954) except Chak No. 197 RB (Baghian wala). Maximum value of SAR $26.96 (\text{mmol}_c \text{ L}^{-1})^{1/2}$ observed at Chak No. 48 JB, while it was minimum $2.83 (\text{mmol}_c \text{ L}^{-1})^{1/2}$ at Chak No. 197 RB (Baghian wala). The SAR of water samples were interpolated with the Inverse Distanced Weighted (IDW) method. The SAR groundwater thematic layer so obtained after interpolation then overlaid with other thematic layers such as road systems and villages using GIS software (Arc Map version 9.1). In general, several hotspots of high SAR were marked in the SAR map. The area under green color indicated the groundwater with SAR value of less than 8 was safer for irrigation, sky blue color with values $8.00\text{--}10.00$ showed that the area had marginally fit groundwater while the area under pink color indicated the groundwater with SAR values greater than 10 was unfit for irrigation according to the criteria described by the Richard (1954). Proposed results are also strongly supported by Saeed *et al.*, (2012).

3.1.3. RSC in ground, canal and wastewater

In accordance with statistical measures of Residual Sodium Carbonates (RSC) in ground water samples, the least and utmost values were $0.00 \text{ mmol}_c \text{ L}^{-1}$ at most of the study sites and $6.76 \text{ mmol}_c \text{ L}^{-1}$ at Chak No. 51JB (Sajadah), respectively. The mean RSC value is $1.40 \text{ mmol}_c \text{ L}^{-1}$ with standard deviation value of $1.04 \text{ mmol}_c \text{ L}^{-1}$. The water samples having RSC value below 2.50 but above the 1.25 value, so ground water is marginally unfit. The RSC of canal water ranged from $0.00\text{--}2.30 \text{ mmol}_c \text{ L}^{-1}$ with a mean value of $1.40 \text{ mmol}_c \text{ L}^{-1}$ at Chak No. 42 JB and at Chak No. 112 JB, respectively. Out of 4 canal water samples 2 samples (50%) were marginally fit for irrigation while other 50% samples were fit for irrigation and not only a single sample of canal water was unfit for irrigation. Wastewater contained minimum to maximum range of RSC from $6.68\text{--}38.08 \text{ mmol}_c \text{ L}^{-1}$ with mean value of $18.95 \text{ mmol}_c \text{ L}^{-1}$ at Chak No. 197 RB (Baghian wala) and at Chak No. 30 JB (Sidhu Pura), correspondingly. All wastewater samples had RSC above the permissible limit $1.25 \text{ mmol}_c \text{ L}^{-1}$ (Richard, 1954) and recommended as unfit for irrigation (Table 1). The ground, canal and wastewater RSC were interpolated

with the Inverse Distanced Weighted (IDW) method. The water RSC layer obtained after interpolation then overlaid with other thematic layers such as road systems and villages using GIS software (Arc Map version 9.1). Many hotspots with high RSC values were marked on the RSC map. The area under green color indicated the groundwater with RSC value of less than 1.25 fit for irrigation; sky blue color (Figure 4) indicated the value of RSC $1.25\text{--}2.50$ falls under marginally fit, while the area under pink color indicated the water with RSC values greater than 2.50 (me L^{-1}) was unfit for irrigation according to Richard, (1954).

The water samples collected from different areas of Lyallpur town were categorized into fit, unfit or marginally fit water on the basis of EC, SAR and RSC. Out of 60 water samples, 31.66 % samples were fit for irrigation, while the other 3.33% were marginally fit, and 61.66 % samples were unfit for irrigation. The data obtained were then subjected to GIS software to draw the maps. Such maps are of practical significance as these provide immediate information regarding under water resources. Based on EC, SAR and RSC all the wastewater samples are unfit for irrigation and would be greatly harmful for soils, plants and environment. The high EC, SAR, and RSC of water might be due to the use of detergents for washing clothes, the use of chemicals in industries, and agrochemicals (Stevens *et al.*, 2011). Wastewater generated from domestic and industrial areas is disposed of into the sewer system linked with surface drains, and these open drains carry it to the river for ultimate disposal. The seepage and discharge effect from these unlined drains might have led to the contamination of groundwater or time due to unlined municipal water supply resulted in increased demand by people who have installed suction pumps around the unlined drains carrying raw effluent from laundries, textile industries, textile dyes and wastes from factories (Haydar *et al.*, 2014; Hussain, 2000). Ghafoor *et al.* (1996) reported that the effluent of Pharang drain and its contributing industrial effluent at Mazipura and Uchkera villages of Faisalabad towns had higher concentrations of solutes, though all were highly hazardous for irrigation. The effluent at four pumping stations, Ghulam Muhammadabad, Satiana Road, Jaranwala Road, and Jhang Road of Faisalabad city, were unfit for irrigation owing to high EC, SAR, and RSC. In addition, high EC, SAR, and RSC of the effluent might be due to the extensive use of poor-quality groundwater, textile industries, cosmetics, use of detergents, and soap in residential areas (Cowan-Ellsberry *et al.*, 2014; Ghafoor *et al.*, 2004; Hussain, 2000).

3.2. Heavy metals concentration in Lyallpur town

3.2.1. Nickel (Ni) concentration in ground, canal and wastewater

The water quality in Lyallpur Town is ongoing contaminated with heavy metals as chemical analysis described that Ni concentration in groundwater samples ranged from 0.007-0.018 mg L⁻¹ with mean value of 0.013 mg L⁻¹. Maximum concentration of Ni in ground water (0.018 mg L⁻¹) was observed at Chak No. 55 JB (Khurd pur) while minimum 0.007 was at Chak No. 60 JB Shahbaz pur. Ni concentration in canal water varied from 0.009-0.015 mg L⁻¹ with the mean value of 0.006 mg L⁻¹. Highly contaminated site was Chak No. 112 JB with maximum concentration of Ni (0.015 mg L⁻¹). The Ni concentration range (0.008-0.018 mg L⁻¹) with mean value of 0.012 mg L⁻¹ was observed in wastewater at the location of Chak No. 197 RB (Baghian wala) (Table 2). The Ni concentration in the ground, canal and wastewater was below the permissible limit (0.2 mg L⁻¹) as proposed by Ayers and Westcott, (1985). The spatial submission of Ni concentration in water was examined using GIS techniques. The Ni focus in water samples was interpolated with the Inverse Distanced Weighted (IDW) technique. The Ni concentration thematic part which was acquired with interpolation then overlaid with other thematic levels such as street techniques and towns using GIS software (Arc Map version 9.1). In map, the area under green color indicated the Ni concentration in water less than 0.20 mg L⁻¹ while the area under sky blue color indicated the water concentration values greater than 0.20 mg L⁻¹ (Figure. 5).

Many small industries such as battery, dyeing, fabric printing, electroplating, metal surface treatment, and paints discharge their untreated effluents in sewage water, which may be the reason of high contents of heavy metals in wastewater. Similar findings were reported by Ramesh and Damodhram, 2016. Saif *et al.*, (2005); Sekhar *et al.* (2006) also stated that Ni concentration in water is increasing due to continuous discharge of Ni carrying contaminated waste by leather tanning and Lado marka soap industries in Lyallpur Town. High Ni concentration (0.02-5.35 mg L⁻¹) in the Korangi area of Karachi was also due to the presence of industrial wastes. In present study Ni concentration remain in permissible limit 0.20 mg L⁻¹ as proposed by Ayres and Westcott, (1985) but continuous application of wastewater may increase the level of Ni in groundwater.

3.2.2. Lead (pb) concentration in ground, canal and wastewater

Collection of ground water samples from varying sites represented that maximum range of Pb concentration (0.24 mg L⁻¹) was reported in Chak No. 105 JB Qazi Wala contrast to lesser Pb concentration (0.01 mg L⁻¹) which was reported in Chak No. 33 JB Viru Wana. The Pb concentration in canal water ranged from 0.10-0.13 with the mean value of 0.118 mg L⁻¹ as the utmost concentration of

Pb (0.13 mg L⁻¹) was observed at Chak No. 42 JB, while lowest (0.10 mg L⁻¹) at Chak No. 116 JB. The Pb concentration in wastewater from least amount to highest range was recorded in Chak No. 59 JB (Nathu Chak) and Chak No. 56 JB (Giyala Khurd) with values of 0.09-0.16 mg L⁻¹, respectively. Mostly wastewater samples were collected from village area where wastewater is not polluted by industrial effluents (Table 2). The Pb concentration in the ground, canal and wastewater samples were below the permissible limit (5 mg L⁻¹) as proposed by Ayers and Westcott (1985). The GIS method was employed to assess the spatial variability of Pb concentration in water samples of Lyallpur town. The Pb concentration in water was interposed with the Inverse Distanced Weighted (IDW) method. The Pb concentrate interpolated part was then overlaid with other thematic stages such as road methods and villages using GIS program (Arc Map version 9.1). The area under green color indicated the Pb concentration in water less than 5.00 mg L⁻¹ while the area under sky blue color indicated the water concentration values greater than 5.00 mg L⁻¹ (Figure 6).

Pb concentration remain in safer limit 5 mg L⁻¹ but continuous irrigation by treated and untreated sewage water results higher concentrations of heavy metals in soil which ultimately increase the Pb concentration in groundwater. Rattan *et al.*, (2005) have also found higher concentration of Pb 0.09 mg L⁻¹ in wastewater as compared to the ground water. This is because Pb has been acknowledged, for hundreds of years, as collective typical metabolic toxins (Adepoju-Bello and Alabi, 2005). It is a neuron toxin and is accountable for the most everyday sort of individual steel toxicosis (Jaishankar *et al.*, 2014). Even at low level of Pb exposures cause hypertension as well as decreased intellect quotient in kids (Zietz *et al.*, 2007).

3.2.3. Cadmium (cd) concentration in ground, canal and wastewater

The maximum concentration of Cd (0.12 mg L⁻¹) in groundwater samples was observed at Chak No. 55 JB Khurd pur while minimum (0.00 mg L⁻¹) was at University of Agri. Fsd with mean value of 0.04 mg L⁻¹. The wastewater sampled from Lyallpur town ranged from 0.01-0.017 with mean value of 0.11 mg L⁻¹. The maximum Cd concentration observed at Chak No. 7 JB Ghafoor town while minimum Chak No. 197 RB (Baghian wala). The Cd concentration in the ground and wastewater samples as according to Ayres and Westcott, (1985) at most of the sites was found above the critical limits (0.01 mg L⁻¹). The sample site Chak No. 116 JB was accounted as severe contaminated place for Cd concentration in canal water with 0.07 mg L⁻¹ value while least affected site was the Chak No.

119 JB (Rasool Pur) for Cd concentration (0.01 mg L^{-1}) with mean value of 0.03 mg L^{-1} (Table 2).

The spatial presentation of Cd in water was examined using GIS techniques. Cd in water samples was interpolated based on the inverse distance Weighted (IDW) technique. Cd emphasis in water was then covered with other thematic layers such as roads and villages with technical GIS application (Arc Map Edition 9.1) acquired. In common, many places of Cd concentration were identified in water map. A green shade showed the Cd in water less than 0.01 mg L^{-1} , while under the sky blue highlighted the water concentration values more than 0.01 mg L^{-1} (Figure 7).

As per allowable limits of heavy metals in water have been set by different Worldwide Organizations such as USEPA, EPA and Western Partnership Percentage (Marcovecchio et al., 2007), thus, heavy metals have highest possible allowable level in water as specified by these organizations. The WHO Edition (2011) also specified standard upper limits for Ni, Pb and Cd are 0.07 mg/L , 0.01 mg/L and 0.003 mg/L , respectively as cited by Egbueri and Mgbenu (2020). Maximum toxic stage (MCL) is an enforceable standard set at a mathematical value with sufficient edge of safety to ensure no negative effect on individual wellness. It is the highest stage of a toxic that is allowed in a water system (Momodu and C.A. Anyakora, 2010). The high concentration of Cd in ground water, canal water and wastewater may be due to the in-situ weathering of parent material. The results are similar to the findings of Saif et al., (2005) who found Cd concentration in various water samples in the similar.

Conclusion

In conclusion due to shortage of good quality water, the use of raw city effluent is increasing for the irrigation of crops which contain a huge amount of salts and different types of heavy metals. The continuous appliance of raw city effluent for irrigation of crops, the heavy metals are accumulating in soils, plants and ultimately enter into the food chain. In conclusion, concerning to chemical properties (EC, SAR, RSC) of water, all the ground and wastewater collected from Lyallpur town, are unfit but canal water considered as marginally fit for irrigation. Among heavy metals contamination, Cd concentration has exceeded the critical limits in all ground, canal and wastewater which leads the water quality towards deterioration while Ni and Pb concentration not hazardous under permissible limit.

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Table 1. Chemical properties of ground, canal and wastewater samples in Lyallpur town, Faisalabad

Site No.	Location	EC (dS m ⁻¹)			SAR (mmolc L ⁻¹) ^{1/2}			RSC (mmolc L ⁻¹)		
		GW	CW	WW	GW	CW	WW	GW	CW	WW
01	Chak No. 31 JB Murad Shah	1.45	-	-	3.71	-	-	3.44	-	-
02	Chak No. 32 JB Karim Pur	0.45	-	-	3.89	-	-	0.86	-	-
03	Chak No. 34 JB	1.66	-	-	5.53	-	-	1.02	-	-
04	Chak No. 33 JB Viru Wana	1.53	-	-	3.57	-	-	0	-	-
05	Chak No. 30 JB	0.45	-	-	4.03	-	-	1.64	-	-
06	Chak No. 59JB Nathu Chak	2.27	-	4.65	5.68	-	18.20	0.84	-	29.92
07	Chak No. 56 JB Giyala Khurd	1.91	-	8.25	3.08	-	19.83	2.66	-	13.50
08	Chak No. 60 JB Shahbaz pur	0.44	-	-	4.40	-	-	0.98	-	-
09	Chak No. 58 JB Lehlian	2.23	-	-	10.83	-	-	5.46	-	-
10	Chak No. 52 JB Mulan pur	2.37	-	-	8.80	-	-	2.82	-	-
11	Chak No. 54 JB Todian	2.26	-	-	8.13	-	-	4.7	-	-
12	Chak No. 50 JB Seth Wala	0.42	-	-	4.13	-	-	1.18	-	-
13	Chak No. 26 JB Nand pura	3.90	-	-	0.73	-	-	0	-	-
14	Chak No. 55 JB Khurd pur	3.08	-	-	0.47	-	-	5.46	-	-
15	Chak No. 27 JB	1.73	-	-	2.62	-	-	2.32	-	-
16	Chak No. 28 JB	1.41	-	-	3.37	-	-	3.94	-	-
17	Chak No. 29 JB	1.38	-	-	3.39	-	-	1.02	-	-
18	Chak No. 30 JB Sidhu pura	3.60	-	6.31	6.32	-	22.98	0	-	38.08
19	Rashidabad	12.71	-	-	5.90	-	-	0	-	-
20	Chak No. 100 JB Kuri Wala	0.40	-	-	0.30	-	-	0	-	-
21	Chak No. 8 JB Panj Garai	1.02	-	-	3.28	-	-	1.22	-	-
22	Chak No. 51 JB Sajadah	1.91	-	-	8.79	-	21.52	6.76	-	16.96
23	Chak No. 6 JB	0.34	-	-	0.84	-	-	0	-	-
24	Chak No. 5 JB	0.35	-	-	2.17	-	-	0	-	-
25	Chak No. 7 JB Ghafoor town	2.73	-	4.35	2.88	-	14.30	6.12	-	13.08
26	Chak No. 119 JB Rasool Pur	2.94	0.40	-	2.98	2.62	-	5.38	1.24	-
27	Chak No. 3 JB	0.60	-	-	1.63	-	-	0	-	-
28	Chak No. 48 JB	2.46	-	5.78	6.15	-	26.96	4.04	-	26.04
29	Chak No. 2 JB Ram Dawali	1.88	-	-	5.23	-	-	4.22	-	-
30	Chak No. 47 JB Mansooran	1.17	-	2.01	3.69	-	16.25	0.44	-	12.85
31	Chak No. 49 JB	0.97	-	-	3.22	-	-	0	-	-
32	Chak No. 119 JB Rasool Pur	0.62	-	-	2.68	-	-	0	-	-
33	Chak No. 104 JB Harmoyan	0.70	-	-	0.85	-	-	0	-	-
34	Chak No. 112 JB	2.73	0.78	-	11.15	3.80	-	3.26	2.3	-
35	Chak No. 4 JB	1.64	-	-	0.67	-	-	3.38	-	-
36	Noor Pur	3.52	-	-	1.91	-	-	0	-	-
37	Dhanola	7.05	-	5.34	1.31	-	25.19	6.06	-	21.76
38	Chak No.195 RB Jandala	1.44	-	-	9.87	-	-	4.32	-	-
39	Chak No. 190 RB	3.12	-	-	7.42	-	-	3.13	-	-
40	Chak No. 108 JB	2.65	-	-	1.60	-	-	3.2	-	-
41	Chak No. 116 JB	1.14	0.29	-	3.74	1.92	-	1.64	0.00	-
42	Chak No. 42 JB	1.13	1.40	-	3.51	3.57	-	0	2.06	-
43	Chak No. 105 JB Qazi Wala	1.56	-	-	5.86	-	-	4.86	-	-
44	Chak No. 114 JB	1.88	-	-	1.87	-	-	2.28	-	-
45	Chak No. 118 JB Bathar	0.27	-	-	0.81	-	-	0	-	-
46	Chak No. 115 JB Diyal Garh	1.27	-	-	1.17	-	-	0	-	-
47	Muslim Town	1.69	-	-	2.39	-	-	0	-	-
48	Taj Colony	1.77	-	-	5.09	-	-	1	-	-
49	Niab Colony	1.11	-	-	5.46	-	-	0	-	-
50	University of Agri. Fsd	0.79	-	-	1.66	-	-	0	-	-
51	Model Town	0.85	-	-	2.14	-	-	0.88	-	-
52	Chak No. 199 RB Gut Wala	1.31	-	-	0.11	-	-	5.04	-	-
53	Chak No. 198 RB Manian wala	1.57	-	-	0.12	-	-	3.52	-	-
54	Chak No. 197 RB Baghian wala	3.52	-	5.34	0.15	-	2.83	4.03	-	6.68
55	Chak No. 192 RB Rasool Nagar	10.85	-	-	0.08	-	-	3.94	-	-
56	Chak No. 201 RB Chandian Talawan	2.18	-	-	0.08	-	-	3.46	-	-
57	Chak No. 191 RB Muiwani Harlan	1.22	-	-	0.05	-	-	5.96	-	-
58	Chak No. 196 RB Gonna	0.74	-	-	0.11	-	-	1.14	-	-
59	New Civil Line	0.81	-	-	0.01	-	-	2.64	-	-
60	New Civil Line (Jinnah Garden)	1.39	-	-	0.04	-	-	0	-	-
	Standard Deviation	6.61	0.50	1.68	0.044	0.87	7.86	4.09	1.04	9.83
	Mean	2.04	0.72	5.45	0.110	2.98	17.42	2.17	1.40	18.95
	Range	0.27-12.71	0.29-1.40	2.01-8.25	0.006-0.24	1.92-3.80	2.83-25.19	0.00-6.76	0.00-2.06	6.68-38.08

GW: Ground water; CW: Canal water; WW: Wastewater

Table 2. Heavy metals concentrations in ground, canal and wastewater samples in Lyallpur town, Faisalabad

Site No.	Location	Ni (mg L ⁻¹)			Pb (mg L ⁻¹)			Cd (mg L ⁻¹)		
		GW	CW	WW	GW	CW	WW	GW	CW	WW
01	Chak No. 31 JB Murad Shah	0.016	-	-	0.08	-	-	0.003	-	-
02	Chak No. 32 JB Karim Pur	0.014	-	-	0.08	-	-	0.003	-	-
03	Chak No. 34 JB	0.012	-	-	0.11	-	-	0.006	-	-
04	Chak No. 33 JB Viru Wana	0.011	-	-	0.01	--	-	0.006	-	-
05	Chak No. 30 JB	0.015	-	-	0.04	-	-	0.003	-	-
06	Chak No. 59JB Nathu Chak	0.011	-	0.015	0.07	-	0.09	0.001	-	0.013
07	Chak No. 56 JB Giyala Khurd	0.015	-	0.013	0.15	-	0.16	0.003	-	0.011
08	Chak No. 60 JB Shahbaz pur	0.007	-	-	0.12	-	-	0.009	-	-
09	Chak No. 58 JB Lehlian	0.014	-	-	0.10	--	-	0.009	-	-
10	Chak No. 52 JB Mulan pur	0.012	-	-	0.09	-	-	0.004	-	-
11	Chak No. 54 JB Todian	0.017	-	-	0.11	-	-	0.005	-	-
12	Chak No. 50 JB Seth Wala	0.013	-	-	0.10	-	-	0.001	-	-
13	Chak No. 26 JB Nand pura	0.013	-	-	0.07	-	-	0.008	-	-
14	Chak No. 55 JB Khurd pur	0.017	-	-	0.09	-	-	0.012	-	-
15	Chak No. 27 JB	0.016	-	-	0.04	-	-	0.001	-	-
16	Chak No. 28 JB	0.015	-	-	0.08	-	-	0.002	-	-
17	Chak No. 29 JB	0.011	-	-	0.03	-	-	0.001	-	-
18	Chak No. 30 JB Sidhu pura	0.016	-	0.011	0.09	-	0.09	0.009	-	0.009
19	Rashidabad	0.015	-	-	0.05	-	-	0.001	-	-
20	Chak No. 100 JB Kuri Wala	0.012	-	-	0.10	-	-	0.006	-	-
21	Chak No. 8 JB Panj Garai	0.015	-	-	0.03	-	-	0.004	-	-
22	Chak No. 51 JB Sajadah	0.012	-	0.009	0.12	-	0.10	0.005	-	0.011
23	Chak No. 6 JB	0.012	-	-	0.16	-	-	0.001	-	-
24	Chak No. 5 JB	0.015	-	-	0.12	-	-	0.006	-	-
25	Chak No. 7 JB Ghafoor town	0.015	-	0.014	0.14	-	0.09	0.003	-	0.017
26	Chak No. 119 JB Rasool Pur	0.015	0.009	-	0.10	0.11	-	0.001	0.001	-
27	Chak No. 3 JB	0.016	-	-	0.14	-	-	0.001	-	-
28	Chak No. 48 JB	0.012	-	0.016	0.15	-	0.11	0.006	-	0.01
29	Chak No. 2 JB Ram Dawali	0.011	-	-	0.08	-	-	0.003	-	-
30	Chak No. 47 JB Mansooran	0.015	-	0.013	0.10	-	0.11	0.002	-	0.016
31	Chak No. 49 JB	0.017	-	-	0.12	-	-	0.002	-	-
32	Chak No. 119 JB Rasool Pur	0.011	-	-	0.13	-	-	0.003	-	-
33	Chak No. 104 JB Harmoyan	0.014	-	-	0.10	-	-	0.003	-	-
34	Chak No. 112 JB	0.017	0.015	-	0.14	0.13	-	0.001	0.007	-
35	Chak No. 4 JB	0.011	-	-	0.15	-	-	0.003	-	-
36	Noor Pur	0.011	-	-	0.12	-	-	0.004	-	-
37	Dhanola	0.015	-	0.008	0.09	-	0.12	0.003	-	0.012
38	Chak No.195 RB Jandala	0.009	-	-	0.04	-	-	0.007	-	-
39	Chak No. 190 RB	0.015	-	-	0.16	-	-	0.009	-	-
40	Chak No. 108 JB	0.013	-	-	0.15	-	-	0.001	-	-
41	Chak No. 116 JB	0.014	0.014	-	0.16	0.10	-	0.001	0.01	-
42	Chak No. 42 JB	0.012	0.013	-	0.14	0.13	-	0.004	0.004	-
43	Chak No. 105 JB Qazi Wala	0.012	-	-	0.24	-	-	0.001	-	-
44	Chak No. 114 JB	0.015	-	-	0.21	-	-	0.003	-	-
45	Chak No. 118 JB Bathan	0.010	-	-	0.13	-	-	0.011	-	-
46	Chak No. 115 JB Diyal Garh	0.013	-	-	0.10	-	-	0.003	-	-
47	Muslim Town	0.012	-	-	0.14	-	-	0.001	-	-
48	Taj Colony	0.016	-	-	0.06	-	-	0.001	-	-
49	Niab Colony	0.018	-	-	0.18	-	-	0.001	-	-
50	University of Agri. Fsd	0.009	-	-	0.10	-	-	0.000	-	-
51	Model Town	0.013	-	-	0.06	-	-	0.003	-	-
52	Chak No. 199 RB Gut Wala	0.012	-	-	0.11	-	-	0.004	-	-
53	Chak No. 198 RB Manian wala	0.014	-	-	0.12	-	-	0.004	-	-
54	Chak No. 197 RB Baghian wala	0.014	-	0.018	0.15	-	0.11	0.005	-	0.008
55	Chak No. 192 RB Rasool Nagar	0.016	-	-	0.08	-	-	0.003	-	-
56	Chak No. 201 RB Chandian Talawan	0.014	-	-	0.08	-	-	0.003	-	-
57	Chak No. 191 RB Mulwani Harlan	0.011	-	-	0.05	-	-	0.007	-	-
58	Chak No. 196 RB Gonna	0.012	-	-	0.11	-	-	0.006	-	-
59	New Civil Line	0.011	-	-	0.01	-	-	0.006	-	-
60	New Civil Line (Jinnah Garden)	0.015	-	-	0.04	-	-	0.003	-	-
	Standard Deviation	0.003	0.003	0.003	0.044	0.015	0.022	0.002	0.004	0.003
	Mean	0.013	0.013	0.013	0.110	0.118	0.109	0.004	0.006	0.012
	Range	0.007-0.018	0.009-0.015	0.008-0.018	0.006-0.24	0.1-0.13	0.09-0.16	0.000-0.012	0.001-0.01	0.008-0.017

GW: Ground water; CW: Canal water; WW: Wastewater

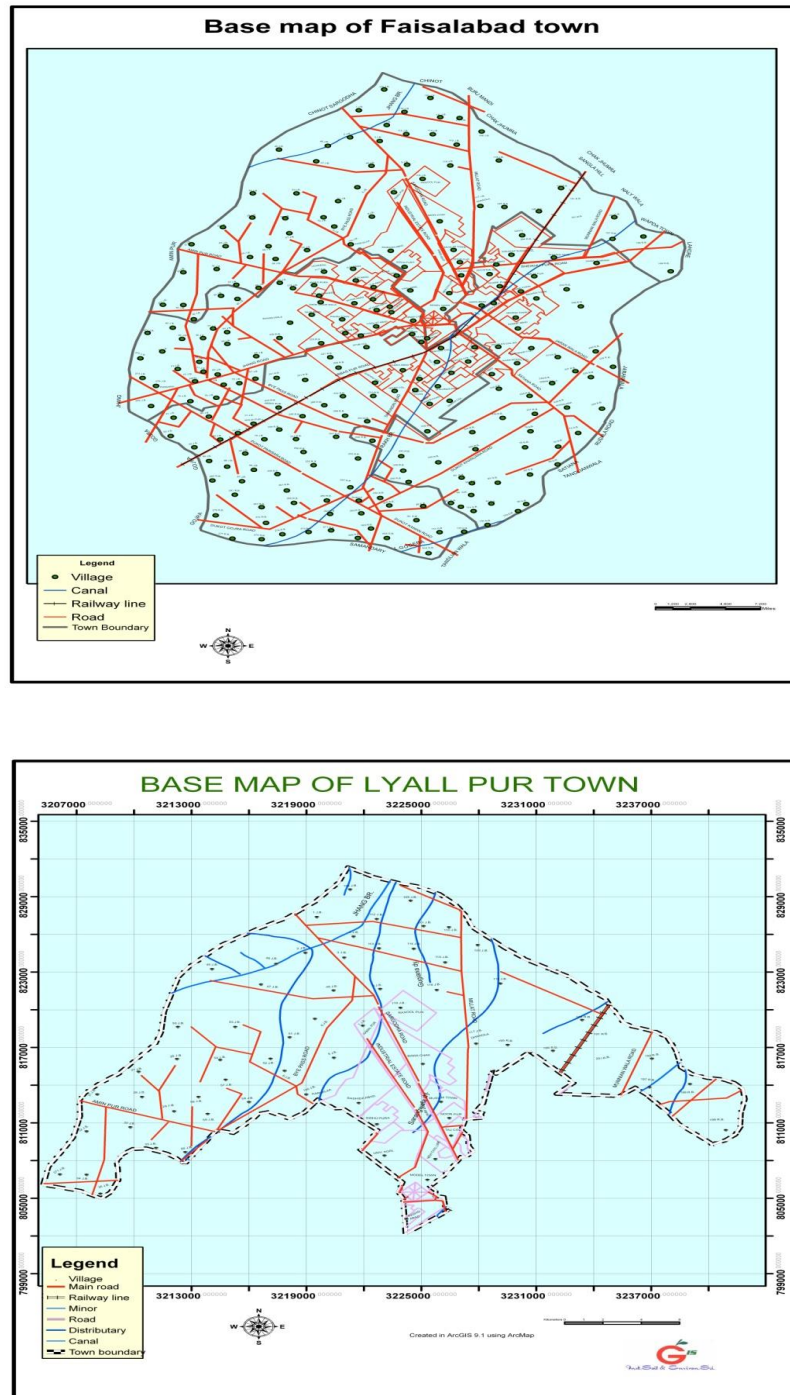


Figure 1. Base maps of Faisalabad city and Lyallpur town



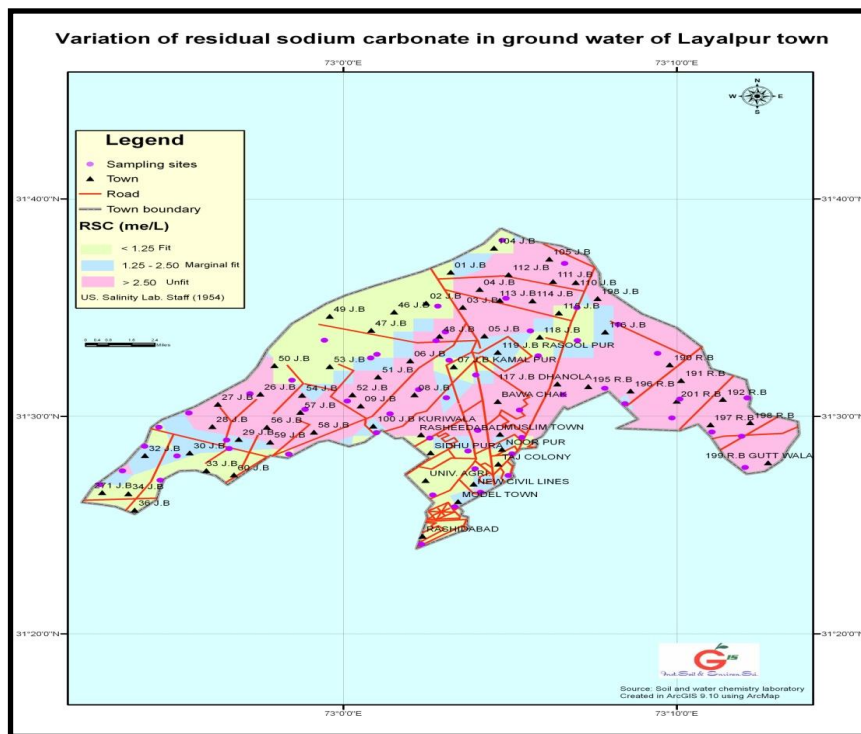


Figure 4. Map of RSC in ground water of Lyallpur town

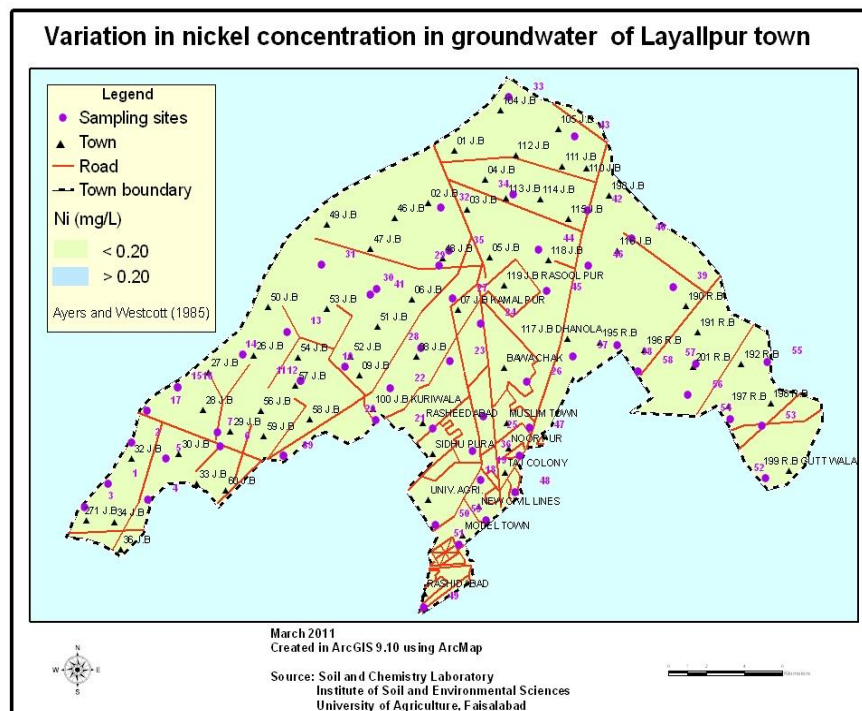


Figure 5. Map of Ni concentration (mg/L) in ground water of Lyallpur town

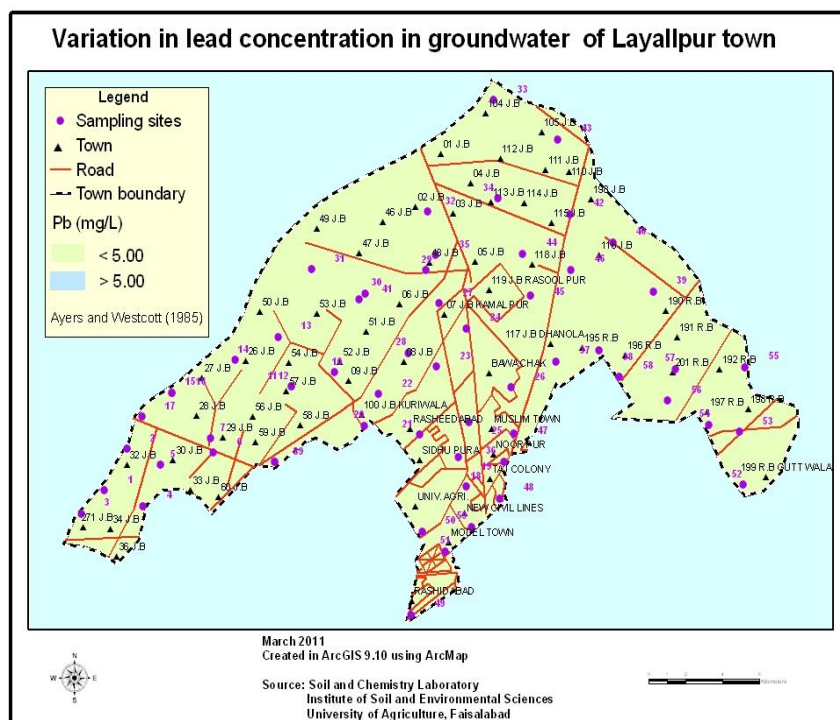


Figure 6. Map of Pb concentration (mg/L) in ground water of Lyallpur town

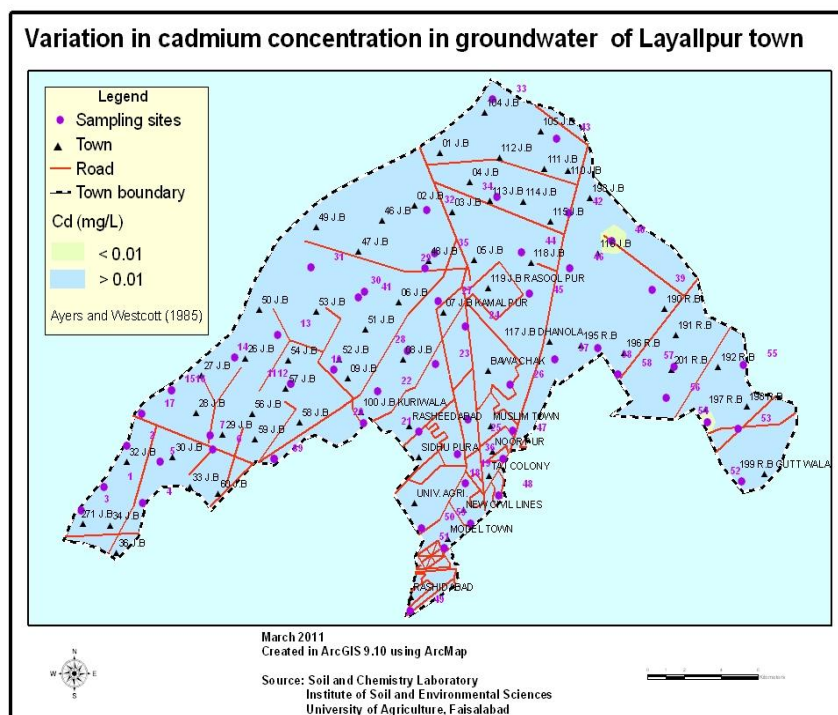


Figure 7. Map of Cd concentration (mg/L) in ground water of Lyallpur town