SPATIAL DISTRIBUTION OF HEAVY METALS IN GROUND WATER OF SHEIKHUPURA DISTRICT PUNJAB, PAKISTAN

Muhammad Akram Qazi, M. Amir Khattak**, Muhammad Salik Ali Khan*, Muhammad Nawaz Chaudhry**, Khalid Mahmood*, Belqees Akhter*, Naveed Iqbal*, Shazia Ilyas** and Umair Asghar Ali****

ABSTRACT

Spatial distribution of heavy metals in ground water of industrial area of district Sheikhupura, Punjab, Pakistan during 2010 was investigated using Geographic Information System (GIS). To check heavy metals, 235 ground water samples were collected along with the latitude and longitude coordinate values. Samples were analysed for irrigation quality parameters i.e. electrical conductivity (EC), sodium adsorption ratio (SAR) and residual sodium carbonate (RSC). Nineteen samples were selected randomly for five heavy metals (Cd, Co, As, Cu and Mn) and analysed using Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES). An area about 107 square kilometers comprising six villages namely Wandala Nasir, Pindi Das, Purab, Noon, Shamke and Zia Abad was investigated. Prediction maps were developed which illustrate that the extreme eastern and western sides of area of interest have fit ground water including the Zia Abad and Wandala Nasir villages. More than 50% area has unfit ground water on the basis of EC and RSC. Regarding heavy metals, results of prediction maps match with ground realities. Most of the area along Motorway to Muridkey road is dense with varied nature of industries. Cluster analysis showed that 52, 45 and 20% of total area has higher Cadmium, Cobalt and Manganese concentrations, respectively than maximum permissible limits for irrigation purpose. However Arsenic and Copper concentrations were within the safe limits except few patches.

KEYWORDS: Heavy metals; Cd; Co; As; Cu; Mn; geographic information system; GIS Punjab, Pakistan.

INTRODUCTION

Pakistan is an agro-based country whose sustainable economical production mainly depends upon the sagacious application of irrigation water. Unfortunately, the quantity of surface irrigation water is not sufficient to meet the crop water requirements. To augment these inadequate water supplies, the available ground water remains the solitary alternative to be gauged for

***Soil and Water Testing Laboratory for Research, Thokar Niaz Baig, Lahore, **College of Earth and Environmental Sciences, University of the Punjab, Lahore, ***Directorate of Soil Fertility Survey and Soil Testing Institute, Lahore, Punjab, Pakistan.**

its judicious application. In rural areas groundwater is an important source for irrigation and drinking water. Due to rapid increase in population and modern land use practices the ground water resources are under great risk of depletion and quality degradation. Khattak *et al.* (8) reported in his study that 79% ground water samples taken from adjoining areas of Hudiara industrial drain were unfit for irrigation purpose. An irrigation water quality survey conducted at Soil and Water Testing Laboratory, Attock from the year 2004-05 to 2008-09 revealed that 88 samples (46 %) out of total 192 were fit, 27 samples (14 %) were marginally fit while 77 samples (40 %) were unfit for irrigation to crops (12). It was also reported that 30 samples (28.3% of total 106 samples) were found unfit for irrigation in district Jhang during the year 2009 and 2010 (14). In another study it was concluded that ground water quality is of great concern for the sustainability of soil health and crop productivity (1). Similarly Kashif *et al.* (8) has suggested monitoring of water quality to avoid the hazards of low quality irrigation water. Among the other irrigation quality parameters, heavy metals are also considered as contaminants which are not readily biodegraded over time. If accumulation of toxic metals in water and sediments is neglected, a potential health risk may generate in near future. Lead poisoning in children causes neurological damage, reduction in intelligence, learning disabilities and problems with coordination. The effects of arsenic include cardiovascular problems, skin cancer and kidney damage (3). It was reported that principal health risks associated with mercury are harmful to the nervous system, with such symptoms as uncontrollable shaking, muscle wasting, partial blindness, and deformities in children exposed in the womb. At levels well below WHO limits, it can damage the fetal and embryonic nervous systems with consequent learning difficulties, poor memory and shortened attention spans (6, 7). Heavy metals especially cadmium (Cd) and lead (Pb) may accumulate when entered into human body through food chain and could be hazardous to health (16). It is established fact that quality of irrigation water has a major concern in sustaining soil health and crop production therefore present study was carried out to assess the suitability of ground water by using geographic information system (GIS) especially focusing on heavy metals. The GIS-based techniques were used to demonstrate the spatial distribution of heavy metals by prediction maps which work as fingerprints for identifying the origin of pollutants and can be used to distinguish between natural and anthropogenic inputs as well and finally for mitigation purposes.

MATERIALS AND METHODS

Total 235 ground water samples were collected from six villages located around Pindi Das and Kala Shah Kaku industrial area of district Sheikhupura, Punjab, Pakistan during 2010. Global positioning system (GPS) readings were recorded for each site along with other necessary descriptions such as depth of tube well, owner name, installation date (Fig. 1). Irrigation quality parameters like electrical conductivity (EC), sodium adsorption ratio (SAR), residual sodium carbonate (RSC) and heavy metals like cadmium (Cd), cobalt (Co), arsenic (As), copper (Cu) and manganese (Mn) were determined. Quantitative variations of these heavy metals show variable degrees of pollution and the human activities in the localities under study.

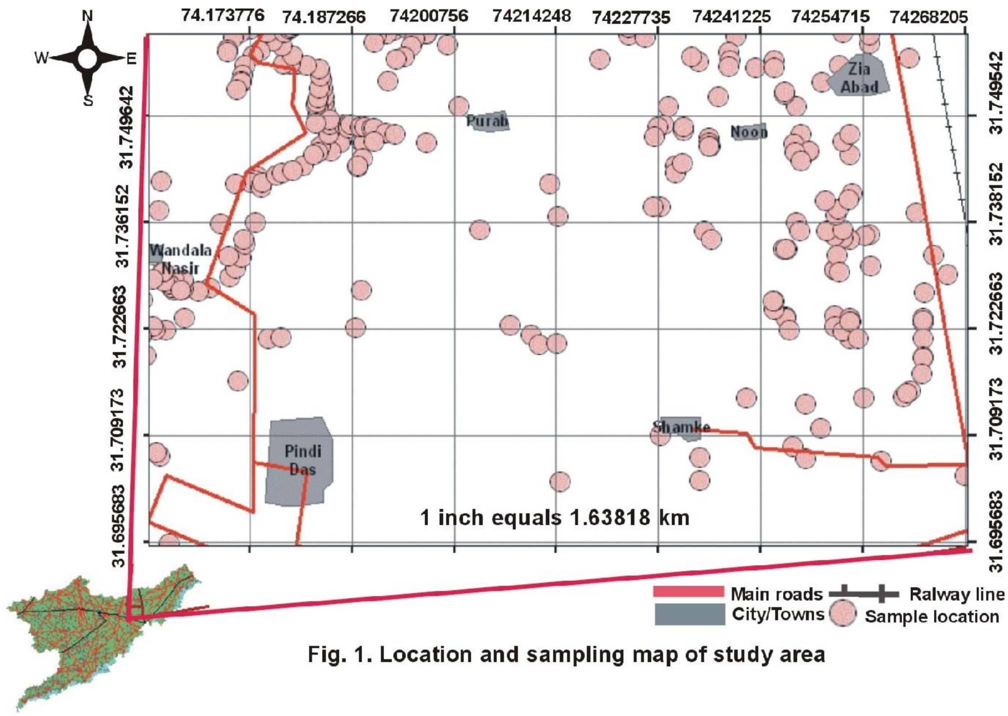

Fig. 1. Location and sampling map of study area

Arc view 9.3 and ArcGIS cluster analysis were used for the generation of various groundwater quality parameter maps. For the present study, the data of EC, SAR, RSC and heavy metals concentrations have been used to construct the spatial maps of the individual parameter using ordinary Kriging. However, estimates of the probability of impact for each parameter under study in term of risk zones modelling have also been performed by DK technique. Applying DK technique, the original data have been transformed to a Gaussian distribution using Hermite polynomials and then the variogram of the transformed variable has been calculated and modelled. Using the variogram, the indicators for each of the threshold or background value for each parameter was estimated. Risk for each parameter is shown by gradient of colours.

Sodium adsorption ratio (SAR) was calculated by following equation given (14). All cations are given in meq/L.

$$SAR = Na^{+} / [(Ca^{+2} + Mg^{+2}) /2] ½$$

Residual sodium carbonate (RSC) was measured in meq/L using the equation

$$RSC = (CO_3^{-2} + HCO_3^{-}) – (Ca^{+2} + Mg^{+2})$$

Heavy metals in water samples were quantified by ICP-OES, Perkin Elmer, Optima 5300 DV. Certified reference materials (CRMs) having traceability to National Institute of Standards and Technology (NIST) were used for preparation of calibration standards. Standard operating conditions were adopted during analysis.

Prediction maps for electrical conductivity (EC), SAR and RSC based on estimated probabilities were categorized into three suitability classes namely fit, marginally fit and unfit for irrigation against the standards established by Agriculture Department, Government of the Punjab, Lahore (Table 1). These suitability classes are illustrated by gradient of colours from dark green to light green and pink for fit, marginally fit and unfit, respectively.

Table 1. Irrigation water quality criteria.

Parameters	Status	Richards (14)	WAPDA (5)	Muhammad(11)	Malik (10)
EC ($\mu S\ cm^{-1}$)	Suitable	750	<1500	<1500	<1000
	Marginal	751-2250	1500-3000	1500-2700	1001-1250
	Unsuitable	>2250	>3000	>2700	>1250
SAR	Suitable	<10	<10	<7.5	<6
	Marginal	10-18	10-18	7.5-15	6-10
	Unsuitable	>18	>18	>15	>10
RSC ($me\ L^{-1}$)	Suitable	<1.25	<2.5	<2.0	<1.25
	Marginal	1.25-2.50	2.5-5.0	2.0-4.0	1.25-2.5
	Unsuitable	>2.5	>5.0	>4.0	>2.5

RESULTS AND DISCUSSION

Electrical conductivity map shows very clear demarcation of the high risk zones for EC in and around Pindi Das, Purab and Wandala Nasir industrial area (Fig. 2). The nature and random locations of industries and geological factors like soil parent material are most likely the factors contributing high risk zone of electrical conductivity. Samples of localities near river Ravi including village Zia Abad were found fit whereas the areas around village Noon was marginally fit for irrigation. Overall, 21.4 square km, (20% of study area) has ground water of fit quality, 26.7 square km (25%) has marginally fit and 58.8 square km (55%) area has unfit ground water regarding EC.

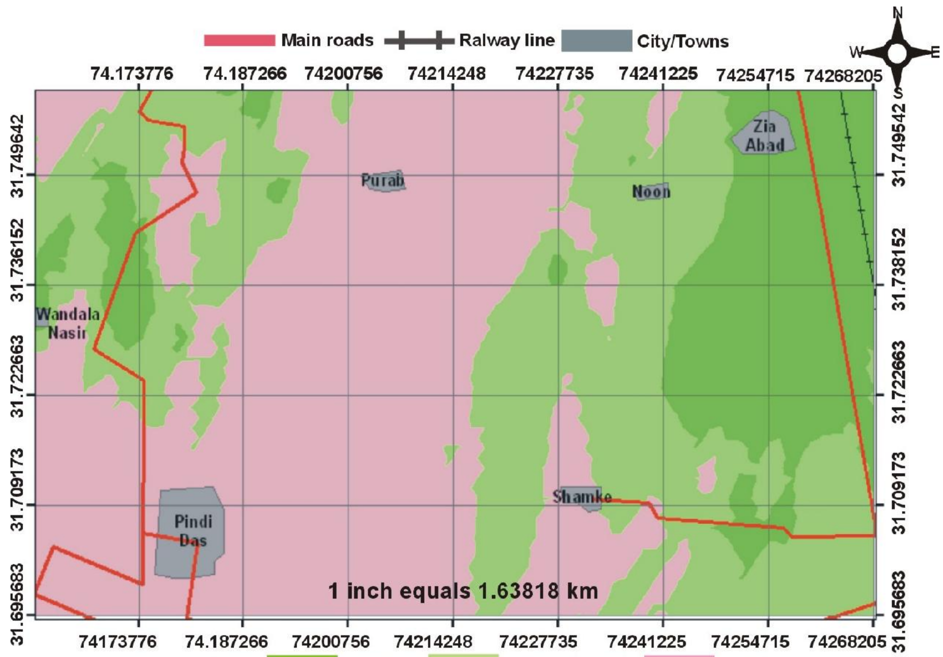

Fig. 2. Risk zone classification map of EC (Pindi Das and K.S.K).

Sodium adsorption ratio map of area of interest illustrates risk zones in and around Wandala Nasir village which is almost 10.7 square km (10%) area (Fig. 3).Fit zone was observed near river Ravi including villages Zia Abad, Noon and Shamke which may be due to river recharge comprising 42.8 square km (40%) whereas the surroundings of villages Purab and Pindi Das (53.5 square km area, 50%) have marginally fit ground water.

Regarding RSC high risk zones were found in and around the villages Wandala Nasir, Purab, Pindi Das and Shamke constituting 62% of total study area (66.3 km²). Fit area was found comprising village Zia Abad and its south east localities. (19.3 km², 18%) whereas 21.4 square km (20%) area covering village Noon and eastern side of village Shamke has marginally fit ground water (Fig. 4).

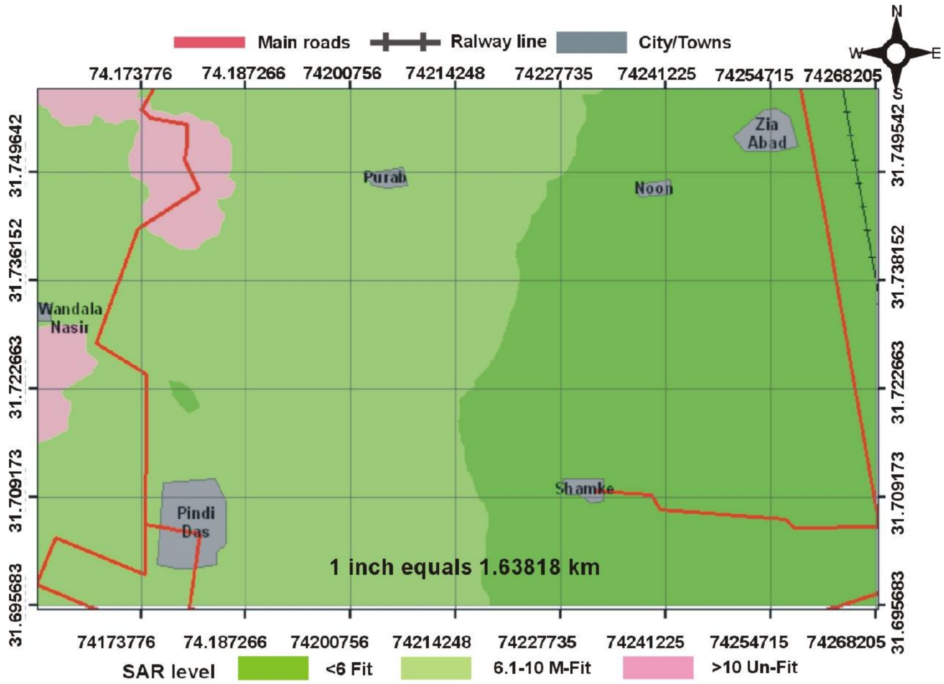

Fig. 3. Risk zone classification map of SAR (Pindi Das and K.S.K).

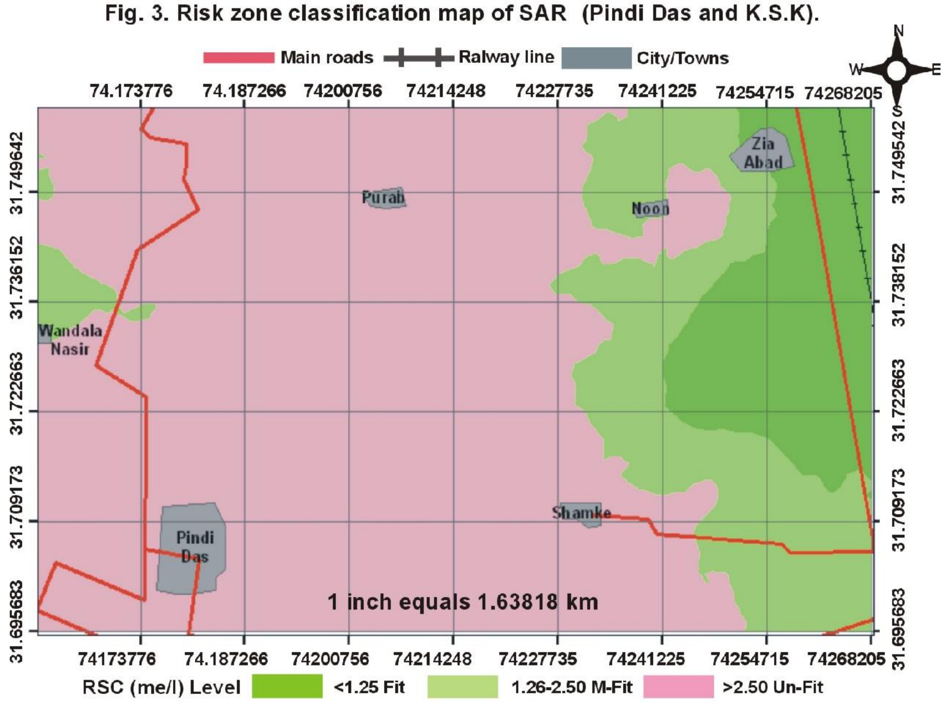

Fig. 4. Risk zone classification map of RSC (Pindi Das and K.S.K).

The heavy metals (Cd, Co, As, Cu and Mn) concentrations in irrigation water were evaluated against standard set by WWF, Pakistan (4). Other international standards are given for comparison (Table 3).

Risk zone categorization of heavy metals is represented by green and pink colours for safe and unsafe categories, respectively. Considering 0.01mg/L safe limit for cadmium (Cd), the ground water of area covering villages Zia Abad, Noon, Wandala Nasir and eastern side of Purab were found unsafe (Fig. 5). On the other hand, groundwater of the Pindi Das, Shamke and western side of Purab was within safe limits. Overall, 51.4 square km (48%) area falls under safe limit while 55.6 square km (52%) area was lying under cadmium risk zone. Cadmium is non essential metal with toxic effects on kidneys. The main sources of Cd are industries like electroplating, pigments, plastic and battery industries.

International limit for Co is 0.05mg/L and the areas around villages Noon, Zia Abad and Wandala Nasir were lying in the risk zone having ground water Co concentration above safe limits (Fig.6). This constitutes 48.2 square km area (45%). Surroundings of Pindi Das, Purab and Shamke indicated by green colour, have safe ground water. Maximum value of Co was found to be 0.23 with mean value of 0.22 mg/L (Table 2).

Table 2. Range, mean and standard deviation of irrigation quality parameters.

Parameters	Minimum	Maximum	Mean	Standard deviation
EC (μS cm^{-1})	500	8910	1108	699.63
SAR	1.98	67.91	6.81	5.89
RSC (me L^{-1})	0.00	7.6	2.15	1.85
Cd (mg/L)	0.36	0.38	0.37	0.002
Co (mg/L)	0.20	0.23	0.22	0.005
As (mg/L)	Nil	0.39	0.14	0.13
Cu (mg/L)	0.07	0.21	0.16	0.040
Mn (mg/L)	0.26	0.28	0.26	0.004

Table 3. Recommended concentrations (mg/L) of heavy metals in irrigation water.

Metal	Concentration (mg/L)	
	International Standards (2, 6 & 12]	WWF (4)
Cadmium	0.01	0.01
Cobalt	0.05	0.05
Arsenic	0.10	0.10
Copper	0.20	0.20
Manganese	0.20	0.20

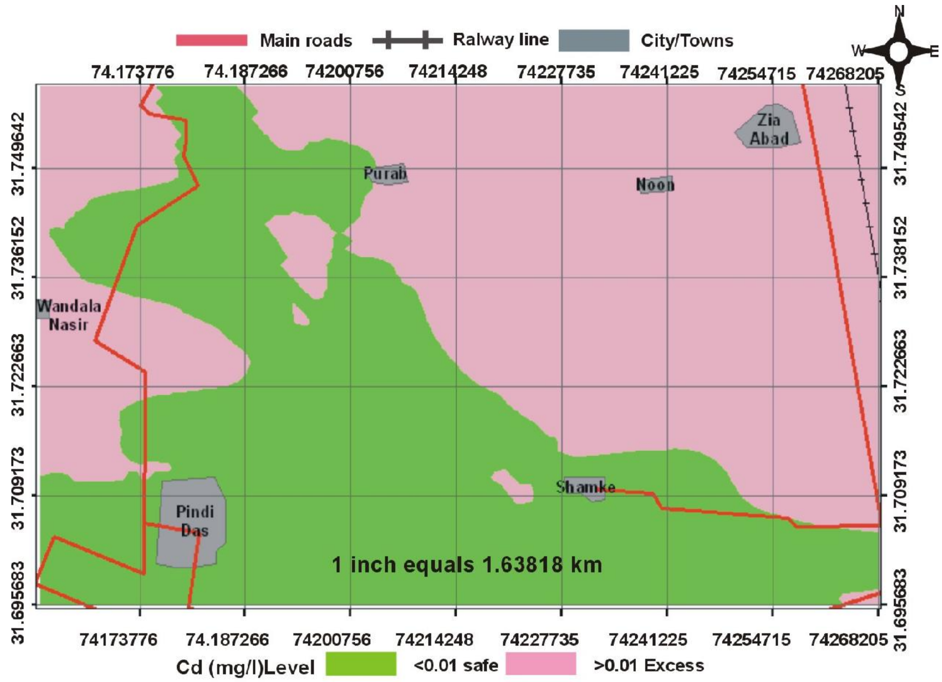

Fig. 5. Risk zone classification map for Cd (Pindi Das and K.S.K).

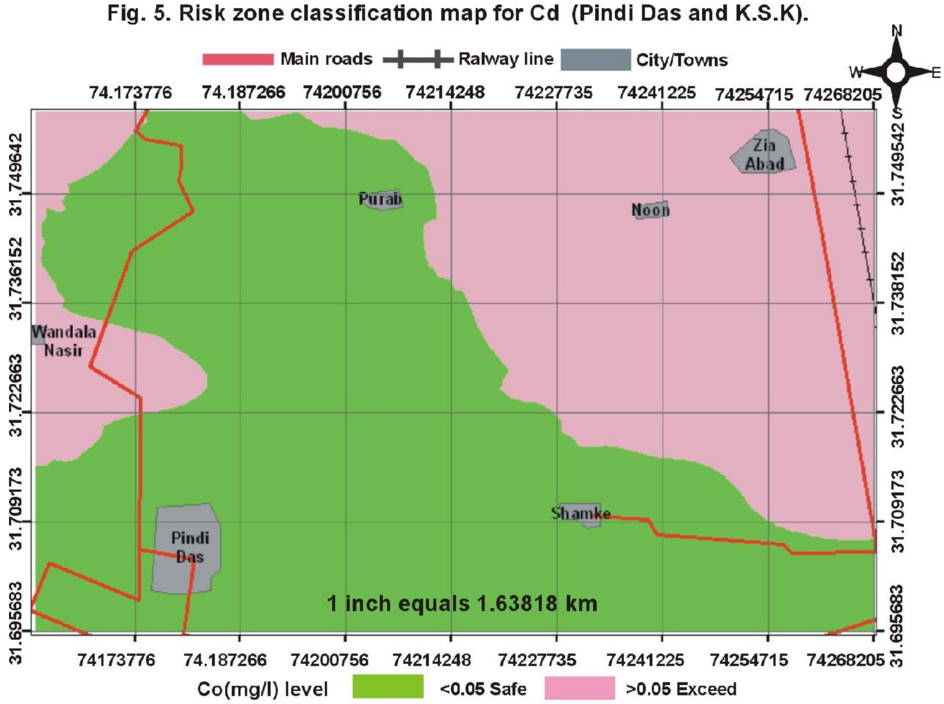

Fig. 6. Risk zone classification map of Co (Pindi Das and K.S.K).

Village Wandala Nasir is lying in the arsenic (As) risk zone having As contents above 0.10 mg/L (Fig. 7). The areas around Pindi Das, Purab, Noon, Zia Abad and Shamke have As contents with in safe limits (below 0.10 mg/L) and constitute 96.3 square km area (90%). Maximum value of As was found as 0.39 mg/L with mean value of 0.14 (Table 2).

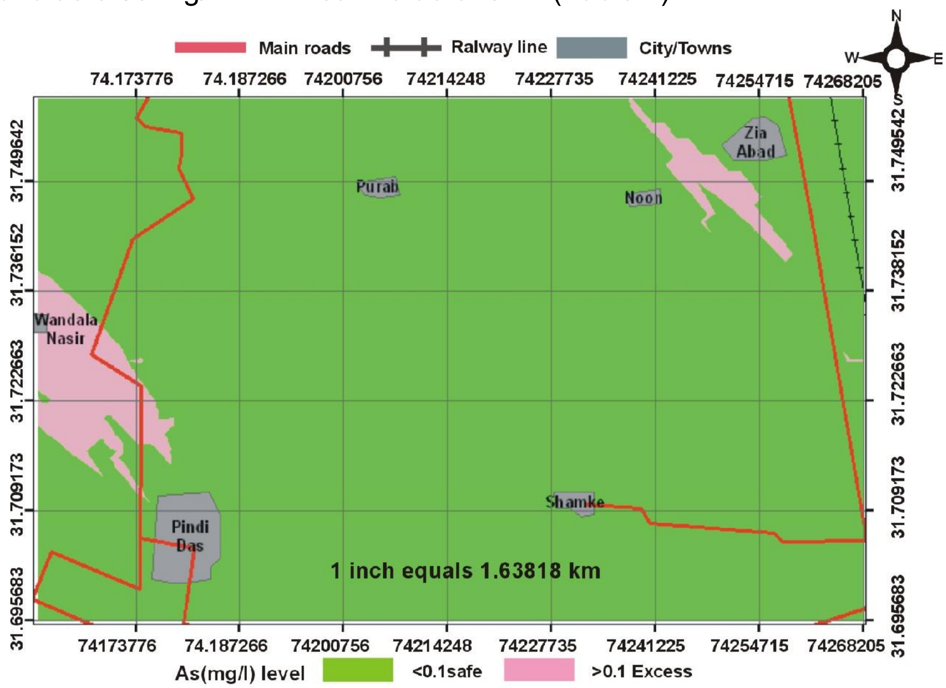

Fig. 7. Risk zone classification map for As (Pindi Das and K.S.K).

Area comprising 99.5 square km (93%) fall under safe copper (Cu) limit (<0.2 mg/L). All the villages of study area Wandala Nasir, Pindi Das, Purab, Noon, Zia Abad, Shamke and their surroundings have safe ground water for irrigation. Seven percent area (7.5 square km) has Cu contamination risk in ground water (Fig. 8). Maximum value of Cu was found to be 0.21 mg/L with mean value of 0.16 mg/L.

Area under the village Wandala Nasir and eastern side of Noon (21.4 square km, 20%) was predicted lying under manganese (Mn) risk zone having Mn contents above 0.20 mg/L whereas Pindi Das, Purab, Shamke and western side of Noon were predicted in safe category. Overall 85.6 square km (80%) of total study area have safe ground water aquifers in this connection (Fig.9). Maximum Mn concentration was found to be 0.28 mg/L (Table 2).

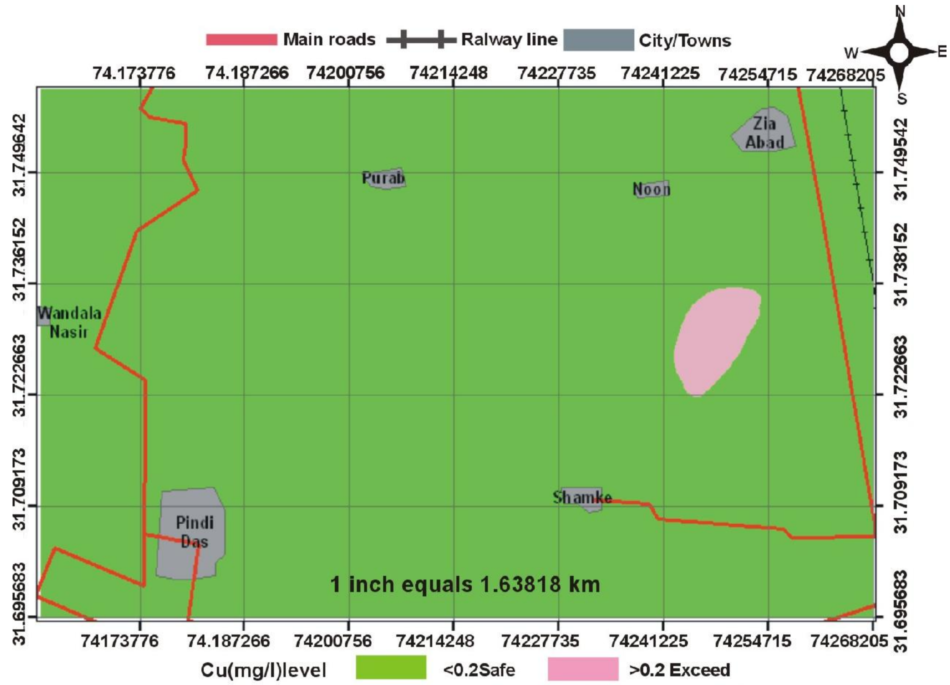

Fig. 8. Risk zone classification map of Cu (Pindi Das and K.S.K).

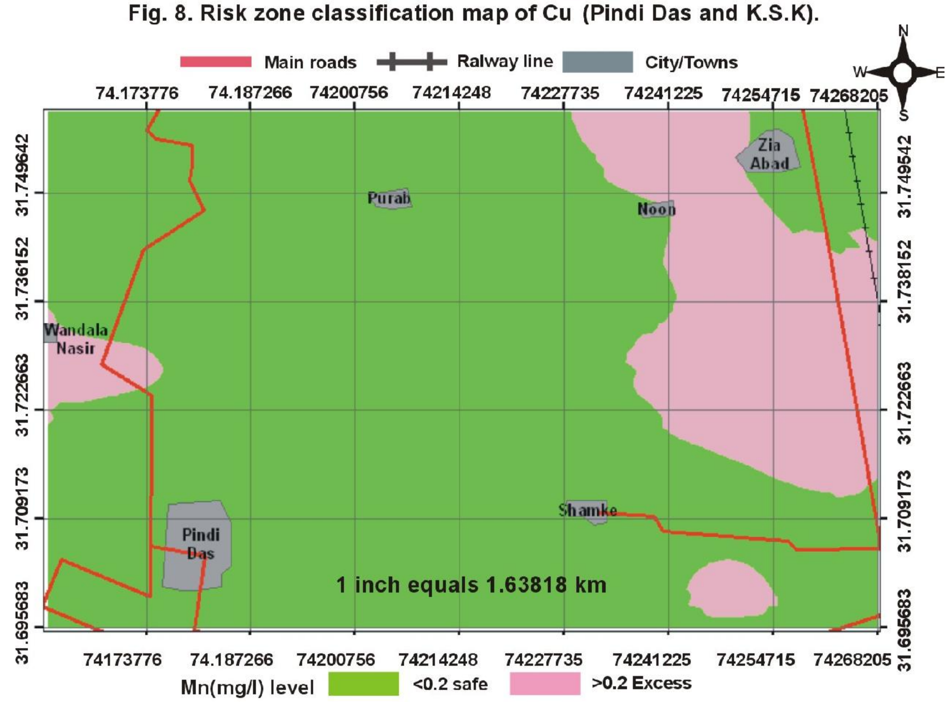

Fig. 9. Risk zone classification map for Mn (Pindi Das and K.S.K).

Ground water reservoirs in extreme eastern and western sides of study area including the Zia Abad and Wandala Nasir villages have no salinity or sodicity problem while the rest of area showed a mixed trend regarding EC, SAR and RSC parameters. Therefore it is recommended that farmers who are residents of risk area should get analyzed their tubewell water from nearby Soil and Water Testing Laboratory of Agriculture Department, Government of the Punjab, for site specific interpretations.

CONCLUSION

It is concluded from the study that concentration of heavy metals Cd, Co and Mn was higher along Motorway to Muridkey road on the eastern side of AOI which has diversified industries including chemicals manufacturing and food processing. This water having variable amounts of heavy metals, if continuously used for irrigation without any treatment or proper management practices may lead to increase in heavy metals concentration in the agricultural land. However arsenic and copper concentrations of ground water were within the safe limits except few patches.

ACKNOWLEDGEMENT

This research work was conducted in collaboration with Directorate of Soil Fertility Survey and Soil Testing Institute, Lahore, Pakistan. Authors are thankful to Dr. Shahzada Munawar Mehdi, Director for his kind permission to utilize GIS facilities.

REFERENCES

1. Ali, M.S., S. Mahmood, M.N. Chaudhry and M. Sadiq. 2009. Irrigation quality of ground water of twenty villages in Lahore district. Soil and Environ. 28(1):17-23.
2. Alloway, W.H. 1968. Agronomic control over the environmental cycling of trace elements. Adv. Agron.20:235-274).
3. Anon. 1997. Health and Environment in Sustainable Development. World Health Organization, Geneva.
4. Anon. 2007. National Surface Water Classification Criteria, Irrigation Water Quality Guidelines for Pakistan, WWF-February, 2007.
5. Anon. 1981. Atlas – Soil salinity survey of irrigated areas of Indus basin 41 million acres. Survey and Research Organization. Planning Division, WAPDA, Lahore.

6. Ayers, R.S. and D.W. Westcot. 1985. Water Quality for Agriculture. Irrigation and Drainage. Paper No. 29, FAO, Rome, Italy.
7. Jorgensen, P.J., R. Dahl, P. Grandjean, P. Wahl, R.F. White and N. Sorensen. 1997. Cognitive deficit in 7-year-old children with prenatal exposure to methyl mercury. Neur. and Tera. 19:417-428.
8. Kashif, S.R. M. Akram, M. Yaseen and S. Ali. 2009. Studies on heavy metals status and their uptake by vegetables in adjoining areas of Hudiara drain in Lahore. Soil and Environ. 28(1):7-12.
9. Khattak, M.A., N. Ahmed, M.A. Qazi, A. Izhar, S. Ilyas, M.N. Chaudhary, M.S.A. Khan, N. Iqbal and T. Waheed. 2012. Evaluation of ground water quality for irrigation and drinking purposes of the areas adjacent to Hudiara industrial drain, Lahore, Pakistan. Pak. J. Agri. Sci. 49(4):549-556.
10. Malik, D.M., M.A. Khan and T.A. Chaudhry. 1984. Analysis method for soil, plant, and water. Soil Fertility Survey and Soil Testing Institute, Punjab, Lahore, Pakistan.
11. Muhammad, S. 1996. Soil salinity, sodicity and water logging. p. 472-506. *In:* Soil Science. A. Rashid and K.S. Memon., (eds) National Book Foundation Islamabad, Pakistan.
12. Pendias, A.K. and H. Pendias. 1984. Trace elements in soils and plants. CRC Press, Boca Raton, FL, USA.
13. Rehman, O., B. Ahmed and S. Afzal. 2011. Sources and quality of irrigation water in district Attock. J. Agric. Res. 49(2).
14. Richards, L.A. 1954. Diagnosis and Improvement of Saline and Alkali Soils, Agriculture Handbook 60: US Department of Agriculture, Washington, DC.1954.
15. Shafiq, M and M. Saleem. 2013. Quality assessment of ground water for irrigation in district Jhang. J. Agric. Res., 51(2).
16. Vannostdam, J., A. Gilman, E. Dewailly, P. Usher, B. Wheatley and H. Kuhnlein. 1999. Human health implications of environmental contaminants in Arctic Canada. A review. Sci. Total Environ.,230:1-82.