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GIS BASED STUDY OF HEAVY METALS CONCENTRATION IN SOIL OF BADIN DISTRICT, SINDH, PAKISTAN

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Abstract

The purpose of this study is to assess heavy metals concentration at various locations in soil of the Badin area by creating GIS-based maps. Twenty soil samples were collected from the study area on various scales using standard methods. Sample concentrations of cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), zinc (Zn), and cobalt (Co) were analysed and the results were recorded on a map using ArcGIS. We used spatial tools of ArcGIS 10.5 for interpolation and to generate the maps. According to the results of heavy metals, it is recognized that all selected heavy metals except chromium have higher concentrations in the study area compared to international standards. The sources of heavy metal pollution in the study area are industrial activities such as use of chemicals in oil and gas exploration and exploitation, sugar mills waste, agricultural waste and household waste. High concentrations of heavy metals in the soil of the reported study areas affect not only the agricultural sector, but the entire ecosystem and maintain the balance of the ecosystem. Therefore, it is recommended to take appropriate measures to balance pollutants in the soil and dispose of industrial and municipal waste promptly and appropriately to keep environmental biodiversity clean and balanced.

Keywords: Heavy metals pollution; spatial distribution; GIS; Badin.

Introduction

Soil and sediment play a very important role in human needs such as agriculture, food, freshwater, fresh air and biodiversity (Keesstra et al., 2016). Soil is a vital part of the geosphere and is very important for the biodiversity of ecosystems. (Sastre et al., 2002). If the concentration of trace elements exceeds the permissible limit in the soil, it can have dangerous effects on the health of plants, animals and humans. Soil plays an important role in controlling the transport of pollutants under the surface and is hydrologically related to the groundwater system. (Kabata-Pendias, 2004). Therefore, it is important to identify and understand the type, level, and cause of pollution. If the soil is contaminated, the groundwater can also be contaminated. (Environment, 2006). As a result of increased industrial and agricultural activity, heavy metal concentrations in surface soils have been found to increase worldwide. (Kabata-Pendias, 2010, Kumar, 2006).

Heavy metal contamination of soil and water is due to industrialization and is a major environmental problem in Pakistan. Therefore, it is important to assess soil and water pollution levels near industrial areas. (Afzal., et al., 2014). Lithological changes can also increase or decrease the levels of heavy and trace metals in soil, but small-scale human activity is a major cause of serious environmental problems around the world. Human effects on the biosphere have been tracked since the Neolithic era, but have caused significant ecosystem degradation in recent decades. (Kabata-Pendias, 2004). The area of study lies between (24º-5` to 25º-25` N) and (68º 21' to 69º 20' E). This district is bounded on the north by the Tando Allahyar District, northwest by the Hyderabad District, on the east by MirpurKhas and Tharparkar districts, on the south by the Kutch district of India, and on the west by Thatta district (Fig.1**).** The total area of the district is 6,726 square kilometers. There are many sugar industries in the district, and it is also called "Sugar state" and also oil and gas producing district in lower Indus basin. Nearly 83% of the population lives in the rural areas with farming as the main source of livelihood. The district is irrigated by the Indus River through the Akram Wah, Phuleli and Guni Canals of Kotri Barrage and the Nasir Canal of Sukkur Barrage.

The Badin city is the main town of the Badin district. This district consists of total five tehsils namely Badin, Tando Bago, Golarchi, Matli and Talhar. A moderate climate is experienced in the entire district. The temperature in the summer rises by 25° to 45°C. However, in the winter the temperature ranges from 30° C to 10°C. The temperature falls during the night and humidity calculated is 76 percent in the district. Rainfall is totally unpredictable, with an average of 170 mm. Badin district is mostly covered up with alluvial deposits of river Indus anciently called Nullah, Gungra, Hakra water courses with a huge alluvial plain. The world's 7th largest Indus delta is located in the southern portion of the district Badin, and the land area is comparatively low in contrast to the northern part of the district Badin. The sand dunes of the Tharparkar area dominate the eastern section of Badin district. The drainage system of this district is grossly inadequate and poorly maintained (IUCN, 2006).

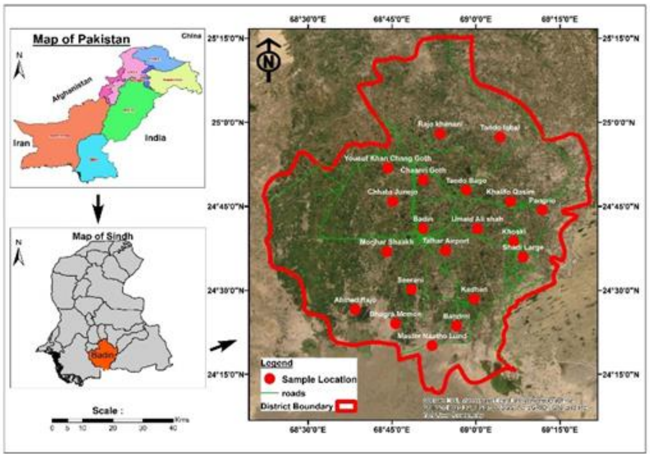

Fig. 1. Location map of study area.

The research area lies in the lower Indus basin that is one of the major sedimentary and structural basins of Pakistan. The Badin area surficially consists of recent deposits (alluvium) and no such rocks are exposed in the Badin area (Fig.2) However, surface geology exhibit Holocene deposits that are the deltaic flood plain deposits showing the abundant traces of old meander belts of course of present rivers which consists of silt, Fine sand and clay the deposits in stream beds and meander belts are a complex, poorly sorted, fine to medium grained sand with the least amount of silt and clay.

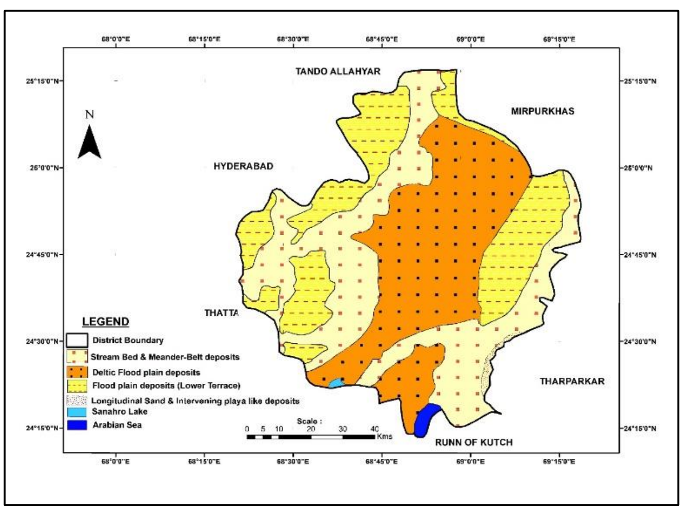

Fig 2. Geological map of study area

The flood plain deposits are compensated by greenish grey to grey silt and clay with subordinate sand (lower terrace). Longitudinal sand and intervening playa like deposits show longitudinal sand dunes are occupying the southern part of Thar desert where wind action is great. The strike is parallel to the wind direction and windward slope is relatively short. The interdunal valleys are vegetated with scattered scrubs, bushes and small trees which are rain fed. Sand dunes vary in thickness from 14 to 93 m, dominantly consisting of fine loose sand and a thick band of silt and clay. Sand and silt consist of moderately to well sorted quartz with scattered minute mica flakes and calcareous grains of soil and fossil fragments (Geological Map of Sindh, 2012).

Material and Methods

A total of 20 soil samples were collected using soil Auger's at various locations in the district, and 0.5 kg of samples weretaken for laboratory analysis and stored in polypropylene zippered bags. Global Positioning System (GPS) was used for each sample location. Each soil sample was spread on a clean plastic tray and dried in a fume hood at room temperature. A clean polypropylene bag was used to store the dry soil samples. In research Centre, ultra-pure water was utilized (produced by a purifier of Milli Q Millipore Corp, Bedford, MA United States). Merck (Darmstadt, Germany) supplied reagents such as Acetic acid, Hydrochloric acid (65 percent, specific gravity 1.4), nitric acid, and hydrogen peroxide (30 percent), with analytical reagent grade. It was examined whether there were any metal defilements. The ammonium acetic acid was produced by Sigma Aldrich Co. Ltd. The Co, Cu, and Zn working standard solutions were prepared by dilution of 1000 ppm approved standard solutions of the relevant metal ions from Fluka Kamica (Buchs, Switzerland). Sigma (Aldrich, Milwaukee, USA) and Merck provided the ammonium acetate (CH_3COONH_4) and hydroxyl ammonium chloride, respectively. For extraction of 50 mL acid-washed polyethylene centrifuge tubes were utilized, while extractant were stored in 50 mL polyethylene vessels Bibby (Sterilin Ltd., UK). WIROWKA Laboratory sort WE-1 centrifuge obtained from Mechanika Phecyzyjna, Poland (speed run 0 6000 rpm, clock 0-60 minutes, 220/50Hz). PEL (Japan) PM023 domestic programmable microwave oven employed for single step extraction method, with power Input 220240V 50 Hz (Volts/Hz), microwave Frequency 2450 MHz, and microwave Output 900 Watt. A WTW pH meter was utilized for reagent pH change and pH soil insurance. Atomic absorption spectrometry (AAS) was carried to determine Cd, Pb, and Cr concentration. As radiation sources, hollow cathode lamps were used. The lamp power, band-pass width, and other analytical parameters were set according to the manufacturer's recommendations. Each collected sample location's latitude/longitude data was recorded in Degree, Minutes, Seconds (DMS) format and turned to decimal degrees (LongDD and LatDD). The converted data were sorted in an Excel format file exported and imported into the Spatial Analyst tool in the ArcGIS 10.5 Desktop software for interpretation of spatial distribution maps for each heavy metal in soil and maps were generated.

Results and Discussion

The standards suggested by Bohn et al., (2001) were adopted in present study. The achieved results are presented and discussed as under:

1. Lead (Pb)

of fossil fuels, smelting, transportation, waste incineration, and agricultural application of sewage have all resulted in an increase in its concentration in soil and water (Holmgren et al., 1993; Moges et al., 2013; Nazir et al., 2015; Wong et al., 2002). The acceptable Pb limit for soil is 10 mg/kg 1 (Bohn et al., 2001).

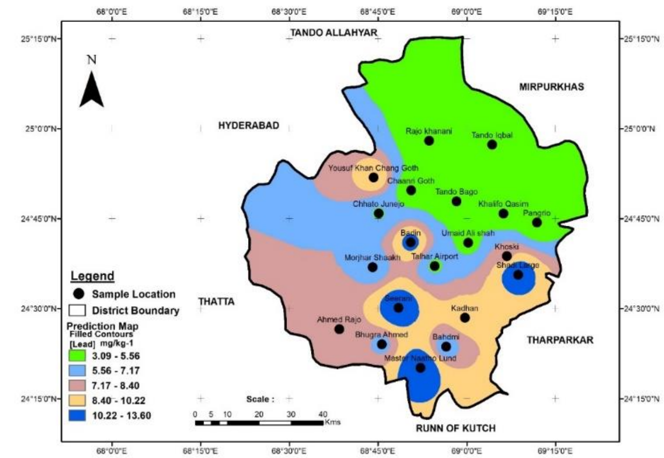

Fig. 3 Spatial distribution map of Lead (Pb) in study area.

2. Zinc (Zn)

Zinc is a key element that is required for plant and animal physiological and metabolic activities. However, its high concentration can be toxic to the organisms. The acceptable Zn limit for soils is 50 mg/kg-1 (Bohn et al., 2001). According to the results of this study, the study area's Zinc (Zn) content ranges from 3.0 to 200.12 mg/kg 1. In study areas of Bhugra memon, Morjhar Shaakh, Umaid Ali shah, Rajo khana Talhar Airport, Pangrio and Tando Bago, the Zn content in the collected samples lies in the permissible limits. Whereas, in the samples from the areas of Tando Iqbal, Khalifo Qasim, Khoski, Kadhan, Chhato Junejo, Shadi Large, Ahmed Rajo, Bahdmi, Chaanri Goth, Badin, Seerani, Master Naatho Lund and Yousuf Khan Chang Goth, the content of zinc is higher (Fig. 4).

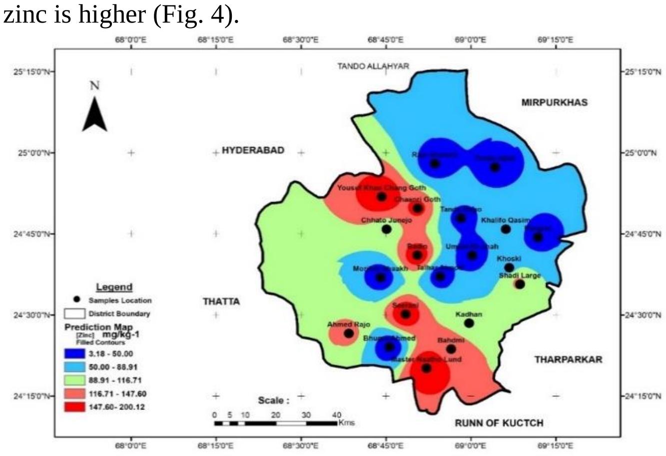

Fig. 4 Spatial distribution map of Zinc (Zn) in study area.

3. Cobalt (Co)

The acceptable Cobalt concentration for soils is 8 mg/kg^{-1} (Bohnet al., 2001). According to the results of this study, the study area's Cobalt content ranges from 0.94 to 23.6 mg/kg^{-1}. In study areas of Chhato Junejo, Talhar Airport, Kadhan, Rajo khanani, Umaid Ali shah, Bhugra memon, Morjhar Shaakh. Bahdmi, Khalifo Qasim, Khoski, Tando Bago, Seerani, Shadi Large, Ahmed Rajo, Badin, Pangrio, Master and Naatho Lund, the cobalt content fall in permissible range except Tando Iqbal, Chaanri Goth, and Yousuf Khan Chang Goth areas where the cobalt content is found to be in high concentration (Fig. 5).

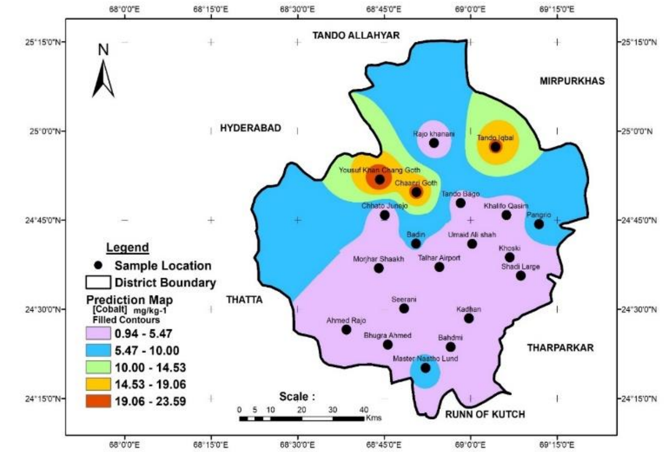

Fig. 5 Spatial distribution map of Cobalt (Co) in study area

4. Copper (Cu)

The average Cu content of soils around the world is 30 mg/kg^{-1} (Bohn et al., 2001**)** suggested that Cu contents level shouldbe **20** mg/kg$^{-1.}$ in normal agriculture soils. According to the results of this study, the Copper (Cu) content ranges from **8.77** to **87.51** mg/kg $^{1.}$ In study areas of Master Naatho Lund, Chhato Junejo, Umaid Ali shah, Kadhan, Bhugra memon, Pangrio,Talhar Airport, Bahdmi, Tando Iqbal, Morjhar Shaakh, Chaanri Goth, Khalifo Qasim, Rajo khanani, Tando Bago and Khoski samples the copper content fall in permissible range. Whereas the sample from areas of Badin, Ahmed Rajo, Shadi Large, Yousuf Khan Chang Goth and Seerani show high concentration of Copper (Fig. 6).

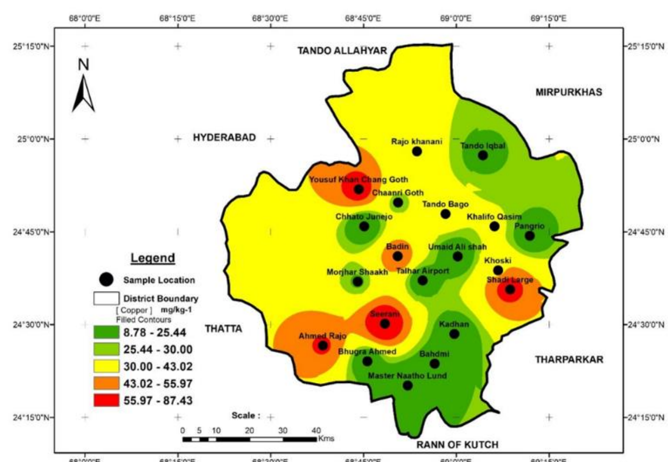

Fig. 6 Map of spatial distribution of Copper (Cu) in study area.

5. Cadmium (Cd)

Cadmium concentration for normal agriculture, water/soil is 0.01 to 7.0 mg/kg^{-1} (Bohn et al., 2001). The results of this study indicated that the Cadmium content in study area ranges from 4.77 to 69.50 mg/kg^{-1}. In study areas of Rajo khanani, Shadi Large and Tando Bago the samples fall in permissible range. Meanwhile, the samples from areas of Kadhan, Khoski, Umaid Ali shah, Khalifo Qasim, Ahmed Rajo, Yousuf Khan Chang Goth, Tando Iqbal, Chaanri Goth, Bhugra memon, Badin, Talhar Airport, Morjhar Shaakh, Bahdmi, Chhato Junejo, Pangrio,Master Naatho Lund and Seerani represent the high concentration of cadmium (Fig. 7).

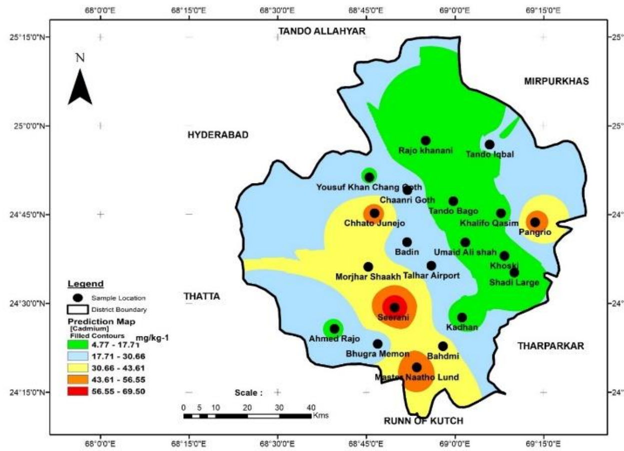

Fig.7 Spatial distribution of Cadmium (Cd) in study area.

6. Chromium (Cr)

The chromium is the widespread element found in different concentrations in air, water, soil, and all biological matters (Adriano, 1986; Jung, 2008). The level of Cr in soil differs from trace to as high as 5.23%. Soils formed from ultramafic igneous rock generally contain high Cr (Jung, 2008). According to (Bohn, et al., 2001) the normal concentration of Chromium for agriculture soils is 20 mg/kg^{-1}. The results of present study indicated that the Chromium concentration in study area range from 1.25 to 19.36 mg/kg^{-1} (Fig. 8).

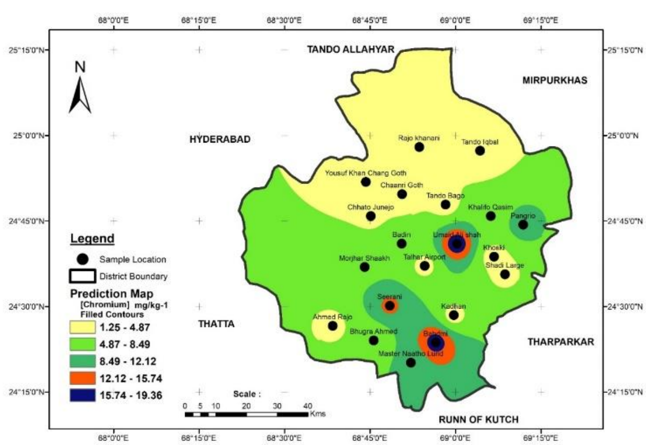

Fig. 8 Spatial distribution of Chromium (Cr) in study area.

Lead is found primarily as lead sulphide (galena) in the crust of earth and is found in low concentrations, however the anthropogenic activity is responsible for a large amount of lead in the environment. Lead contaminates agriculture, soil, water, food, and the air, and it enters the environment through mining and fuel combustion (IARC, 2006). The exposure of lead (Pb) in the human body can result in a wide range of health problems, from minor changes in metabolism and intelligence to convulsions, coma, renal failure, and death (Papanikolaou et al., 2005). The concentration of lead in study area lies within limits of 3.09 to 13.60 mg/kg^{-1}and is not harmful for agriculture.

Zinc is a necessary micronutrient that catalyzes enzyme activity and plays a wide range of roles in cell growth, cell division, wound healing, and carbohydrate breakdown in the human body and regulates gene expression and contributes to protein structure. (Waseem et al., 2014) The zinc concentration in the soil of the studied area ranges between 3.0 to 200.18 mg/kg^{-1} which is not suitable for agriculture. The normal limit of Zn for agriculture soils is 50 mg/kg^{-1}as suggested by Bohn et al., (2001).

Cobalt has been found in the environment due to both natural and human pollution causes (Barceloux, 1999). Weathering of rocks and soil, erosion (wind-blown continental dusts), volcanoes, forest fires, plant extraction, and seawater spray are all natural sources of environmental Cobalt. Cobalt emissions into the atmosphere are estimated to be 5350 to 6170 tonnes per year worldwide (Mackenzie& Lantzy, 1979; Nriagu, 1989).Mining and processing (smelting) of cobalt-bearing ores, application of cobalt-containing sludge or phosphate fertilizers to soil, disposal of cobalt-containing waste, and atmospheric deposition from activities such as fossil fuel combustion and metal smelting and refining are all major anthropogenic sources of environmental cobalt (Smith & Carson, 1981).Mined ore frequently includes less than 0.1 percent elemental cobalt, which is usually coupled with copper or nickel (W.H.O, 2006). The normal concentration limit of Cobalt for agriculture soils is 8 mg/kg^{-1} as suggested by Bohnet al., (2001). In study area cobalt ranges between 0.94 to 23.61 mg/kg^{-1} which is harmful and not suitable for agriculture.

Copper is the third most widely used metal in the world (VCI, 2011). Copper is a vital element for plant and animal growth. It contributes to the human body's production of blood hemoglobin. Cu is essential for seed production, disease resistance, and water regulation in plants. Copper is a basic requirement for both humans and plants, but excessive amounts can result in different diseases. Copper is found commonly in drinking water because to Cu pipes and algae development (ISRN Ecology, 2011). The normal concentration of copper in soil is 30 mg/kg^{-1}as suggested by Bohn et al., (2001). The range of copper in study area is 8.77 to 87.51 mg/kg^{-1} which shows high concentration and not suitable for agriculture soil. The concentration of cadmium is 0.01 to 7.0 mg/kg^{-1} as suggested by Bohn et al., (2001).In the areas of study the range of Cd lies between 4.77 to 69.50 mg/kg^{-1} while the range shows high concentration of Cd which is harmful and not suitable for agriculture. Cadmium is a natural byproduct of the zinc and lead refining operations.

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Agricultural additions, biosolids, and industrial waste disposal such as fertilizer, pesticides, and bio solids (sewage sludge), industrial waste disposal, or air pollutant deposition are all responsible for raising the overall concentration of Cd in soils (Weggleret al., 2004). Cadmium is highly bio persistent, although it has minimal toxicological characteristics, and it stays in an organism for many years after it is ingested. Cadmium affects various enzymes in the body, as per research. The kidney damage that leads to proteinuria is thought to be caused by Cd interfering with enzymes involved in protein reabsorption in kidney tubules (Manahan, 2003).

The natural composition of the rocks and sediments that make up the soil affects the concentration of Cr in the soil. The increases concentration of chromium in the soil can be caused by human-caused deposition, such as air pollution as well as the disposal of chromium-bearing liquid and solid waste products such as chrome byproducts and ferrochrome-slag, or chromium plating baths (Oliveira, 2012). The concentration of chromium in normal agriculture soils is 20 mg/kg^{-1}. The present study indicated that the Chromium content in study area ranges from 1.25 to 19.36 $mg/kg^{-1.}$ It is interpreted that the range of Cr lies in limit which is not harmful for agriculture. the range of Cr lies in limit which is not harmful for agriculture.

Conclusion

It was observed that the soil samples taken from various location of district Badin were contaminated with Cd, Zn, Pb, Cu, and Co due to activities of oil and gas exploration and exploitation companies working in study area,dumping of sugar mills waste in study area and municipal garbage into the water bodies therefore water quality as well as agricultural soil especially near the downstream were contaminated. The source of hazardous waste and contamination are caused by companies that producing fertilizers, drilling activities, pulp and paper, cement, and sugar industry. Wastewater produced in Badin, Matli and Talhar is usually sent to surface drainage canals and natural canals. Household waste, which consists primarily of biodegradable food waste and garden waste, is another source of pollution in coastal areas. Plastic waste accounts for the majority of non-biodegradable waste. Burning wood, coal, coke and other combustible waste is another source of pollution primarily caused by household activities. Various sources are responsible for this high concentration of metals in the soil under investigation. Until now, targeted improvements such as regular monitoring of surface and groundwater and soil in the Badin area have been unavoidable. Urgent treatment is needed in areas where the impact has reached dangerous levels so that the population can be saved from unforeseen disasters.

References

Afzal, M., et al. (2014). Assessment of Heavy Metal Contamination in Soil and Groundwater at Leather Industrial Area of Kasur, Pakistan. CLEAN - Soil. 42. 10.1002/clen.201100715.

Adriano, D., (1986). Heavy metal metals in the environment Springer-Verlag. New York.

Ali, Z., et al. (2015). Heavy Metal Built-Up in Agricultural Soils of Pakistan: Sources, Ecological Consequences, and Possible Remediation Measures, Heavy Metal Contamination of Soils. Springer, 23-42.doi:10.1007/978-3-319-14526-6-2.

Barceloux, D.G, & Barceloux, D.D, (1999). Cobalt, Journal of Toxicology: Clinical Toxicology, 37:2, 201-216, DOI: 10.1081/CLT-100102420

Bohn, et al. (2001). Soil chemistry third edition. John Wiley and Sons. New York, NY, 303, 48-66.

deVries, W., Lofts, S., E. Tipping, M. Meili, J.E. Groenenberg, and G. Schütze, (2007). Impact of soil properties on critical concentrations of cadmium, lead, copper, zinc, and mercury in soil and soil solution in view of ecotoxicological effects, Reviews of Environmental Contamination and Toxicology. Springer, 191.47-89

Environment, C.C. (2006). A protocol for the derivation of environmental and human health soil quality guidelines, Canadian Council of Ministers of the Environment. 215Pp.

Geological map of Sindh, issued by Geological survey of Pakistan, (2012).

Helena Oliveira., (2012). Chromium as an Environmental Pollutant: Insights on Induced Plant Toxicity, Journal of Botany, Article ID 375843, 2 pages, 2012. https://doi.org/10.1155/2012/375843.

Holmgren, G., et al. (1993). Cadmium, lead, zinc, copper, and nickel in agricultural soils of the United States of America. Journal of environmental quality, 22(2): 335-348.

IARC, (2006). IARC Monographs on the Evaluation of Carcinogenic Risks to Human, vol. 87, Inorganic and Organic Lead Compounds, International Agency for Research on Cancer.

IUCN, (2006). District Vision–Badin. A Framework for Sustainable Development. International Scholarly Research Network ISRN Ecology, 2011, Article ID 402647, 20 pages doi:10.5402/2011/402647 pp 6-7.

Jung, M.C., (2008). Heavy metal concentrations in soils and factors affecting metal uptake by plants in the vicinity of a Korean Cu-W mine. Sensors, 8(4): 2413-2423.

Kabata-Pendias, A., (2004). Soil–plant transfer of trace elements an environmental issue. Geoderma, 122(2): 143-149.

Kabata-Pendias A., (2010). Trace elements in soils and plants. Fourth Edition. CRC press.

Keesstra, S. D., et al. (2016). The significance of soils and soil science towards realization of the United Nations Sustainable Development Goals, SOIL, 2, 111–128, https://doi.org/10.5194/soil-2-111-2016.

Kumar, A., (2006). Heavy Metal Pollution Research: Recent Advances. Daya Publishing house, TriNagar, Delhi.

Lantzy RJ, Mackenzie FT., (1979). Atmospheric trace metals: Global cycles and assessment of man's impact. Geochimica et Cosmochimica Acta, 43:511–525.

Mackenzie, F. & Lantzy, Ronald & Paterson, Virginia. (1979).

  ISSN 2415-2234

Global trace metal cycles and predictions. Mathematical Geology. 11. 99-142. 10.1007/BF01028961.

Manahan, S.E., (2003). Toxicological Chemistry and Biochemistry, CRC Press, Limited Liability Company (LLC), 3rd edition,

Moges, A., Dagnachew, M., Yimer, F., (2013). Land use effects on soil quality indicators: A Case Study of Abo-Wonsho Southern Ethiopia. Applied and Environmental Soil Science,. vol. 2013, Article ID 784989, 9 pages, doi:10.1155/2013/784989.

Nazir, et al. (2015). Accumulation of heavy metals (Ni, Cu, Cd, Cr, Pb, Zn, Fe) in the soil, water and plants and analysis of physico-chemical parameters of soil and water collected from Tanda Dam Kohat. Journal of Pharmaceutical Sciences and Research. 7. 89-97.

Nriagu J.O, (1989). A global assessment of natural sources of atmospheric trace metals. Nature, 338:47–49.

Papanikolaou, N. C., et al. (2005). Lead toxicity update: a brief review. Medical Science Monitor, vol. 11, no. 10, pp. RA329– RA336. SA Junejo., er al. (2016). Assessment of Pb, Zn, Cu, Ni, Cr and Co in the Soils of Badin area, Sindh, Pakistan. Sindh University Research Journal. Vol. 48. 527-532.

Sabudak, T., et al. (2007). Determination of trace elements in soil and sunflower (Helianthus annuus L.) plant parts. Fresenius Environmental Bulletin, 16(10): 1274.

Sastre, J., et al. (2002). Determination of Cd, Cu, Pb and Zn in environmental samples: microwave-assisted total digestion versus aqua regia and nitric acid extraction. Analytica Chimica Acta, 462(1): 59-72.

Smith IC, Carson BL, (1981). Trace metals in the environment. Ann Arbor, MI, Ann Arbor Science Publishers.

VCI, (2011). Copper history/Future, Van Commodities Inc. http://trademetalfutures.com/copperhistory.html.

Waseem, A., et al. (2014). Pollution Status of Pakistan: A Retrospective Review on Heavy Metal Contamination of Water, Soil, and Vegetables", BioMed Research International, vol. 2014, Article ID 813206, 29 pages, https://doi.org/10.1155/2014/813206.

WHO, (2006). Report of "COBALT AND INORGANIC COBALT COMPOUNDS".

Wong, S., et al. (2002). Heavy metals in agricultural soils of the Pearl River Delta, South China. Environmental Pollution, 119(1): 33-44.

Weggler, K., et al. (2004). Effect of Chloride in Soil Solution on the Plant Availability of Biosolid-Bornm Cadmium. Journal of Environmental Quality, vol. 33, no. 2, pp. 496–50.