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Review

A Review: Heavy Metal Contamination in Drinking Water of Different Areas of Sindh, Pakistan

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Abstract. The survival of life on earth depends on access to water. The overgrowth population has seriously affected water quality, urbanization, rapid growth in industrialization and other human activities equally involved in water contamination. Heavy metals are a group of metals and metalloids with greater atomic density. These metals are toxic in nature, even at very low concentration and causes serious health issues to humans and animals. Industrial discharge and agricultural runoff are the main sources of these heavy metals entering the aquatic system. Drinkable water has become a challenge for developing countries like Pakistan. Heavy metals such as Cd, Cr, Cu, Fe, Pb, Co, Mn, Hg, Ni and Zn were used in their study. Their study revealed that, the concentrations of heavy metals were compared to those of national and international agencies as WHO (2008), USEPA, EUC and EPA. in the research area varied in provinces with maximum admissible and desirable limits and some were within the permissible limit. Therefore, this study aims to look into the research on the level of heavy metal contamination in drinking water sources in certain districts of Sindh province.

Keywords: heavy metals, human health, atomic absorption

Introduction

Metals have a greater Z (atomic number) value and greater density, known as heavy metals, Cd, Pb, Hg, Ni, Cr, Mn, Fe, Zn and (arsenic) are all heavy metals. Heavy metals can contaminate our water. The water we drink may be contaminated with these heavy metals; these all have highly toxic effects on human, plant and animal health (Punia *et al*., 2022; Perveen *et al*., 2012). Heavy metals are emitted from many sources, such as industries that do not properly use wastewater or other wastes. They randomly throw all their waste into an environment that will reach the water and waste it. Heavy metals may also be created by natural sources and other human activities, such as humans creating waste. They do not get through their waste product carefully or through their waste, so many sources bring heavy metals and waste our water (Shakya and Singh, 2022; Sharma *et al*., 2013).

Heavy metals are two types, essential and non-essential; some heavy metals provide benefits but the heaviest metals are toxic to our health and environment.(Iftikhar *et al*., 2022) Heavy metals, which benefit us in body growth and other functions which are Co, Cu, Fe, Mn, Ni, and Zn but some heavy metals are toxic for us, such as arsenic, Cd, Cr, Pb and Hg. (Mohan *et al*., 2022; Iqbal *et al*., 2019; Phulpoto *et al*., 2017; Kurnaz *et al*., 2016). There are more than 50 elements that are considered seventh of the heavy metals and are both

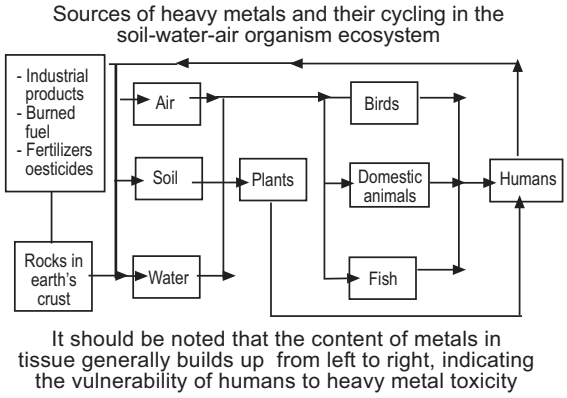

Fig. 1. Environmental contamination by heavy metals, (Masindi and Muedi, 2018).

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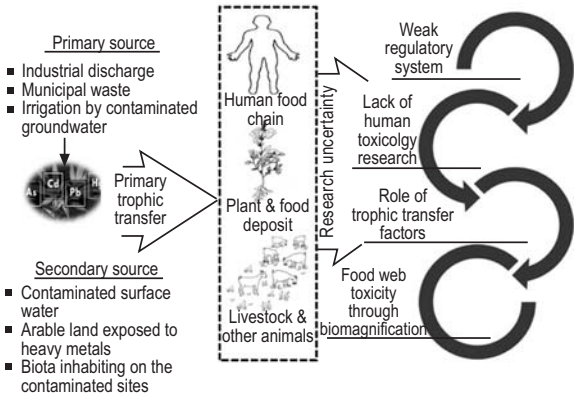

Fig. 2. Heavy metals contamination and related health concerns in food (Sarker *et al*., 2022).

very hazardous and easily accessible. Zn is included in essential heavy metals because it plays a vital role in many body functions; excess zinc causes stomach and vomiting problems, while its deficiency in our body causes diabetes.

Similarly, iron is also an essential element and helps us in the formation of protein and hemoglobin. When iron is taken in excess amounts, it may cause negative impacts on our health, whereas its deficiency results in headaches and weakness. The most poisoning heavy metals in drinking water are lead, iron, cadmium, copper, zinc, chromium, etc. Water pollution has a direct correlation to water contamination. Therefore, it is essential to regularly evaluate the quality of supplies for both surface and ground water. Although present in small amounts, heavy metals in water are more hazardous to human health. This review aims to highlight the risks of heavy metals in water and offer suggestions for reducing the risk of toxic heavy metals contaminating drinking water and found different authors show

There are various methods involved in the determination of heavy metals from drinking water, including; inductively coupled plasma optical emission spectroscopy (ICP-OES) or (ICP-MS) (Sibal and Espino, 2018) and spectrophotometer (Huang *et al*., 2022; Sharma *et al*., 2013). Inductively coupled plasma spectroscopy (ICP/AES) technique is used to detect heavy metals at even low concentrations (Radulescu *et al*., 2014; Öztürk *et al*., 2009). In contrast, atomic absorption spectroscopy (AAS) is a technique used to determine heavy metals (He *et al*., 2022) rapidly. Besides these techniques, Atomic fluoresce spectroscopy in cold water (CV-AFS) and cold vapour AAS (CV- AAS) are both techniques used in the determination of mercury (Hg). (Sibal and Espino, 2018; Radulescu *et al*., 2014) Moreover, in work presented in the current review, authors have used atomic absorption to determine heavy metals in the drinking water of Sindh province with the help of approved literary techniques. The drinking water samples were collected in caped polyethene bottles pre-washed with detergent and doubly deionized water. The drinking water samples were obtained directly from the tap, then acidified with 1% HNO_3 and kept in 500 mL bottles.

This review discusses the work of various authors on heavy metals Determination in the drinking water of Sindh Province, Pakistan.

The heavy metal concentrations found in their work were beyond the maximum permissible limit. The authors' findings Table 1 were compared with those of other international organizations, including the WHO, USEPA, EPA EUC, MAC, etc. Pb, Cd, Cu, Zn, As, Mn, Cr, Ni, Co, Fe and Ar were the heavy metals in drinking water samples that the scientists investigated since their presence is linked to chronic diseases.

In (Jakhrani *et al*., 2011) . Studied the tube well and hand pump water to determine arsenic and iron concentration in water at Gambat, Khairpur, Sindh, Pakistan. They have used the atomic absorption spectroscopy (AAS) technique to determine arsenic and

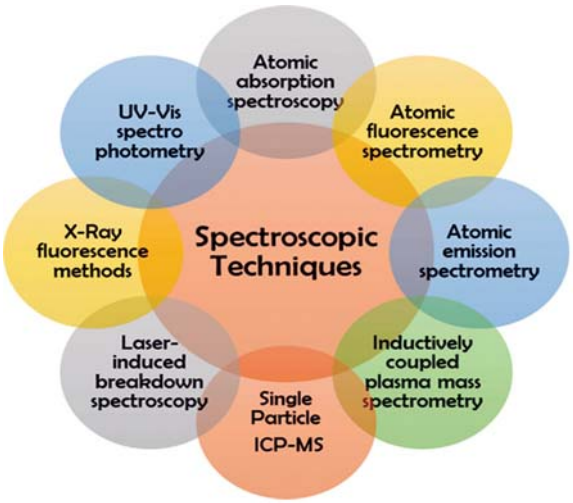

Fig. 3. Analytical methods for determining heavy metals in water. (Raja *et al*., 2021).

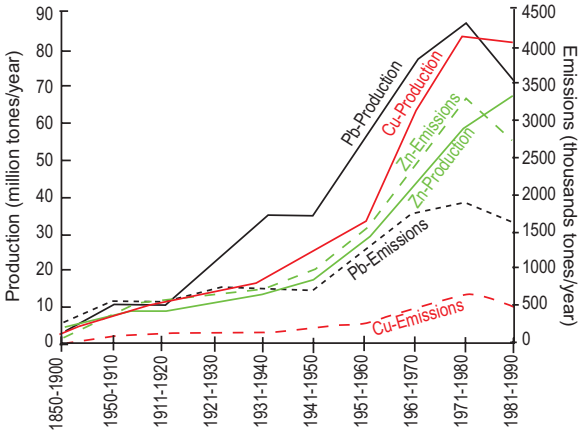

Fig. 4. A computational study on the adsorption of several heavy metal cations on pure heptazine and triazine graphitic carbon nitride quantum dots. (Kamal, 2021).

found that the level of arsenic is more than the WHO limits. They found that the arsenic and Iron in HP (hand pump) and TW (tube well) water range from 0.02 µg/L and 01 µg/L. Arsenic level in HP &TW Ranges from <0.01 – 126 µg/L. Iron level in HP & TW ranges from <0.004 mg/L – 1.6 mg/L and <0.004 – 1.5 mg/L, which is dangerous for human health. On the other hand, in WHO 2008, normal limits for iron were(0.3 mg/L) and for arsenic were (10 µg/L) (Jamshaid *et al*., 2018; Jakhrani *et al*., 2011). In September-October, 2014, (Samo *et al*., 2018) studied the groundwater of taluka Daur, district shaheed Benazir Abad Sindh, Pakistan, to check metal ions and Arsenic concentrations. They found that 72% of samples of the area under study were highly contaminated with arsenic and other toxic metals, which reveals that the people of Daur and its surrounding area are at life risk. (Kandhro *et al*., 2016). In the same year, (Shar *et al*., 2014) investigated the heavy metal in the drinking water of Thari Marwah town and its neighbouring villages of Khairpur. Their findings for metals in the following ranges: Ca 8.35-329.33 mg/L, Ni 0.006-0.154 mg/L, Mn 0.003-0.401 mg/L, Zn 0.002-0.533 mg/L, Co 0.00-0.040 mg/L, Cr 0.0054-0.0322 mg/L, Cu 0.004-0.169 mg/L, Na 2.57-1066 mg/L, Fe 0.002-0.499 mg/L, Cd 0.002-0.014 mg/L. These concentrations suggest that the water of Thari Mirwah and its neighbouring villages is highly polluted and unsafe for drinking purposes (Shar *et al*., 2014).The quality of drinking water has become a serious problem to be solved on priority bases; keeping in view this concern, in 2018, the contribution of authors to investigate the heavy metal contamination in Sindh, Pakistan, raised remarkably. (Hussain *et al*., 2019) and Fifty two samples of groundwater studied by collected from the 17 union councils of Moro. They found 27 samples free from arsenic, while in 13 samples, arsenic were within the permissible range as recommended by the WHO, whereas 12 samples resulted in high values of arsenic than the (Jakhrani *et al*., 2018). Three hundred thirty three samples from Sobhodero Khairpur Sindh, Pakistan, were colleeted He found metals ranges in hand pumps from as (arsenic) (19.5-58 µg/L), Cu (85-260 µg/L), Fe (209-412 µg/L), Ni (01-19 µg/L), Pb (06-14 µg/L) and Zn (114-420 µg/L), while in TW samples range from As (arsenic) (8.6-36 µg/L), Cu (16-90 µg/L), Fe (45-100 µg/L), Ni (01-09 µg/L), Pb (03-08 µg/L) and Zn (22-111 µg/L). They concluded that arsenic concentration is very high in both tubes and hand pump samples (Iqbal *et al*., 2019; Bhatti *et al*., 2018). In the same year, illustrated the results of Hilly areas of Nagarparker, Sindh, Pakistan. Samples were collected from dug wells or man-made wells. Fe, Cu, Mn, Zn and arsenic were found beyond the permissible limits recommended by WHO (Lanjwani *et al*., 2020). Later, in October 2020, worked on groundwater taluka Ratodero, district Larkana, Sindh, Pakistan and collected samples from hand pumps at various sampling areas and found that Cu, Co, Mn, Zn and Fe were in the normal ranges as per WHO guidelines but Cd, Ni, Pb and Cr were in excess. They did not find arsenic in any sample and concluded that except in Ratodero town, the water of Larkana is safe for drinking purposes (Shar *et al*., 2020). In the same year, conducted research in the coastal areas of taluka Keti Bandar, Sindh, Pakistan, to determine the arsenic and heavy metal concentration. For this purpose, samples were collected from 16 villages/towns. Arsenic determination was done through the arsenic kit method and heavy metal determination was done through atomic absorption spectrophotometer (AAS). Fe, Cu, Zn, found below WHO limits and arsenic above WHO limits in the villages of Baghan town, Muhammad Essa Khaskheli, Esso Baloch, Manjhi Khan Baloch, Haji Qadir Bux Baloch, Sajjan Wari, M. Hassan Perozani Baloch, Haji Yaqoob Memon and Ali Muhammad Ultra are all Baloch names. Except for Muhammad Essa Khaskheli, every community has significant levels of cadmium and excess mn was discovered in the village of Pir Usman shah Jhaloo. Ni is also discovered in villages' high-value limitations.

Table 1. concentration of heavy metals present in analyzed drinking water samples by various authors in their papers.

As	Ni	Cr	Cd	Pb	Zn	Co	Mn	Cu	Fe	WHO maximum permissible (mg/L) limit.	Various papers by various authors (work on heavy metals in water)	Area of research
<0.01-126 mg/L	-	-	-	-	-	-	-	-	<0.004-1.6& <0.004-1.5 mg/L	Fe=0.3, As=10	Jakhrani *et al.* (2011)	Gambat, Sindh, Pakistan.
10-200 µg/L	-	-	-	-	-	-	-	-	-	As=10	Kandhro *et al.* (2016)	Taluka Daur, district Shaheed Benazir Abad, Sindh, Pakistan.
-	0.006-0.154 mg/L	0.0054-0.0322 mg/L	0.002-0.014 mg/L	-	0.002-0.533 mg/L	0.00-0.040 mg/L	0.003-0.401 mg/L	0.004-0.169 mg/L	0.002-0.499 mg/L	Zn=3.0,Cu=2.0, Co=0.1, Cr=0.05, Fe=0.30	Shar *et al.* (2014)	District Khairpur, Sindh, Pakistan.
BDL-90ppb	-	-	-	-	-	-	-	-	-	As=10	Hussain *et al.* (2019)	Taluka Moro, district Naushahro Feroze, Sindh, Pakistan
-	0.072-0.1892	-	0.0216-0.1662	0.022-0.1891	0.111-0.5391	-	0.007-0.132	0.023-0.2913	-	Cd=0.01, Pb=0.05, Ni=0.02, Cu=1.5, Mn=0.1, Zn=15	Bhatti *et al.* (2018)	Nagarparkar, Sindh, Pakistan
BDL-0.010 Mg/L	12.9-77.3 µg/L	12-57.2 µg/L	BDL-13.7 µg/L	BDL-33.7 µg/L	27.7-359 µg/L	12.9-88.8 µg/L	11.5-92.1 µg/L	13.4 - 77.5 µg/L	16.2 - 154.4 µg/L	Co=100, Zn=1000, Pb=10 Cd=3, Cr=30, Ni=30, As=0.01	Lanjwani *et al.* (2020)	Taluka Ratodero, district Larkana, Sindh, Pakistan
0.00006 -0.00031	0.00020 -0.00032	0.00044 -0.00076	0.00004 -0.00051	-	0.00049 -0.00355	-	0.00011 -0.000 72	0.00037-0.00392	0.00037 -0.00122	Mn=0.05, As=0.01, Fe=0.3, Cu=2.0, Zn=3.0	Shar *et al.*(2020)	Coastal area of Taluka Keti Bandar, Sindh, Pakistan
-	10.6-45.65µg/L	2.4 -46.2 µg/L	0.0-23.7 µg/L	0.0-28.10 µg/L	30.4-470µg/L	1.60-43.4µg/L	4.0-128.9µg/L	4.90-143µg/L	1.10-170.5µg/L	Cd=3, Pb=10, Ni=30, Cu=200 Fe=300, Cr=30, Zn=1000, Mn=500, C0=100	Lanjwani *et al.* (2021)	Dokri groundwater, including the historical site Mohenjo-Daro, Sindh, Pakistan.
0.0-50 & 10-80µg/L	-	-	1-10 &1.2-11.2µg/L	-	-	-	-	-	-	Cd=3	Shar, *et al.* (2021)	Talukas Ghorabari and Mirpur Sakro, Sindh, Pakistan.
0.02 µg/L	0-700µg/L (HP) 0-360 µg/L(TW)	-	-	-	-	0.230µg/L (HP) 4-110 µg/L(TW)	-	0-556 µg/L (HP) 0-50 µg/L (TW)	4-1610 µg/L (HP)5-1620 µg/L(TW)	As=10	Jakhrani *et al.* (2018)	Khairpur Mir's, Pakistan.
5.0-25.0 µg/L	11.0-38.2 µg/L	5.4-37.3 µg/L	0.0-5.5 µg/L	0.0-19.0 µg/L	34.3-488.8 µg/L	10.2-27.2 µg/L	9.6-34.0 µg/L	10.4-104.5 µg/L	20.3-110.5 µg/L		Lanjwani, *et al.* (2022)	Taluka Bakrani, Larkana, Sindh, Pakistan.

Haji Qadir Bux Baloch, M. Hassan Perozani Baloch, Haji Yaqoob Memon, M. Essa Khaskheli and Ranamori (Shar *et al*., 2021). The drinking water of Ghorabari, Sindh, Pakistan, was studied with his team. They have collected 25 groundwater samples from different locations in the said area to check heavy metals through atomic absorption spectrophotometer (AAS). They found Cr, Fe, Mn and Ni in the high limits than the normal WHO limits and Cu and Zn in the WHO limits (Lanjwani *et al*., 2021). extended their research area to taluka Dokri district Larkana Sindh, Pakistan. For this purpose, 40 groundwater samples were collected from taluka Dokri and Mohenjo-Daro is also included in the sample sites. Zn, Fe, Cu, Mn and Co were normal permissible limits. In 77.50% of samples, Cr, Cd, Pb, and arsenic were found within WHO limits (Jamali *et al*., 2022). Recently, a study was done to determine the heavy metal concentration in the soil of Badin district Sindh Pakistan. 20 samples were collected from the research area to determine Cd, Cu, Pb, Zn and Co. They found all metals at safe levels described by WHO (Sareen *et al*., 2014). At the end of this review, a recent work of Taluka Bakrani district Larkana Sindh, Pakistan, is presented by (Lanjwani *et al*., 2022). The authors collected 25 groundwater samples and drinking water safe from contamination.

Conclusion

Water is the basic need of all living organisms for survival. Plants, animals and even human beings also need water to live on the earth's planet. In this modern world, science and technologies developed many techniques for determining or detecting heavy metals in water. Heavy metals cause many diseases in human beings, such as kidney failure, nervous system diseases, and many other organ diseases. In this review, the authors' research about the drinking water of various regions of Sindh, Pakistan, suggests that most samples contain higher metal concentrations than the WHO the permissible limit. The contaminated sites' water needs continuous monitoring, and the quality control agencies should filter the water in these areas. People may suffer from the disease by consuming water that has more heavy metals. The digestive, circulatory, kidney, nervous, and a number of other organs and bodily systems may be affected physiologically.

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Conflict of Interest. The authors declare that they have no conflict of interest.

References

Bhatti, N., Siyal, A., Qureshi, A. 2018. Groundwater quality assessment using water quality index: a case study of Nagarparkar, Sindh, Pakistan. *Sindh University Research Journal-SURJ* (*Science Series*), **50:** 227-234.

He, H., Shetty, N., Kubatkin, S., Stadler, P., Löfwander, T., Fogelström, M., Miranda-Valenzuela, J.C., Yakimova, R., Bauch, Lara-Avila, S. 2022. Highly efficient UV detection in a metal–semiconductor–metal detector with epigraphene. *Applied Physics Letters*, **120:** 191101.

Huang, F., Peng, S., Yang, H., Cao, H., Ma, N., Ma, L. 2022. Development of a novel and fast XRF instrument for large area heavy metal detection integrated with UAV. *Environmental Research*, **214:** 113841.

Hussain, S., Habib-Ur-Rehman, M., Khanam, T., Sheer, A., Kebin, Z., Jianjun, Y. 2019. Health risk assessment of different heavy metals dissolved in drinking water. *International Journal of Environmental Research and Public Health*, **16:** 1737.

Iftikhar, R., Parveen, I., Khalid, A., Mazhar, A., Iqbal, I.S., Kamal, G. M., Hafeez, F., Pang, A.L., Ahmadipour, M., Ahmadipour, M. 2022. Small organic molecules as fluorescent sensors for the detection of highly toxic heavy metal cations in portable water. *Journal of Environmental Chemical Engineering*, **11:** 109030.

Iqbal, M., Ali, A., Nahyoon, N.A., Majeed, A., Pothu, R., Phulpoto, S., Thebo, K. H. 2019. Photocatalytic degradation of organic pollutant with nanosized cadmium sulfide. *Materials Science for Energy Technologies*, **2:** 41-45.

Jakhrani, M., Malik, K., Sahito, S., Jakhrani, A. 2011. Analytical investigation of arsenic and iron in hand pump and tube-well groundwater of Gambat, Sindh, Pakistan. *Pakistan Journal Chemistry*, **1:** 140-144.

Jakhrani, M.A., Qasim, M., Ali, S., Memon, S.F. 2018. Monitoring of elemental contamination in groundwater samples of Sobhodero Khairpur, Sindh, Pakistan. *International Journal of Sciences*, **7:** 10-23.

Jamali, M. A., Markhand, A. H., Kumar, D., Agheem, M. H., Arain, A. Y. W., Mahar, M. H. 2022. Gis based study of heavy metal concentration in soil of badin district, sindh, pakistan. *Bahria University Research Journal of Earth Sciences*, **7:** 20-25.

Jamshaid, M., Khan, A.A., Ahmed, K., Saleem, M. 2018. Heavy metal in drinking water its effect on human health and its treatment techniques-a review. *International Journal of Biosciences*, **12:** 223-240.

Kamal, K.E.S. 2021. Adsorption of cations of different heavy metals on pristine heptazine and triazine graphitic carbon nitride quantum dots of corrugated structures: computational study. *Bachlor Thesis*, Deptartmentof Material Science, Zewail Universit of Science and Technology.

Kandhro, A.J., Samoan, N.A., Laghari, J. H., Chandio, A.M., Yousfani, A.H. 2016. Assessment of arsenic and essential metal ions in the quality of groundwater sources of Taluka Daur, district Shaheed Benazeer Abad, Sindh, Pakistan. *Journal of Peoples University of Medical & Health Sciences Nawabshah*.(*JPUMHS*), **6:** 01-08.

Kurnaz, A., Mutlu, E., Uncumusaoglu, A.A. 2016. Determination of water quality parameters and heavy metal content in surface water of Çigdem Pond (Kastamonu/Turkey). *Turkish Journal of Agriculture-Food Science and Technology*, **4:** 907-913.

Lanjwani, M.F., Khuhawar, M.Y., Khuhawar, J.M.Y. 2022. Assessment of groundwater quality for drinking and irrigation uses in taluka Ratodero, district Larkana, Sindh, Pakistan. *International Journal of Environmental Analytical Chemistry*, **102:** 4134-4157.

Lanjwani, M.F., Khuhawar, M.Y., Jahangir, T.M., Lanjwani, A.H., Soomro, W.A., Hameed A., Ali, W., Waheed, L. 2021. Evaluation of hydrochemistry of the Dokri groundwater, including historical site Mohenjo-Daro, Sindh, Pakistan. *International Journal of Environmental Analytical Chemistry*, 1-25.

Lanjwani, M.F., Khuhawar, M.Y., Jahangir Khuhawar, T.M. 2020. Assessment of groundwater quality for drinking and irrigation uses in taluka Ratodero, district Larkana, Sindh, Pakistan. *International Journal of Environmental Analytical Chemistry*, 1-24.

Raju, M.M., Scalvenzi, L., Radice, M. 2021. Novel insights of microbial exopolysaccharides as bio-adsorbents for the removal of heavy metals from soil and wastewater. *Microbial Exopolysaccharides as Novel and Significant Biomaterials*, 265-283.

Masindi, V., Muedi, K.L. 2018. Environmental contamination by heavy metals. *Heavy Metals*, **10:** 115-132.

Mohan, B., Tao, Z., Kumar, S., Xing, T., Ma, S., Huang, W., Yang, Y., You, H., Ren, P. 2022. Water and pH-stable methylthio containing metal organic frameworks as luminescent sensors for metal-ion detection. *Crystal Growth & Design*, **22:** 5407-5415.

Öztürk, M., Özözen, G., Minareci, O., Minareci, E. 2009. Determination of heavy metals in fish, water and sediments of Avsar dam lake in Turkey. *Journal of Environmental Health Science & Engineering*, **6:** 73-80.

Perveen, S., Samad, A., Nazif, W., Shah, S. 2012. Impact of sewage water on vegetables quality with respect to heavy metals in Peshawar, Pakistan. *Pakistan Journal of Botany*, **44:** 1923-1931.

Phulpoto, S., Memon, M., Yan, S., Geng, J. 2017. Macroporous graphene thin films as electrochemical electrodes: enhancing the sensitivity for detection of metal ions. *Nanoscience and Nanotechnology*, **17:** 1-6.

Punia, P., Bharti, M. K., Dhar, R., Thakur, P., Thakur, A. 2022. Recent advances in detection and removal of heavy metals from contaminated water. *ChemBioEng Reviews*, **9:** 351-369.

Radulescu, C., Dulama, I., Stihi, C., Ionita, I., Chilian, A., Necula, C., Chelarescu, E.D. 2014. Determination of heavy metal levels in water and therapeutic mud by atomic absorption spectrometry. *Romanian Journal of Physics*, **59:** 1057-1066.

Samo, S.R., Saand, A., Keerio, M.A., Bhuriro, A.A. 2018. Ground water quality assessment of Daur Taluka, Shaheed Benazir Abad. *Engineering, Technology & Applied Science Research*, **8:** 2785-2789.

Sareen, D., Kaur, P., Singh, K. 2014. Strategies in detection of metal ions using dyes. *Coordination Chemistry Reviews*, **265:** 125-154.

Sarker, A., Kim, J.-E., Islam, A.R.M.T., Bilal, M., Rakib, M.R.J., Nandi, R., Rahman, G.M., Islam, T. 2022. Heavy metals contamination and associated health risks in food webs-a review focuses on food safety and environmental sustainability in Bangladesh. *Environmental Science and Pollution Research*, **29:** 3230-3245.

Shakya, A.K., Singh, S. 2022. State of the art in fibre

optics sensors for heavy metals detection. *Optics and Laser Technology*, **153:** 108246.

Shar, A.R., Shar, G.Q., Wassan, S.M., Jatoi, W.B., Bhatti, Z., Jakhrani, M.A., Shar, A.A. 2021. Risk assessment of arsenic and cadmium in groundwater of Talukas Ghorabari and Mirpur Sakro, Sindh, Pakistan. *Pakistan Journal of Analytical & Environmental Chemistry*, **22:** 100-114.

Shar, A.R., Shar, G.Q., Jatoi, W.B., Shar, N.Z., Bhatti, Z., Shar, N.U.H., Jogi, G.M., Rind, A.H. 2020. Physical and chemical characteristics of drinking water in coastal area of Taluka Keti Bandar, Sindh, Pakistan: a case study. *Pakistan Journal of Analytical & Environmental Chemistry*, **21:** 140-151.

Shar, G.Q., Shar, A.R., Jatoi, W.B., Shar, L.A., Ghouri, W.M. 2014. Assessment of the quality of drinking water of Thari Mirwah town and surrounding villages, district Khairpur, Sindh, Pakistan. *Pakistan Journal of Analytical & Environmental Chemistry*, **15:** 21.

Sharma, M.P., Dubey, A., Chatterjee, S. 2013a. Post monsoon analysis of physico-chemical parameter of surface and ground water samples in (Arang block) Raipur districts, Chhattisgarh, India. *IOSR Journal of Applied Chemistry*, **5:** 22-26.

Sharma, P., Dubey, A., Chatterjee, S. 2013b. Determination of heavy metals in surface and ground water in an around (Agrang Block) Raipur District, Chhattisgarh, India. *International Journal of Scientific Engineering Research*, **4:** 722-724.

Sibal, L.N., Espino, M.P.B. 2018. Heavy metals in lake water: a review on occurrence and analytical determination. *International Journal of Environmental Analytical Chemistry*, **98:** 536-554.