RESEARCH ARTICLE
DOI: 10.4274/cjms.2024.2023-129

Investigation of Some Heavy Metal Levels in Hematology Analyzer Wastewater in March-April 2021

Çiftçi et al. Heavy Metal Levels in Hemogram Device Wastewater

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Abstract
BACKGROUND/AIMS: Micro pollutants are one of the important environmental problems that can be found in wastewater at very low concentrations. Heavy metals in the micro-pollutant class are the most common and toxic substances found in wastewater. If exposure to heavy metals exceeds the concentration allowed by WHO, it can cause serious health problems.
MATERIALS AND METHODS: In this study, our aim is to determine some heavy metal amounts of samples taken from hematology analyzer wastewater on 7 different days by ICP-MS. Quantitative analysis of 10 different heavy metals was made with ICP-MS and the results were obtained in ppb. Statistically minimum-maximum, median and average values were obtained.
RESULTS: Aluminium (135.9 µg/L), chromium (29.5 µg/L), manganese (41.8 µg/L), nickel (103.4 µg/L), copper (2776.1 µg/L), zinc (9662.9 µg/L), arsenic (1.3 µg/L), cadmium (0.2 µg/L) and lead (202 µg/L) were found. Vanadium was not found in any of the measurements. Aluminium, arsenic, chromium, and cadmium elements were below the micro-pollutant levels, while the amount of manganese and nickel elements were determined above the micro-pollutant levels. The amounts of copper, zinc, and lead elements, which have serious toxic effects on human and environmental health, were found much higher than the micro-pollutant levels.
CONCLUSION: It is thought that it would be appropriate not to discharge the wastewater of the hemogram device directly into the groundwater, but to pass it through appropriate treatment systems beforehand.
Keywords: Heavy metal, hematology analyzer, wastewater

To cite this article: Çiftçi İ, Kara F, Ovalı F, Vatansev H. Investigation of Some Heavy Metal Levels in Hematology Analyzer Wastewater in March-April 2021.

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26.12.2023
15.01.2024

INTRODUCTION

The existence of the micro pollutants in the wastewater is one of the most important environmental problems. Micro pollutants are various chemical compound groups that exist at significantly low concentrations (ngL^{-1}) in the environment [1]. Synthetic organic materials such as pharmaceuticals, personal care products, industrial chemicals, pesticides, polycyclic aromatic hydrocarbons, food additives, detergents and natural compounds like oestrogen and heavy metals are participants of the micro pollutants [2]. Micro pollutants are organic and inorganic compounds which are result of the human activities. These compounds cause endocrine failure, and they are mostly toxic for the environment and people. Decrease of the entrance of the micro pollutants in the environment and protection of the water source have become important case for the public health. Heavy metals such as Cd, Zn, Pb, Fe, Cu, Hg, Ni, Mn, Co etc. are classified as micro pollutants and exist only trace amounts in the normal conditions but it is accepted that they are the most toxic compounds and common in wastewater [3]. Heavy metals can be pumped in living organisms because of the high concentrations in the aquatic environments. When the heavy metals enter the food chain, accumulation can be observed in the human body at high concentrations. Higher concentrations than the WHO regulations for the heavy metals can cause severe health problems [4]. These heavy metals accumulate in soft tissues and harm the body because they cannot metabolize by the human body. The maximum tolerable micropollutant concentrations (MCS) of the human body have been determined [5]. Excessive accumulation of copper is toxic to cell membranes, DNA and proteins, as a result of which copper is affected by bone health, immune function and increased infection frequency, cardiovascular risk and changes in cholesterol metabolism, liver disease and severe neurological defects [6-8]. Long-term and high-dose zinc supplementation prevents copper uptake. Therefore, most of the toxic effects of zinc are actually caused by copper deficiency [9-11]. Excessive exposure or intake of manganese can lead to dopaminergic neuronal death and manganism, a neurodegenerative disorder with parkinsonian-like symptoms [12-14]. In arsenic exposure, skin, lung, liver and bladder cancer, nausea and vomiting, decrease in erythrocyte/leukocyte production, abnormal heart rhythm, skin lesions, circulatory disorders, neurological complications, diabetes, respiratory complications, and deaths due to chronic diseases may occur [15-17]. Kidney, bone and lung damage are observed in cadmium toxicity [15-19], neurological disorders, osteomalacia, accumulation in the liver, development of cholestasis, normo- or microcytic anemia, and impaired erythropoiesis are observed in aluminum toxicity [20]. Inhalation of high levels of chromium can cause respiratory problems such as nasal ulcers, runny nose, asthma, cough, shortness of breath, skin contact can cause skin ulcers, long-term exposure can cause damage to the liver, kidney circulatory and nerve tissues, as well as skin irritation [21-

23]. Lead exposure causes neurological, cardiovascular, hematological disorders, encephalopathy and edema [24, 25]. Toxic effects of nickel include Allergy, cardiovascular and kidney diseases, lung fibrosis, lung cancer, mitochondrial dysfunctions and oxidative stress [26-28].

Trace elements which have atomic density more than 4 ± 1 g/cm^3 are known as heavy metals and they are persistent in wastewater resulting from natural and anthropogenic factors. The main natural sources of the heavy metal pollutants are soil erosion, urban waste, aerosol particles, volcanic activities, dump, metal plating and electroplating, and extraction processes [3]. Hospitals are important sources of these micro pollutants. Diagnosis, laboratory, and research activities furthermore drug excretion from patients cause a wide variety of micro contaminants [29]. Most of the micro pollutants are removed insufficiently in the traditional wastewater treatment plants. In this case, these micro pollutants are emitted to aquatic environment at low concentrations (ng /L - µg/L). Even at very low concentrations, these compounds can affect the sensitive organisms living in water because the most of them are designed as biologically active. Therefore, they are named as micro pollutants [30, 31]. Until today, many technologies have been used to remove heavy metals from wastewater. Commonly used refinement technologies are shown in figure 1.

The aim of this study is to investigate the levels of some heavy metals in the hematology analyzer effluent, which is formed after the necessary tests are performed on the hematology analyzer with blood samples of patients admitted to different polyclinics due to different diseases.

MATERIALS AND METHODS

The most important heavy metals, the permitted concentrations of the heavy metals in tap water and wastewater by WHO, and toxic effects of these heavy metals are summarized in Table 1.

Collection of Hematology Analyzer Wastewater

This study was carried out at the exit of the hematology analyzer, where routine examinations are performed, without contact with any patients. Accumulated wastewater samples were collected from the wastewater tank of the Beckman Coulter DHX850 hematology analyzer placed in the Biochemistry Laboratory of Selçuk University Faculty of Medicine, in 4 replicate 15 ml metal-free tubes on 7 different days for 45 days. Approximately 35 liters of wastewater was collected every 7 days on average. The wastewater tank was mixed manually to homogenize the sample before sampling. Samples are stored at 4°C until analysis.

ICP-MS Analyse

Hematology analyzer wastewater samples were filtered separately using 0.45 µm pore cellulose membrane filters at Selçuk University Advanced Technology Research Centre. To prevent any metal precipitation, the filtered samples were acidified to reach 0.1 mol L-1 nitric acid concentration and heavy metal contents were determined by ICP-MS device.

Tuning solution containing 10 µg L-1 of lithium (Li), cobalt (Co), yttrium (Y), cerium (Ce) and thallium (Tl) for optimization of resolution, mass calibration and sensitivity data required for pre-measurement calibration of ICP-MS was used. The required operating and optimization parameters for the ICP-MS device are shown in Table 2.

Statistical Analysis

All statistical analyzes were performed with the help of IBM SPSS 21.0 package program. Descriptive statistics for numerical variables are presented with median and minimum-maximum. In addition, measurement averages were given with mean and standard deviation graphs.

RESULTS

ICP-MS Results

Wastewater samples were collected from Medical Biochemistry Laboratory of Selçuk University Medical Faculty. Heavy metal analysis was performed with ICP-MS in Selçuk University Advanced Technology Research Centre. Result of the analysis are shown in ppb in Table 3. According to obtained results, aluminium was found above maximum pollutant level (MPL) in the fourth measurement. Vanadium was not determined any of the measurements. Chrome was detected below the MPL in all measurements. Manganese, nickel, lead, copper, zinc levels were found above the MPL in all measurements. Arsenic and cadmium levels were found below the MPL in all measurements.

According to data in Table 3, aluminium was not determined in fifth and seventh measurement (M5 and M7) and higher results was observed according to other measurements in the fourth one (M4). While arsenic was found only in the first four measurement (M1, M2, M3, M4), it was not found in the last three measurements (M5, M6, M7). Cadmium was detected just in the first measurement (M1) but not more than MPL. Levels of chromium, copper, manganese, nickel, lead and zinc were found close to the average value in each measurement.

Data from Hospital Information System

The data that contains patient numbers and the polyclinics which the hemogram analysis applied on patients according to day and hour when the samples were collected are shown in Table 4. Hemogram test samples were collected at seven different times which has four repetitions. It is thought that heavy metal contents are different for each measurement due to the difference in the number of patients whose hemogram analysis was performed on the day of measurement. For example, while there were 26 patients coming from dermatology polyclinic in the first measurement (M1), there were 2 patients coming from dermatology polyclinic in the fourth measurement (M4). Since there are differences in the used drug group and body reaction, it is thought that blood samples of patients who come from different polyclinics and underwent hemogram analysis affect heavy metal contents found in water.

Results of Statistical Analysis

Mean, median, maximum and minimum values of each heavy metals were calculated from seven measurements. In addition to these, MPL values and % deviation from MPL values are shown in Table 5. Standard deviation graphs of the data are shown in graph 1. According to these results, it is observed that Al, As, Cr, and Cd elements were below their MPL and they were not at a harmful level for human health. On the other hand, while Mn and Ni elements were detected above their MPLs, especially Cu, Zn and Pb elements much higher above their MPLs.

DISCUSSION

Since it is very difficult to obtain permission to conduct analytical research on hospital wastewater, literature data is also scarce. In a review, Verlicchi et al. reported mean concentrations for different classes of compounds, using all data from previous studies on hospital wastewater (HWW) and urban wastewater (UWW). According to these data, average concentrations in HWWs were determined to be approximately 2-150 times higher than average concentrations in UWWs. [29].

In the research conducted, wastewater originating from Konya province, state hydraulic works, it has been stated that it reaches Tuz Lake (Salt Lake) through irrigation channels and that heavy metal concentrations in the water cause heavy metal pollution in Tuz Lake. Kalıpçı et al. In his study, Heavy metals in the water were analyzed along the Konya Main Drainage Channel and the results were evaluated seasonally. Within the scope of the study, 7 measurement stations were used in 2014; In a total of 28 samples taken in 4 seasons: spring, summer, autumn and winter, 20 heavy metals (silver, aluminum, arsenic, barium, chromium, copper, iron, potassium, lithium, magnesium, manganese, sodium, nickel, lead, selenium, tin, zinc boron, mercury, phosphorus) parameters were examined. When the analysis results are examined; It was determined that especially arsenic, barium, chromium, copper, nickel, lead, tin and boron parameters were at higher values in the autumn period, unlike other seasons. It was determined that heavy metal concentrations in spring, summer and winter periods were generally close to each other [32].

In a study conducted in Giresun, cadmium, arsenic, lead, nickel and chromium metals in the wastewater of different car wash centers were determined by ICP-MS. The highest metal concentrations for the analyzed wastewater samples were; As (15.2 ±0.3 µg L-1), Pb (26.9 ±0.4 µg L-1), Ni (31.5 ±1.1 µg L-1) and Cr (9.8 It was determined as ±0.4 µg L-1) [33].

In a study similar, Agbere et al. investigated the physicochemical properties of wastewater obtained from various laboratory equipment. According to their results, some trace element concentrations detected by atomic absorption spectrometry in Mindray brand hematology analyzer wastewater are as follows; arsenic: 105.80±0.96, cadmium: 6.53±0.49, lead: 61.98±5.15, mercury: 10.63±1.17. Trace element concentrations were found to be below WHO standards [34].

The aim of this study is to investigate the levels of some heavy metals in the hematology analyzer wastewater, which is formed after the necessary tests are performed on the hematology analyzer with blood samples of patients who apply to different outpatient clinics due to different diseases. Since the medications used and treatments received by patients who apply to different outpatient clinics for different diseases will be different, their body metabolites and therefore the microelements found in their blood samples will also differ. According to the results, we observed that the amounts of each element were different on the day of analysis. The reason for this situation was thought to be due to the different outpatient variations of the patients compared to the hemogram, but the concentrations of trace elements released from clinical laboratory vending machines are mainly due to chemicals and test kits. The heavy metal content of the standard solutions used in the relevant device for hematology analyzes is unknown. If we look at the general picture, according to the MKS values we obtained as a result of the literature review, in the average values of 7 measurement days, Al, Cr, Cd, and As elements were detected below these levels and it is estimated that they will not have a toxic effect. While Mn and Ni elements were detected above the MKS, especially Cu, Zn, and Pb elements were detected at values much higher than the MKS. Detection much higher than MKS values poses a serious danger. In addition, heavy metal levels may change every day of analysis due to the lack of continuous mixing equipment and manual mixing before sampling. This can cause heavy metals to precipitate. People's domestic, industrial and agricultural activities increase the concentration of heavy metals in wastewater. These heavy metals, which have serious toxic effects, should be treated in hospital wastewater with appropriate treatment systems and then discharged. Disposal of micropollutants requires important processes and the most appropriate process should be selected. Advanced purification processes such as activated carbon adsorption, advanced oxidation processes, nanofiltration, reverse osmosis, and membrane bioreactors can provide higher and more consistent micropollutant removal. However, no matter which technology is used, the removal of micropollutants depends on the physico-chemical properties of the micropollutants and treatment conditions. Assessing the removal of micropollutants from wastewater should cover a range of aspects from sources to end uses. After the release of micropollutants, a better understanding and modeling of their fate in surface waters is essential to effectively predict their impact on the receiving environment.

CONCLUSION

There are currently preferred systems that can be recommended for the proper disposal of hospital wastewater. It is generally known that hospital wastewater mixes with urban wastewater at some point. It is recommended to establish a separate treatment plant to prevent micropollutants from mixing with urban wastewater. In addition, since other physicochemical parameters such as total dissolved salts, electrical conductivity, pH, total suspended solids and temperature are strongly related to trace elements in hematology wastes, it is important to examine these parameters in further studies. Further studies and experimental research are needed to evaluate the removal capacity of micropollutants from hemogram device wastewater and to provide information on the most technically and economically efficient ones.

MAIN POINTS

- Laboratory equipment wastewater contains heavy metals.
- Appropriate processes should be selected for wastewater treatment in hospitals.
- Exposure to heavy metals above permissible concentrations is dangerous to living things.

REFERENCES

1. Goswami, L., et al., Membrane bioreactor and integrated membrane bioreactor systems for micropollutant removal from wastewater: a review. Journal of water process engineering, 2018. 26: p. 314-328.
2. Grandclément, C., et al., From the conventional biological wastewater treatment to hybrid processes, the evaluation of organic micropollutant removal: a review. Water research, 2017. 111: p. 297-317.
3. Chai, W.S., et al., A review on conventional and novel materials towards heavy metal adsorption in wastewater treatment application. Journal of Cleaner Production, 2021. 296: p. 126589.
4. Barakat, M., New trends in removing heavy metals from industrial wastewater. Arabian journal of chemistry, 2011. 4(4): p. 361-377.
5. Babel, S. and T.A. Kurniawan, Low-cost adsorbents for heavy metals uptake from contaminated water: a review. Journal of hazardous materials, 2003. 97(1-3): p. 219-243.
6. Araya, M., M. Olivares, and F. Pizarro, Copper in human health. International Journal of Environment and Health, 2007. 1(4): p. 608-620.
7. Araya, M., et al., Understanding copper homeostasis in humans and copper effects on health. Biological research, 2006. 39(1): p. 183-187.
8. Uriu-Adams, J.Y. and C.L. Keen, Copper, oxidative stress, and human health. Molecular aspects of medicine, 2005. 26(4-5): p. 268-298.
9. Agnew, U.M. and T.L. Slesinger, Zinc toxicity. 2020.
10. Nriagu, J., Zinc toxicity in humans. School of Public Health, University of Michigan, 2007: p. 1-7.
11. Plum, L.M., L. Rink, and H. Haase, The essential toxin: impact of zinc on human health. International journal of environmental research and public health, 2010. 7(4): p. 1342-1365.
12. Avila, D.S., R.L. Puntel, and M. Aschner, Manganese in health and disease. Interrelations between essential metal ions and human diseases, 2013: p. 199-227.
13. Dobson, A.W., K.M. Erikson, and M. Aschner, Manganese neurotoxicity. Annals of the New York Academy of Sciences, 2004. 1012(1): p. 115-128.
14. Santos-Burgoa, C., et al., Exposure to manganese: health effects on the general population, a pilot study in central Mexico. Environmental research, 2001. 85(2): p. 90-104.
15. Abdul, K.S.M., et al., Arsenic and human health effects: A review. Environmental toxicology and pharmacology, 2015. 40(3): p. 828-846.
16. Martin, S. and W. Griswold, Human health effects of heavy metals. Environmental Science and Technology briefs for citizens, 2009. 15: p. 1-6.

17. Mazumder, D.G., Chronic arsenic toxicity & human health. Indian J Med Res, 2008. 128(4): p. 436-447.
18. Godt, J., et al., The toxicity of cadmium and resulting hazards for human health. Journal of occupational medicine and toxicology, 2006. 1(1): p. 1-6.
19. Han, J.-X., Q. Shang, and Y. Du, Effect of environmental cadmium pollution on human health. Health, 2009. 1(03): p. 159.
20. Osińska, E., D. Kanoniuk, and A. Kusiak. Aluminum hemotoxicity mechanisms. in Annales Universitatis Mariae Curie-Sklodowska. Sectio D: Medicina. 2004.
21. Almahmoudy, A., Determination of chrome in drinking water. 2005.
22. Demir, A. and M. Arisoy, Biological and chemical removal of Cr (VI) from waste water: cost and benefit analysis. Journal of Hazardous Materials, 2007. 147(1-2): p. 275-280.
23. Wachtman, J.B., Materials and Equipment-Whitewares-Refractory Ceramics-Basic Science, Volume 16, Issue 1. 2009: John Wiley & Sons.
24. Almeida, C., et al., Assessing the replacement of lead in solders: effects on resource use and human health. Journal of Cleaner Production, 2013. 47: p. 457-464.
25. Debnath, B., W.S. Singh, and K. Manna, Sources and toxicological effects of lead on human health. Indian Journal of Medical Specialities, 2019. 10(2): p. 66.
26. Buxton, S., et al., Concise review of nickel human health toxicology and ecotoxicology. Inorganics, 2019. 7(7): p. 89.
27. Genchi, G., et al., Nickel: Human health and environmental toxicology. International journal of environmental research and public health, 2020. 17(3): p. 679.
28. Zambelli, B. and S. Ciurli, Nickel and human health. Interrelations between essential metal ions and human diseases, 2013: p. 321-357.
29. Verlicchi, P., et al., Hospital effluents as a source of emerging pollutants: an overview of micropollutants and sustainable treatment options. Journal of hydrology, 2010. 389(3-4): p. 416-428.
30. Barbosa, M.O., et al., Occurrence and removal of organic micropollutants: An overview of the watch list of EU Decision 2015/495. Water research, 2016. 94: p. 257-279.
31. Margot, J., et al., Treatment of micropollutants in municipal wastewater: ozone or powdered activated carbon? Science of the total environment, 2013. 461: p. 480-498.
32. KALIPÇI, E. and Z. CEYLAN, Konya ana tahliye kanalında ağır metal kirliliğinin izlenmesi. Dicle Üniversitesi Mühendislik Fakültesi Mühendislik Dergisi, 2017. 8(3): p. 649-658.
33. BAHADIR, Z., Atık Su Örneklerinde Bazı Ağır Metallerin İndüktif Eşleşmiş Plazma Kütle Spektrometresi ile (ICP-MS) Tayini. Journal of Anatolian Environmental and Animal Sciences, 2020. 5(1): p. 56-60.
34. Agbere, S., et al., Physico-chemical quality of ashes post-incineration and waste from laboratory automaton biochemistry, hematology and serology in Togo. Journal of Biosafety and Biosecurity, 2023. 5(3): p. 107-115.

Table 1. The permitted boundaries for toxic heavy metals and toxic effects on human health				
Heavy metals	**Micro pollutants concentrations that tolerate by human body at max.(MKS) [8]**	**Secure limits on tap water suggested by WHO**	**Secure limits on wastewater suggested by WHO**	**Toxic effects**
Cupper (Cu)	25 µg/L	<2 mg/L	1 mg/L	It affects bone health, immune function and increased frequency of infections, cardiovascular risk and changes in cholesterol metabolism, liver disease and serious neurological defects, its excessive accumulation is toxic to cell membranes, DNA, and proteins.
Zinc (Zn)	800 µg/L	<3 mg/L	2-5 mg/L	Long-term, high-dose zinc supplementation inhibits copper uptake. Therefore, most of its toxic effects are due to copper deficiency.
Manganese (Mn)	20 µg/L	<0,12 mg/L	<0,2 mg/L	Excessive exposure or ingestion can lead to dopaminergic neuronal death and manganism, a neurodegenerative disorder with parkinsonian-like symptoms.
Arsenic (As)	50 µg/L	<0,01 mg/L	Yok	Skin, lung, liver and bladder cancer, nausea and vomiting, decrease in erythrocyte/leukocyte production, abnormal heart rhythm, skin lesions, circulatory disorders, neurological complications, diabetes, respiratory complications, deaths due to chronic diseases may occur.
Cadmium (Cd)	5 µg/L	0,003–0,005 mg/L	0,003 mg/L	Kidney, bone and lung damage.
Krom (Cr)	50 µg/L	<0,05 mg/L	0,05 mg/L	With high levels of inhalation, respiratory problems such as nasal ulcers, runny nose, asthma, cough, shortness of breath, skin contact can cause skin ulcers, long-term exposure can cause damage to the liver, kidney circulatory and nerve tissues, as well as skin irritation.
Nikel (Ni)	20 µg/L	0,02–0,07 mg/L	0,02 mg/L	Allergy, cardiovascular and kidney diseases, lung fibrosis, lung and nose cancer, mitochondrial dysfunctions and oxidative stress.
Lead (Pb)	6 µg/L	<0,01 mg/L	0,01 mg/L	Impairment of body function, which can be neurological, cardiovascular, haematological and reproductive, leads to malfunction of the central nervous system (CNS) and

				ultimately encephalopathy and oedema, which mainly affects the cerebellum.
Aluminium (Al)	200 µg/L	<0,2 mg/L	0,2 mg/L	Post-dialysis encephalopathy, neurological disorders, osteomalacia, accumulation in the liver, development of cholestasis, normo- or microcytic anaemia, impaired erythropoiesis.

Table 2. Perkin Elmer ELAN DRC-e ICP-MS maintenance and optimization parameters

Parameter	**Value, Unit**
ICP RF Power	1300 Watt (W)
Plasma Gas Flow	18.0 L/min
Nebulization Gas Flow	0.76 L/min
Omega Lens	10.75 V
Auxiliary GasFlow	1.40/min

Table 3. Average Amounts of Measurements (M1, M2, M3, M4, M5, M6, M7) which are measure four times in ppb (µg/L)

Element	**Unit**	**MPL**	**M1**	**M2**	**M3**	**M4**	**M5**	**M6**	**M7**
Al	ppb	**200**	129,1	117,8	1,9	361,8	0	114,8	0
V	ppb	**-**	0	0	0	0	0	0	0
Cr	ppb	**50**	40,6	33,9	26,8	31,2	27,7	24,4	21,9
Mn	ppb	**20**	42,9	36,8	51,3	42,2	30,6	42,5	46,5
Ni	ppb	**20**	141,5	102,4	106	101,4	96,9	89,8	85,6
Cu	ppb	**25**	3205,3	2853,5	2684	2816,1	2628,7	2655,6	2589,7
Zn	ppb	**800**	12900,8	12511,5	10815,4	9215,9	8438,4	7002,2	6755,9
As	ppb	**50**	2,42	0,87	0,15	0,95	0	0	0
Cd	ppb	**5**	0,2	0	0	0	0	0	0
Pb	ppb	**6**	223,2	205,2	197,9	209	195,3	194,2	189,3

Table 4. Polyclinics where patients who underwent hemogram tests were examined and the number of patients

Polyclinic	M1	M2	M3	M4	M5	M6	M7
Emergency medicine	6	9	11	13	7	10	9
Family medicine	4	7	5	1	7	2	3
Anaesthesiology	2	1	3	4	5	2	0
Brain and Nerve Surgery	5	6	5	5	5	15	5
Paediatric Emergency	2	3	4	5	1	3	6
Paediatric Allergy	2	1	3	4	5	0	2
Paediatric Surgery	3	0	3	2	3	0	2
Paediatric Endocrinology	1	1	1	2	1	1	2
Paediatric Infection	4	2	5	4	4	2	0
Paediatric Gastroenterology	13	11	5	10	15	7	16
Paediatric Cardiology	7	2	8	0	6	4	3
Paediatric Nephrology	12	10	13	11	9	7	5
Paediatric Neurology	6	3	5	1	5	3	2
Paediatric Oncology	9	2	2	3	4	5	1
Paediatric Rheumatology	4	9	6	8	17	10	7
Dermatology	26	16	5	2	8	6	13
Endocrinology and Metabolism	19	21	11	11	17	16	15
Infection Diseases	7	11	12	25	30	10	8
Physiotherapy	13	10	4	6	11	7	7
Gastroenterology	13	15	13	18	5	10	6
General Surgery	21	5	7	11	11	15	6
Chest Diseases	10	15	7	25	9	26	10
Ophtalmology	6	3	1	2	4	4	5
Haematology	14	9	18	10	10	14	9
Internal Medicine	19	6	4	12	3	9	10
Gynaecology and Oncology	2	2	1	0	1	1	0
Obstetrics and Gynecology	28	25	28	34	26	25	21
Cardiology	16	16	11	13	11	11	6
Nephrology	10	12	10	9	9	5	7
Neurology	12	10	11	14	9	10	8
Orthopaedics	13	19	15	9	10	7	11
Plastic Surgery	3	2	7	2	2	2	1
Rheumatology	30	21	21	22	34	23	20
Medical Oncology	17	14	20	17	13	14	12
Urology	9	6	8	3	7	7	6

Table 5. Statistical values for whole measurements

Element	Median	Min.	Max.	Mean	MPL (ppb)	(%) Deviation from MPL
Al	117,825	1,9	361,85	115,69	200	↓%32
Cr	27,725	18,85	43,1	32,08	50	↓%41
Mn	37,6	26,05	73,55	39,11	20	↑%109
Ni	98,9	82,15	180,35	92,96	20	↑%417
Cu	2738,75	2519,9	3365,6	2432,23	25	↑↑ %11000
Zn	9319,375	4852,7	17823,15	8555,04	800	↑↑%1108
As	1,1	0,1	2,9	6,80	50	↓%2528
Cd	0,2	0,2	0,2	0,65	5	↓%96
Pb	197,35	187,45	243,05	177,52	6	↑↑%3267

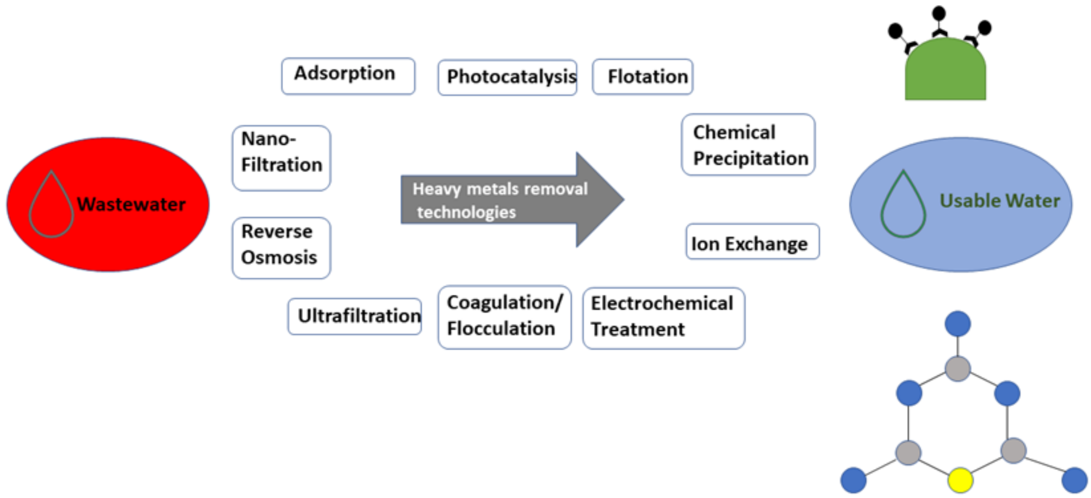
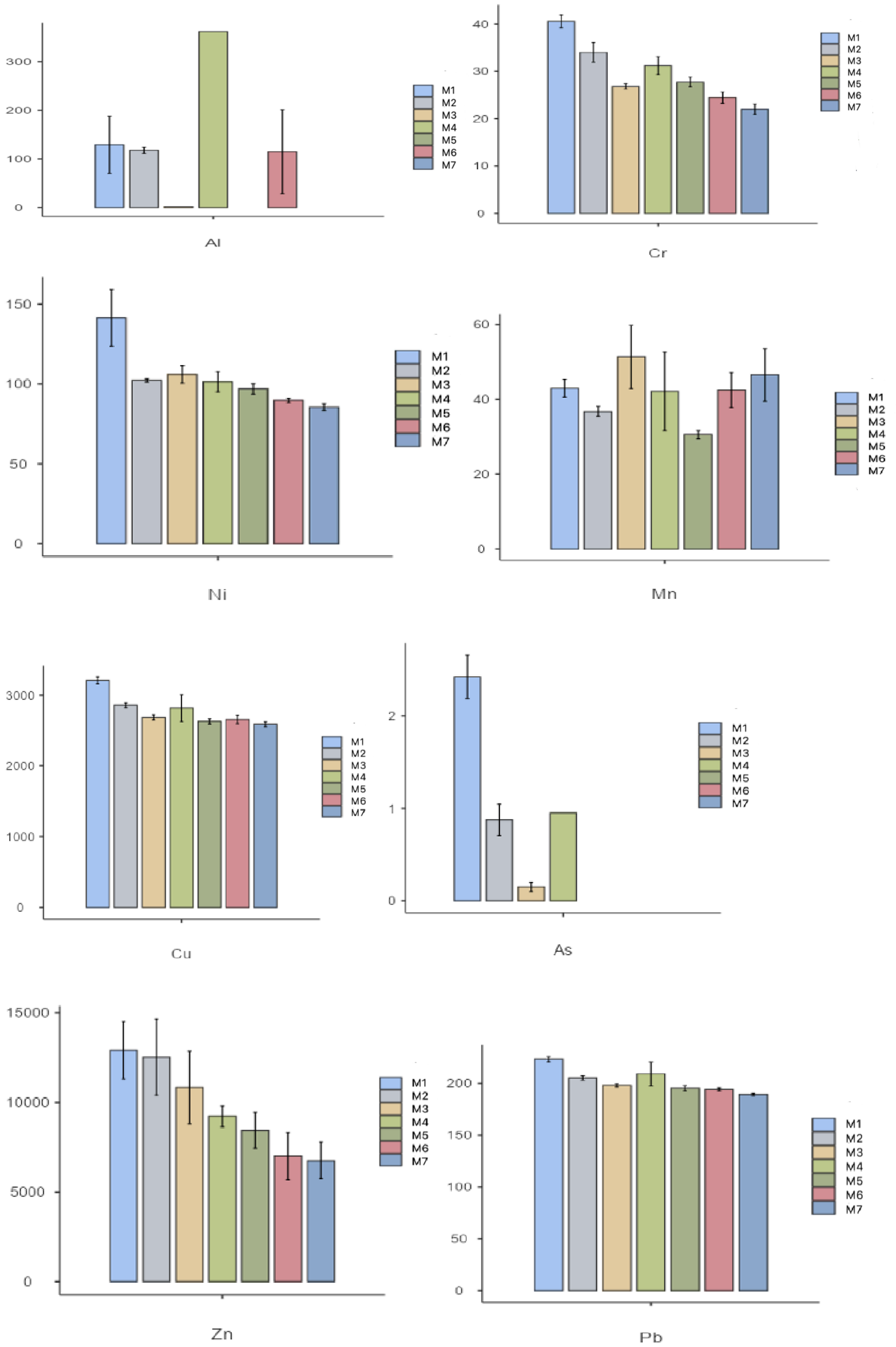


Figure 1. Commonly used refinement technologies for heavy metals from wastewater.



Graph 1. Standard deviation graphs of the data.