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

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Abstract

BACKGROUND/AIMS: Micropollutants are an important environmental problem that can be found in wastewater at very low concentrations. Heavy metals classified as micro-pollutant are the most common and toxic substances found in wastewater. Exposure to heavy metals exceeds the concentration allowed by the World Health Organization can cause serious health problems.

MATERIALS AND METHODS: In this study, our aim was to determine heavy metal contents in samples taken from hematology analyzer wastewater on 7 different days using inductively coupled plasma - mass spectrometer (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: Aluminum (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 detected. Vanadium was not detected in any of the measurements. Aluminum, arsenic, chromium, and cadmium were below the micro-pollutant levels, while the amounts of manganese and nickel were above the micro-pollutant levels. The amounts of copper, zinc, and lead, which have serious toxic effects on human and environmental health, were much higher than the micro-pollutant levels.

CONCLUSION: It is considered appropriate not to discharge the wastewater of the hemogram device directly into groundwater but to pass it through appropriate treatment systems beforehand.

Keywords: Heavy metal, hematology analyzer, wastewater

INTRODUCTION

The existence of the micropollutants in wastewater is one of the most important environmental problems. Micropollutants are 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 estrogen and heavy metals are microparticle pollutants.[2] Micropollutants are organic and inorganic compounds resulting from human activities. These compounds cause endocrine failure, and they are mostly toxic to the environment and people. Decreased entry of micro pollutants into the environment and protection of water sources have become important cases for public health. Heavy metals such as Cd, Zn, Pb, Fe, Cu, Hg, Ni, Mn, Co, etc. are classified as micro pollutants and exist only in trace amounts under normal conditions; however, it is accepted that they are the most toxic compounds and common in wastewater.[3] Heavy metals can be pumped into living organisms

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because of their high concentrations in aquatic environments. When heavy metals enter the food chain, they accumulate in the human body at high concentrations. Higher concentrations of heavy metals than the World Health Organization (WHO) guidelines can cause severe health problems.[4] These heavy metal accumulate in soft tissues and harm the body because they cannot be metabolized by the human body. The maximum acceptable micropollutant concentrations 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, increased infection frequency, cardiovascular risk, changes in cholesterol metabolism, liver disease, and severe neurological defects.[6-8] Long-term and high-dose zinc supplementation prevents copper uptake. Therefore, the toxic effects of zinc are mostly 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] Exposure to arsenic, skin, lung, liver, and bladder cancer, nausea and vomiting, decreased 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, and 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, and hematological disorders, encephalopathy, and edema.[24,25] The toxic effects of nickel include Allergy, cardiovascular and kidney diseases, lung fibrosis, lung cancer, mitochondrial dysfunction, and oxidative stress.[26-28]

Trace elements with an atomic density greater 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 heavy metal pollutants are soil erosion, urban waste, aerosol particles, volcanic activities, dumps, metal plating and electroplating, and extraction processes.[3] Hospitals are important sources of these micropollutants. Diagnosis, laboratory, and research activities, as well as drug excretion from patients, cause a wide variety of microcontaminants.[29] Most micro pollutants are insufficiently removed in traditional wastewater treatment plants. These micropollutants are emitted into the aquatic environment at low concentrations (ng/L-µg/L). Even at very low concentrations, these compounds can affect sensitive organisms living in water because most are biologically active. Therefore, they are referred to as micropollutants.[30,31] Until now, many technologies have been used to remove heavy metals from wastewater. Common 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 using blood samples from patients admitted to different polyclinics due to different diseases.

MATERIALS AND METHODS

This study was approved by the Ethics Committee of Selçuk University Faculty of Medicine (approval number: 2019/194, date: 26.06.2019).

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

Collection of Hematology Analyzer Wastewater

This study was performed at the exit of the hematology analyzer, where routine examinations are performed, without contact with any patient. Accumulated wastewater samples were collected from the wastewater tank of the Beckman Colter 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 L of wastewater was collected every 7 days on average. The wastewater tank was manually mixed to homogenize the samples before sampling. Samples were stored at 4 °C until analysis.

ICP-MS Analyze

The hematology analyzer wastewater samples were filtered separately using 0.45 µm pore cellulose membrane filters at Selçuk University

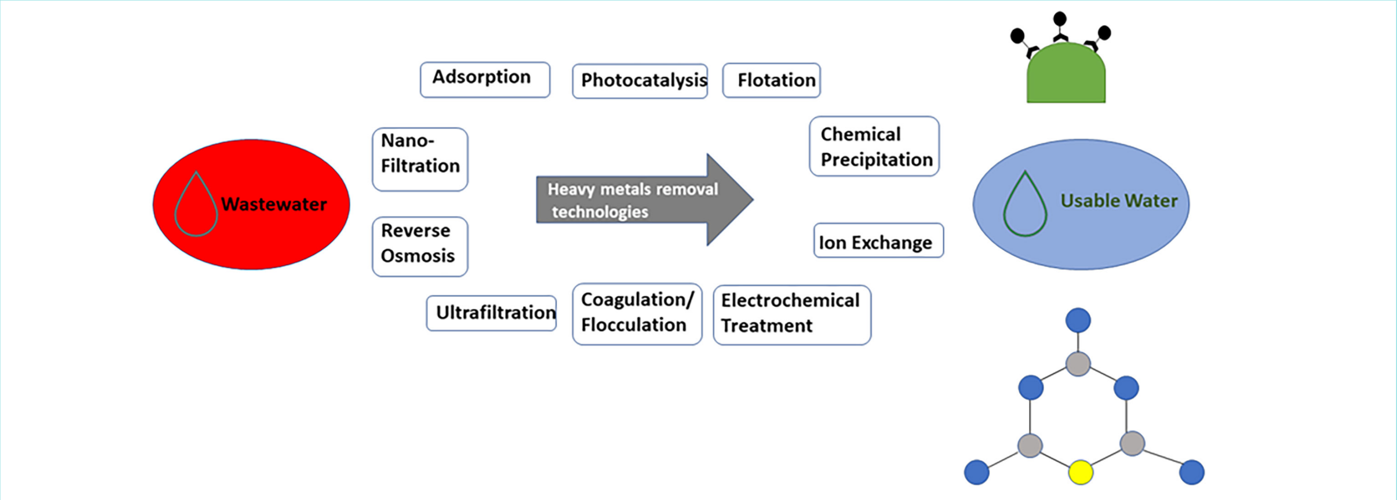

Figure 1. Commonly used refinement technologies for heavy metals from wastewater.

Advanced Technology Research Center. To prevent any metal precipitation, the filtered samples were acidified to a 0.1 mol L1 nitric acid concentration, and heavy metal contents were determined by inductively coupled plasma - mass spectrometer (ICP-MS) device.

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

Statistical Analysis

All statistical analyses were performed using the IBM SPSS 21.0 package program. Descriptive statistics for numerical variables are presented as median and minimum-maximum. In addition, measurement averages are presented as mean and standard deviation (SD) graphs.

RESULTS

ICP-MS Results

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

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

Hospital Information System

The data containing patient numbers and polyclinics for which hemogram analysis was applied to patients according to the day and hour when the samples were collected are shown in Table 4. Hemogram test samples were collected at seven different times with four repetitions. It is thought that heavy metal contents differ for each measurement due to differences in the numbers of patients who underwent hemogram analysis on the day of measurement. For example, while there were 26 patients coming from the dermatology

Table 1. Permitted boundaries for heavy metal toxicities and toxic effects on human health

Heavy metals	Micro pollutants concentrations that are tolerated by the 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 and immune function, increases the frequency of infections, cardiovascular risk, changes in cholesterol metabolism, liver disease, and serious neurological defects, and 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 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	None	Skin, lung, liver, and bladder cancer, nausea and vomiting, decreased erythrocyte/leukocyte production, abnormal heart rhythm, skin lesions, circulatory disorders, neurological complications, diabetes, respiratory complications, and death 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 inhalation levels, respiratory problems, such as nasal ulcers, runny nose, asthma, cough, shortness of breath, and skin contact can cause skin ulcers. Long-term exposure can cause damage to 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 dysfunction, 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, hematological, or reproductive, leads to malfunction of the central nervous system and ultimately encephalopathy and edema, which mainly affect the cerebellum.
Aluminum (Al)	200 µg/L	<0.2 mg/L	0.2 mg/L	Post-dialysis encephalopathy, neurological disorders, osteomalacia, liver accumulation, cholestasis, normo- or microcytic anemia, impaired erythropoiesis.

WHO: World Health Organization.

polyclinic in the first measurement (M1), there were 2 patients coming from the dermatology polyclinic in the fourth measurement (M4). Since there are differences in the drugs used and body reactions, it is thought that blood samples of patients who come from different polyclinics and who undergo hemogram analysis affect heavy metal contents found in water.

Statistical Analysis

The mean, median, maximum, and minimum values of each heavy metal were calculated from seven measurements. In addition, the MPL values and percentage deviation from the MPL values are shown in Table 5. SD graphs of the data are shown in Figure 2. According to these results, it is observed that Al, As, Cr, and Cd elements were below their MPL and they were not harmful to human health. On the other hand, Mn and Ni were detected above their MPLs, especially Cu, Zn, and Pb, which were much higher above their MPLs.

DISCUSSION

Because it is very difficult to obtain permission to conduct analytical research on hospital wastewater (HWW), the literature on this topic is also scarce. In their review, Verlicchi et al.[29] reported mean concentrations for different classes of compounds using all data from previous studies on HWW and urban wastewater (UWW). According to these data, average HWW concentrations 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, 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. In this study, Heavy metals in the water were analyzed along the Konya Main Drainage Channel, and the results were evaluated seasonally.[32]

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 gas flow	1.40/min

ICP-MS: Inductively coupled plasma - mass spectrometer.

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, in particular, 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 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 in 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 similar study, Agbere et al.[34] 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 the Mindray hematology analyzer wastewater were 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 from 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 differ, their body metabolites and therefore the microelements found in their blood samples will also differ. According to the results, the amounts of each element differed on the day of analysis. The reason for this was thought to be the different outpatient variations of the patients compared with the hemogram, but the concentrations of trace elements released from clinical laboratory vending machines were mainly due to chemicals and test kits. The heavy metal content of the standard solutions used in the relevant devices for hematology analyses 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 were detected below

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
Anesthesiology	2	1	3	4	5	2	0
Brain and nerve surgery	5	6	5	5	5	15	5
Pediatric emergency	2	3	4	5	1	3	6
Paediatric allergy	2	1	3	4	5	0	2
Pediatric surgery	3	0	3	2	3	0	2
Paediatric endocrinology	1	1	1	2	1	1	2
Pediatric 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
Pediatric neurology	6	3	5	1	5	3	2
Paediatric oncology	9	2	2	3	4	5	1
Pediatric 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
Ophthalmology	6	3	1	2	4	4	5
Hematology	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
Orthopedics	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	↑↑ 11,000%
Zn	9319.375	4852.7	17823.15	8555.04	800	↑↑ 1,108%
As	1.1	0.1	2.9	6.80	50	↓ 2,528%
Cd	0.2	0.2	0.2	0.65	5	↓ %96%
Pb	197.35	187.45	243.05	177.52	6	↑↑ 3,267%

Min.: Minimum, max: Maximum.

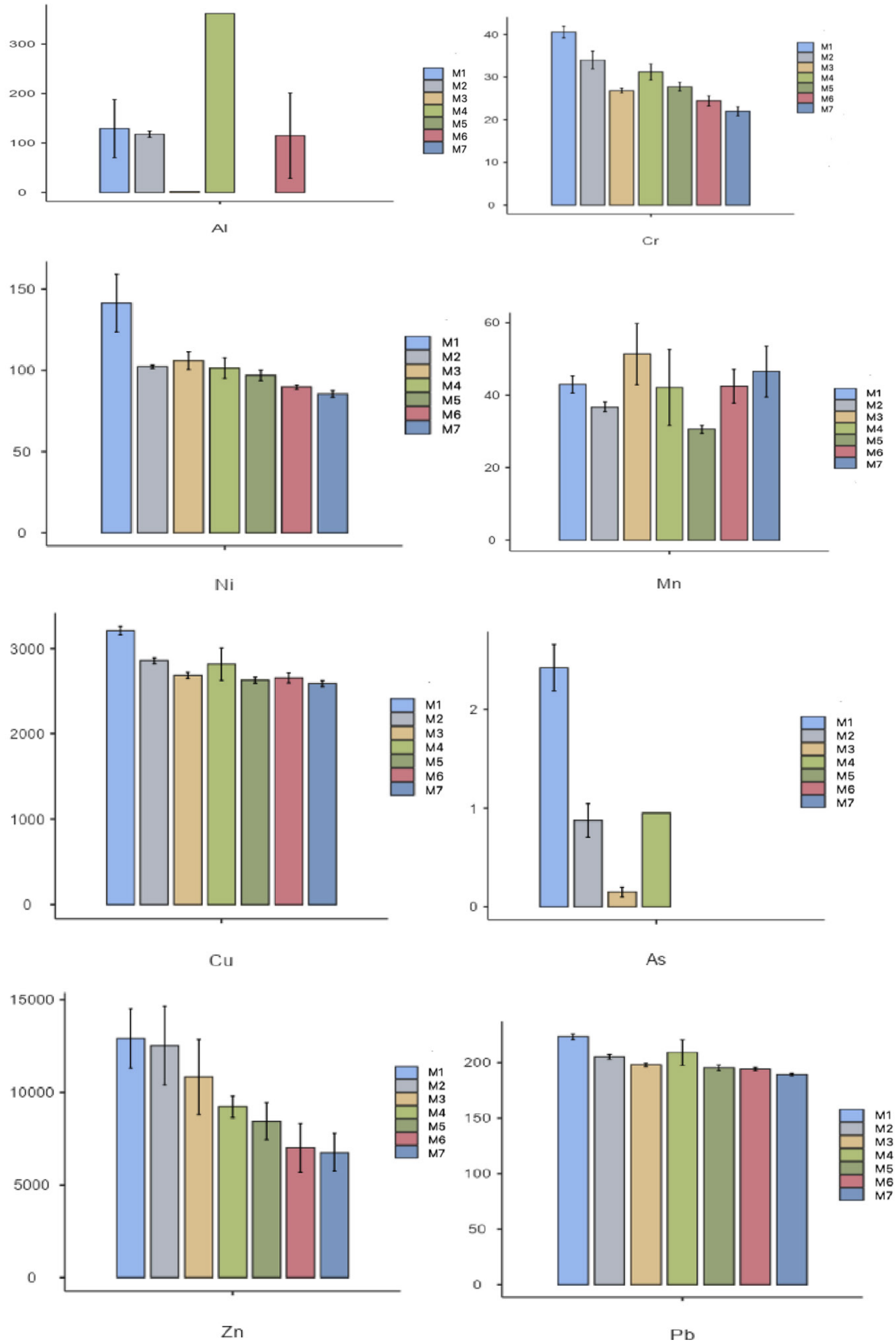

Figure 2. Standard deviation graphs of the data.

these levels, and it is estimated that they will not have a toxic effect. While Mn and Ni were detected above the MKS, Cu, Zn, and Pb were detected at values much higher than the MKS. Detection that is much higher than the MKS value poses a serious risk. In addition, heavy metal levels may change daily during analysis due to the lack of continuous mixing equipment and manual mixing before sampling. This can cause the precipitation of heavy metals. Domestic, industrial, and agricultural activities increase the concentration of heavy metals in wastewater. Heavy metals with serious toxic effects should be treated in HWW using appropriate treatment systems and then discharged. The disposal of micropollutants requires important processes, and the most appropriate process should be selected. Advanced purification processes such as activated carbon adsorption, oxidation, nanofiltration, reverse osmosis, and membrane bioreactors can provide higher and more consistent removal of micropollutant. However, regardless of the technology, the removal of micropollutants depends on the physicochemical properties and treatment conditions. Assessing the removal of micropollutants from wastewater should cover a range of aspects, from sources to end use. After the release of micropollutants, a better understanding and modeling of their fate in surface waters is essential for effectively predicting their impacts on the receiving environment.

CONCLUSION

Currently, preferred systems can be recommended for the proper disposal of HWW. It is generally known that HWW is mixed with UWW at some point. It is recommended that separate treatment plants be established to prevent micropollutants from mixing with UWW. In addition, because 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 methods.

MAIN POINTS

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

ETHICS

Ethics Committee Approval: This study was approved by the Ethics Committee of Selçuk University Faculty of Medicine (approval number: 2019/194, date: 26.06.2019).

Informed Consent: It wasn't obtained.

Authorship Contributions

Surgical and Medical Practices: İ.Ç., F.K., F.O., H.V., Concept: İ.Ç., F.K., F.O., H.V., Design: İ.Ç., F.K., F.O., H.V., Data Collection and/or Processing: İ.Ç., F.K., F.O., H.V., Analysis and/or Interpretation: İ.Ç., F.K., F.O., H.V., Literature Search: İ.Ç., F.K., F.O., H.V., Writing: İ.Ç., F.K., F.O., H.V.

DISCLOSURES

Conflict of Interest: No conflict of interest was declared by the authors.

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