05.00.00 Engineering science

05.00.00 Технические науки

UDC 62

Investigation of Seasonal Heavy Metal Contents in the Activated Sludge Wastewater Treatment Plant: Case Study

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Abstract. In this study, composite sewage sludge samples were taken from the drying beds of the Elazig City Activated Sludge Treatment Plant in order to investigate the seasonal heavy metal concentrations in the samples. According to the results of the analysis, the acid extractable annual heavy metal concentrations of the effluent sludge coming from the drying beds were found as Fe >Zn> Mn >Cu >Cr >Ni >Pb> Co> Cd. İron concentration in the sewage sludge was found to be the highest where Cd was detected in the lowest concentration value.

According to the independent t-test applied to the summer and winter pollution loads of the sewage sludge, statistical differences for the average values were observed between the groups for the iron, copper, and cadmium contents ($p<0.05$). On the other hand, no statistical differences were observed for the average values between the groups for the iron, zinc, manganese, chromium, nickel, lead, and cobalt contents ($p>0.05$).

Keywords: activated sludge; bioaccumulation; heavy metal; independent t-test; sewage sludge.

1. Introduction

The sewage sludge generated from the urban wastewater treatment facilities includes heavy metals in different concentration values depending on the wastewater type and the water treatment process. In general, sewage sludge comprises toxic elements. When applied on land, the sewage sludge causes various environmental problems such as odor, aesthetic pollution, pathogens, toxic organic chemicals, salts and heavy metals (Wong et al., 2001). When the sewage sludge is disposed as a fertilizing material, it causes soil pollution and as a result, unwanted metals bioaccumulation occurs in the plants and animals in time (Madyiwa et al., 2002). The risks related with the heavy metals presence in sludge, can be controlled by limiting the amount of sludge that will be applied to soil (Hanay and Hasar, 2007). Therefore, the seasonal heavy metal concentrations in the sludge must be measured for the seasonal land applications.

For annualy land applications, maximum heavy metal loads have to be 1500 mg/kg lead, 15 mg/kg cadmium, 1500 mg/kg chromium, 1200 mg/kg copper, 300 mg/kg nickel, and 3000 mg/kg zinc (Terz, 2007).

Shed fertilizer Fe:Cu:Cd rate of urban sewage sludge Fe:Cu:Cd rate is about 23:7:5. (Bozkurt and Yarilgac, 2003).

In the current study, seasonal composite sewage sludge samples were taken from the drying beds of the Elazig City Activated Sludge Treatment Plant in order to investigate the heavy metal concentrations for the seasonal applications.

2. Materials and Methods

The Elazig City Wastewater Treatment Plant treats both industrial and domestic wastewater. Since it is assumed that the heavy metals pollution load can be variational in the final effluent sludge taken from the drying beds, various sludge samples were taken to be analysed.

The sampling was conducted during one year between the dates of 15 January and 15 December. Hourly samples (for fifteen day of every month) were taken from 9.30 a.m to 12.00 a.m and composite samples were prepared by mixing them. The samples were kept in the refrigerator (according to the EPA's protection appliances) prior to the analyses.

The sludge samples were dried in 65⁰C for 12 hours. The dried samples were homogenized in a mortar and then sieved through 2 mm.

The sludge was processed with 5 ml concentrated nitric acid (Lue-Hing et al., 1992) in order to measure the heavy metals concentrations. A 5 ml of nitric acid and 100 ml of distilled water was added to 3 grams of dried sludge and the mixture is boiled until the color becomes lighter. Then the digestate was filtered through fitler paper and the volume was completed to 100 ml again. The heavy metal analyses were conducted by using Atomic Absorbtion Spectrometer (Schmidtke, 1980).

Table 1. Comparison the heavy metal limit values in the Sewage Sludge Regulation (Germany 1983) and Turkish Legal Obligations, European Countries accepted by the European Union, the United Nations Environmental Protection Agency and the average annual heavy metal concentration values in the effluent sludge of the Elazig City Wastewater Treatment Plant

	The maximum allowable heavy metal contents in sewage sludge that will be used in agricultural activities (OG, 1991) and heavy metal standards in sewage sludge according to the German Regulation (April 1, 1983) (mg/kg dry weight) (Akca et al., 1996)	The metal concentration limit values of the United Nations Environmental Protection Agency (mg/kg dry weight) (McFarland, 2000)		The maximum allowable heavy metal concentrations in sewage sludge in European Union Countries (mg/kg dry weight) (Akca et al., 1996)								The average annual heavy metal concentration values in the effluent sludge of the Elazig City Wastewater Treatment Plant (mg/kg dry weight)
Heavy Metal	Standard Values	Average Concentration	Maximum Concentration Limits	Belgium	Denmark	Germany	Holland	France	İreland	Spain	E.U.	
Lead	1,200.00	134.40	840.00	600.00	120.00	900.00	100.00	800.00	750.00	750.00	750.00-1,200.00	63.85
Cadmiyum	20.00	6.90	85.00	1.20	0.80	5.00/10.00*	1.25	20.00	20.00	20.00	20.00-40.00	4.30
Chromium	1,200.00	-	-	500.00	100.00	900.00	75.00	1,000.00	-	1.000.00	1,000.00-1,500.00	84.15
Copper	1,200.00	741.00	4,300.00	750.00	1,000.00	800.00	75.00	1,000.00	1,000.00	1.000.00	1,000.00-1,750.00	216.60
Nickel	200.00	42.70	420.00	100.00	30.00	200.00	30.00	100.00	300.00	300.00	300.00-400.00	65.90
Mercury	25.00	5.20	57.00	10.00	0.80	8.00	0.75	10.00	16.00	16.00	16.00-25.00	-
Zinc	3,000.00	1,202.00	7,500.00	2,500.00	4,000.00	2,000.00/2,500.00*	1,400.00	3,000.00	2,500.00	2,500.00	2,500.00-4,000.00	1,168.18
Arsenic	-	9.90	75.00	-	-	-	-	-	-	-	-	-
Selenium	-	5.20	100.00	-	-	-	-	-	-	-	-	-
Molibden	-	9.20	75.00	-	-	-	-	-	-	-	-	-
İron	-	-	-	-	-	-	-	-	-	-	-	7,701.88
Manganes	-	-	-	-	-	-	-	-	-	-	-	515.55
Cobalt	-	-	-	-	-	-	-	-	-	-	-	10.79

*THA maximum values for the solid matter including less than 5% clay with pH=5-6

3. Results and discussion

The monthly changes of iron, zinc, manganese, chromium, copper, nickel, lead, cobalt, and cadmium concentrations in the effluent sludge of the Elazig City Wastewater Treatment Plant are shown with Figs. 1-9.

Table 1 summarizes the heavy metal limit values in the Sewage Sludge Regulation (Germany 1983) and Turkish Legal Obligations, the sludge standards valid in various European Countries accepted by the European Union, the metal limit values of the United Nations Environmental Protection Agency and the average annual heavy metal concentration values in the effluent sludge of the Elazig City Wastewater Treatment Plant.

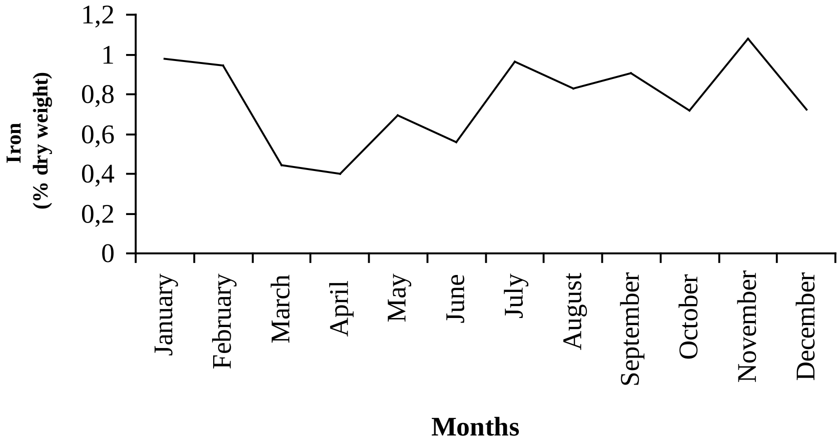

Fig. 1: The monthly changes of iron, concentrations in the effluent sludge of the Elazig City Wastewater Treatment Plant

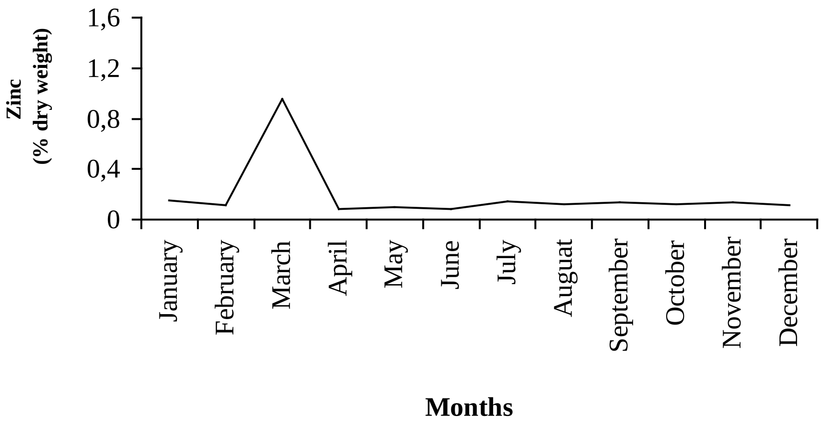

Fig. 2: The monthly changes of zinc, concentrations in the effluent sludge of the Elazig City Wastewater Treatment Plant

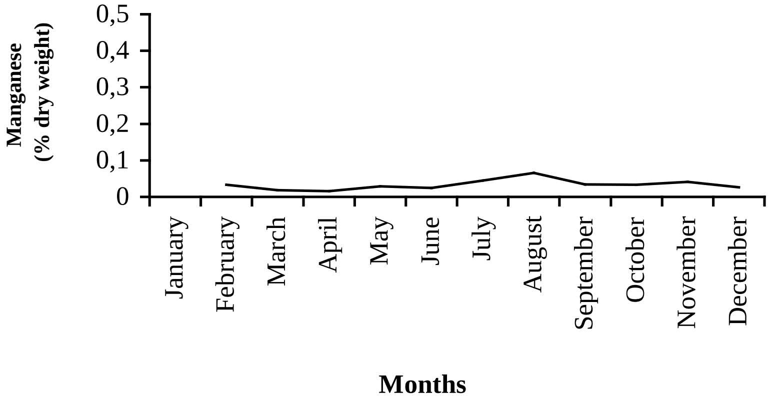

Fig. 3: The monthly changes of manganese concentrations in the effluent sludge of the Elazig City Wastewater Treatment Plant

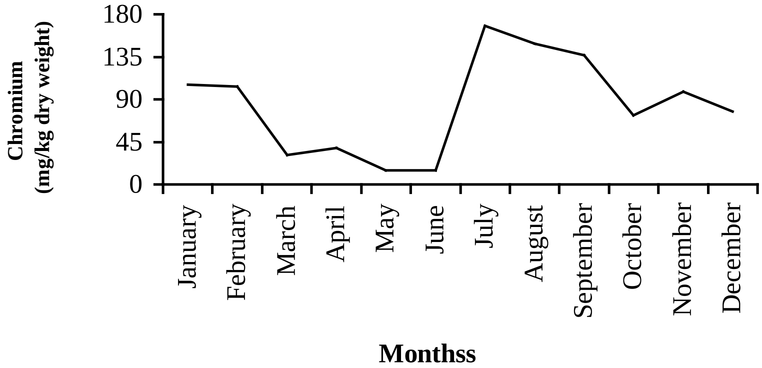

Fig. 4: The monthly changes of chromium concentrations in the effluent sludge of the Elazig City Wastewater Treatment Plant

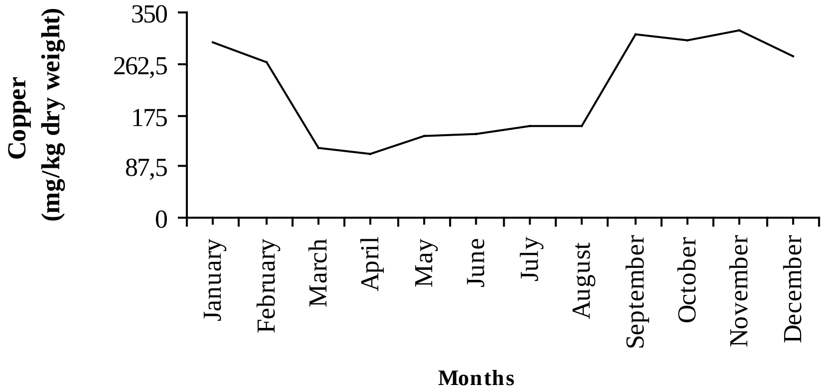

Fig. 5: The monthly changes of copper concentrations in the effluent sludge of the Elazig City Wastewater Treatment Plant

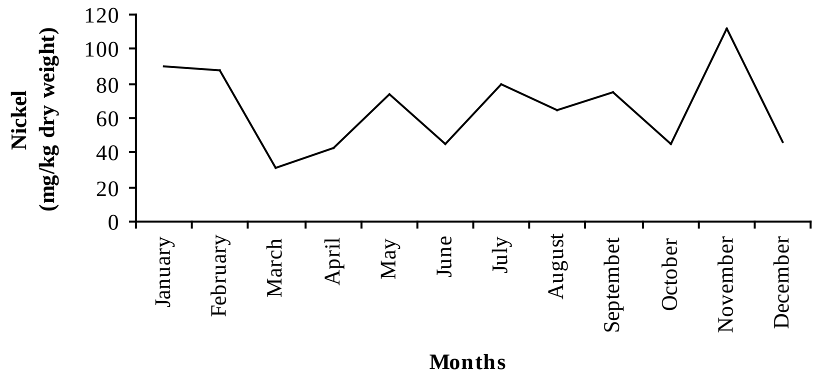

Fig. 6: The monthly changes of nickel concentrations in the effluent sludge of the Elazig City Wastewater Treatment Plant

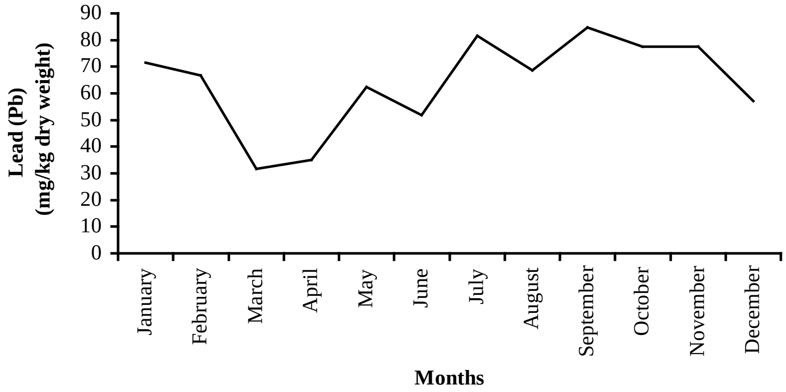

Fig. 7: The monthly changes of lead concentrations in the effluent sludge of the Elazig City Wastewater Treatment Plant

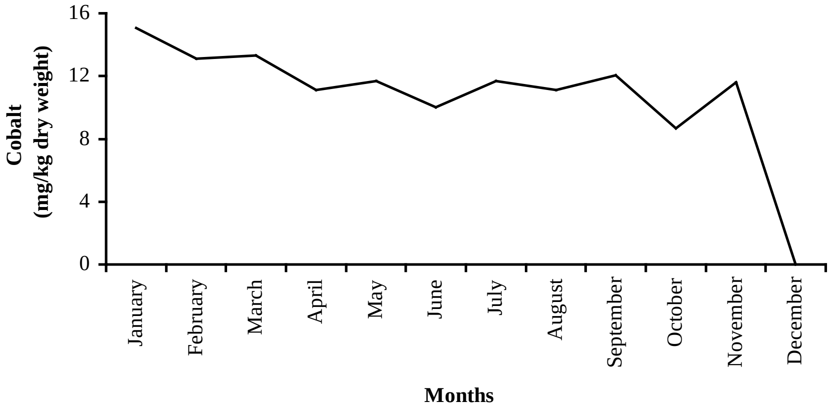

Fig. 8: The monthly changes of cobalt concentrations in the effluent sludge of the Elazig City Wastewater Treatment Plant

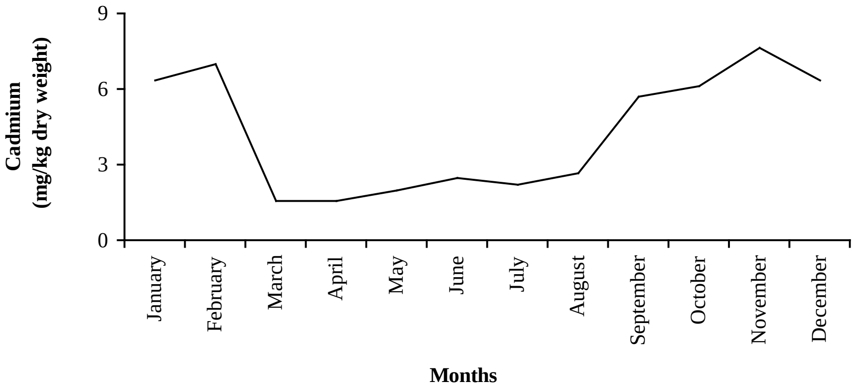

Fig. 9: The monthly changes of cadmium concentrations in the effluent sludge of the Elazig City Wastewater Treatment Plant

According to the results of the analysis, the annual heavy metal concentrations of the effluent sludge in the drying beds were found as Fe >Zn> Mn >Cu >Cr >Ni >Pb> Co> Cd. İron concentration in the sewage sludge was found to be the highest where Cd was detected in the lowest concentration value.

The monthly heavy metal concentrations of the effluent sludge in the current study were lower than the limit values of the German Solid Wastes Control Regulation and the limit values in Turkey (Table 1).

The seasonal lead, cadmium and zinc concentrations were found to be appropriate according to the Table 1.

Some of the monthly heavy metal concentrations of the effluent sludge exceeds the limits of the heavy metals bioaccumulation concentrations in animals and plants according to the United Nations Environmental Protection Agency's limit values (detected by land and laboratory studies) in Table 1 and Fig.1-Fig.9.

The independent t-test was applied to summer (March, April, May, June, July, August) and winter (September, October, November, December, January, February) heavy metals pollution loads in sewage sludge. Table 2 gives the average and standard error values.

Heavy Metal	Between September-February	Between March-August
Fe	8,914.00±588.00**	6,489.80±906.00
Zn	1,289.10±61.00	1,047.30±94.00
Mn	337.10±18.00	694.00±356.00
Cr	99.00±9.00	69.30±28.00
Cu	296.20±9.00**	137.00±8.00
Ni	75.80±11.00	56.00±8.00
Pb	72.50±4.00	55.20±8.00
Co	10.10±2.00	11.50±5.00
Cd	6.50±0.30**	2.10±0.20

$P \geq 0.05$

Table 2. The average and standard error values for the summer (March, April, May, June, July, August) and winter (September, October, November, December, January, February) heavy metals pollution loads in sewage sludge (mg/kg dry weight)

Cadmium ions are found in low concentrations in sewage sludge because of its formation of non-soluble compounds.

Even low concentrations of zinc, copper, and nickel cause toxic effects in the plants. Therefore they enter the food chain and may even influence the human health.

The nickel and zinc concentrations obtained from the sewage sludge exceeds the limits of the heavy metals bioaccumulation concentrations in animals and plants according to the United

Nations Environmental Protection Agency's limit values (detected by land and laboratory studies) in some of the months of this study. This may cause toxic effect risks at any time.

The iron, copper and cadmium concentrations in the effluent sludge were higher in summer when compared to winter values ($p<0.05$). Besides, no statistical differences were observed for the average values between the groups for the iron, zinc, manganese, chromium, nickel, lead, and cobalt contents ($p>0.05$).

4. Conclusion

Industrial effluents are submitted urban wastewater treatment plant. Industrial productions are made depending on actual requirements. Depending on production potential, the loads of heavy metals in wastewaters and sewage sludge vary. Elazig City industrial area has about 13 different sectors. Mainly, respectively: Marble industry, plastic industry, forest industry, metal products industry, electrical machinery industry, food industry, textile and clothing industry, chemical industry, baked clay and cement industy, glass industry, agricultural equipment and machinery manufacturing industry, paper industry, and fertilizer industry. According to the production potential of these sectors, the heavy metal pollution loads of sewage sludge vary.

Although the heavy metal concentrations were found to be appropriate for the standards, continuous applications on soil may cause long time accumulations and toxic effects for food cycle via the plants. Therefore, annual metal accumulations should be calculated to predict this effect.

We can discuss about iron, copper, and cadmium pollution in soil which are exposed to sewage sludge generated from the wastewater treatment plant drying beds.

Shed fertilizer Fe:Cu:Cd rate of urban sewage sludge Fe:Cu:Cd rate is about 23:7:5. (Bozkurt and Yarilgac, 2003). If sewage sludge is reguired to apply area instead of shed fertilizer, we should take into consideration this rate.

In addition, respectively, annually sewage sludge zinc, cadmium, nickel, and copper loads very high (>100 %). Therefore land applications have to be made in respect of these heavy metals's loads.

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УДК 530

Исследование сезонного содержания тяжелого металла на заводе по очистке сточных вод активированным илом: ситуационное исследование

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Аннотация. В статье для изучения сезонных концентраций тяжелых металлов были взяты пробы осадков сточных вод с иловых площадок завода по очистке сточных вод активированным илом города Элязыг. Согласно результатам анализов, экстрагированное ежегодное содержание кислотных тяжелых металлов в иловых площадках составило Fe >Zn> Mn >Cu >Cr >Ni >Pb> Co> Cd. Содержание железа в осадке сточных вод оказалось наивысшим, содержание Cd оказалось в наименьшей концентрации.

Согласно независимой проверке концентрации загрязнителей в осадке сточных вод по критерию Стьюдента, проведенной в летнее и зимнее время, статистические различия средних величин были зафиксированы между группами, содержащими железо, медь и кадмий ($p<0.05$). С другой стороны, статистические различия средних величин были зафиксированы между группами, содержащими железо, цинк, марганец, хром, никель, свинец и кобальт ($p>0.05$).

Ключевые слова: активированный ил; бионакопление; тяжелый металл; независимая проверка по критерию Стьюдента; осадок сточных вод.