ORIGINAL ARTICLE

Removal of Chromium and Cadmium from Wastewater in Waste Stabilization Ponds, Yazd-Iran

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Abstract

Background: Heavy metals have destructive and irreversible effects on the human, plants and animals. Some industries in Yazd enter industrial wastewater to municipal wastewater collection system. This can lead to high levels of heavy metals in wastewater and in turn in the wastewater treatment plant effluent.
Methods: This study was carried out during four months from December 22, 2009 to May 20, 2010. The experiment was performed on the inflow, outlet of anaerobic pond and first and second facultative ponds of wastewater treatment plant and then transferred to the laboratory and measured by atomic absorption spectroscopy.
Results: The results of the experiments showed that the average cadmium concentrations in the inflow, anaerobic pond outlet, and first and second facultative pond outlet were 0.0066, 0.0087, 0.0076, and 0.0083µg/l, respectively. The average amounts of chromium in the inflow, anaerobic pond outlet, and first and second facultative pond outlet were 0.0076, 0.0065, 0.0043, and 0.0056 µg/l, respectively. Cadmium concentration in the effluent was higher than standard.
Conclusion: The comparison of the obtained data with Iranian standards for wastewater treatment for reuse in irrigation shows that the cadmium concentration exceeded the standard and the chromium concentration was lower than the standard. Therefore, it is not suitable for reuse in the crop farms and aquatic life.

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Introduction

Waste Stabilization Ponds [WSPs] are large shallow basins where raw sewage is treated by bacteria and algae.[1] Very high efficiency in the removal of pathogenic organisms and less sensitivity to shock hydraulic and organic loading and toxins are among the advantages of these ponds. They are used for wastewater treatment in productive industries such as slaughterhouses, dairy and conserve industries.[2] Often, wastewater can be used for irrigation of agricultural lands which results in higher levels of production.[3] But it should be noted that irrigation with wastewater, especially industrial wastewater and urban runoff,[4]can lead to higher levels of toxins and heavy metals in the soil and yield.[5-7]

Different definitions and interpretations have been presented in texts for heavy metals.[8,9] According to the definition accepted by UNEP,[1] heavy metals refer to metals which are above calcium in the periodic table of elements, are highly toxic and have a density of more than 5 grams per cubic centimeter.[10] These metals enter the water and soil in the form of solution and contaminate the groundwater, surface water and soil.[11]

Yazd have a very hot and dry climate. The city is located in central Iran. The treatment system in the Yazd wastewater treatment plant (WWTP) is wastewater stabilization ponds. First, the wastewater stream collected enters the anaerobic pond, the outlet of which enters a set of two facultative ponds (in series). Finally, the effluent from the second facultative pond is used to irrigate green spaces in the area including olive farms.[12]

These metals accumulate in the human body and affect the kidneys and bones and also cause cancer.[13] Chromium has adverse effects on human health in the short-term including inflammation and irritation of the mouth, nose, lungs, and skin, and damage to kidneys and liver.[14]

In a study by Juanico and colleagues on removal of trace elements from wastewater in two reservoirs in series used for the seasonal storage of wastewater effluents for irrigation, the concentrations of metals were reduced between 20 and 75%, to the base level found in unpolluted groundwater in the region.[15] In a study conducted by Mehdinejad and colleagues on Heavy Metals Concentration (Zinc, Lead, Chromium and Cadmium) in Water and Sediments of Gorgan Gulf and Estuarine Gorganroud River, Iran when compared to standard limits in water, Cr, Cd, and Pb had more concentrations than standard limits of world health organization.[16]

According to the above points and given that many large and small industries pour their sewage into the Yazd wastewater collection network, addressing this issue is very important. Therefore, continuous monitoring of these metals in wastewater effluent is necessary. The aim of this study was to evaluate the chromium and cadmium in wastewater and removal rate in wastewater treatment.

Materials and Methods

This descriptive, cross-sectional study was carried out from December 22, 2009 to May 20, 2010 in Yazd. All materials were purchased from Merck, Germany.

Samples were taken from four parts, i.e. the WWTP inflow, anaerobic pond outlet, first facultative pond outlet, and the WWTP outlet. Because of the large surface of the ponds, three equal samples were taken from each part and mixed. During the research period, a total of 16 samples were taken. A plastic 2-liter container was used for sampling. The samples were fixed and transferred to the laboratory of Isfahan solid waste management organization. Chromium and cadmium were measured using atomic absorption spectroscopy (AAS). AAS was calibrated according to the standard procedure. All tests were done three times. The results were analyzed using EXCEL. The graphs and tables are discussed in the results section.

Results

In this study, the temperature, pH, electrical conductivity and dissolved oxygen were measured in four points of the stabilization pond. The temperature was higher at the inflow of the pond than in other points. In all ponds, the pH values were higher than 8. Table 1 shows concentrations of cadmium and chromium in Yazd WWTP effluent and Iranian standards for the use of wastewater in agriculture and irrigation.

According to Table 1, although chromium concentration is lower than the standard level, cadmium concentration in the effluent is higher than the standard amount. Therefore, it is not suitable for reuse in the crop farms and aquatic life.

According to Table 2, the average cadmium concentrations in the inflow, anaerobic pond outlet, and first and second facultative pond outlet were 0.0066, 0.0087, 0.0076, and 0.0083 µg/l, respectively. Based on Figure 1, the average amounts obtained for chromium in the inflow, anaerobic pond outlet, and first and second facultative pond outlet were 0.0076, 0.0065, 0.0043, and 0.0056 µg/l, respectively. Chromium had the highest removal rates.

The average concentration of cadmium in four points of Yazd stabilization ponds is shown in Figure 2.

Based on Figure 2, the percentage of chromium removal in the anaerobic and first facultative ponds are

Table 1: Heavy metals of stabilization ponds' effluent (µg/l) and their comparison with standards

	Cadmium(µg/l)	Chromium (µg/l)
Sample from the outlet of second facultative pond	0.0083	0.0056
Water standards for crop farms	0.005	0.1
Water standards for aquatic life	0.005	0.05

Table 2: Comparison of temperature, pH, EC and oxygen dissolved in the four points of the stabilization pond

Sampling points	Temperature (°C)	pH	EC µs/Cm	DO mg/l
Inflow	26.7	8.6	1850	0
Anaerobic Pond	24.5	8.7	2380	0
First facultative Pond	24.2	8.6	2720	3.8
Second facultative Pond	23.9	8.6	2450	7.7

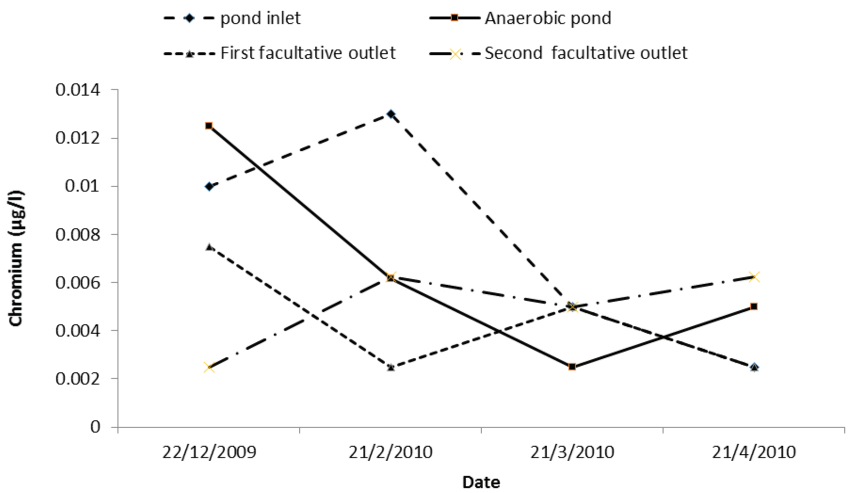

Figure 1: Cadmium concentrations in Yazd wastewater stabilization ponds.

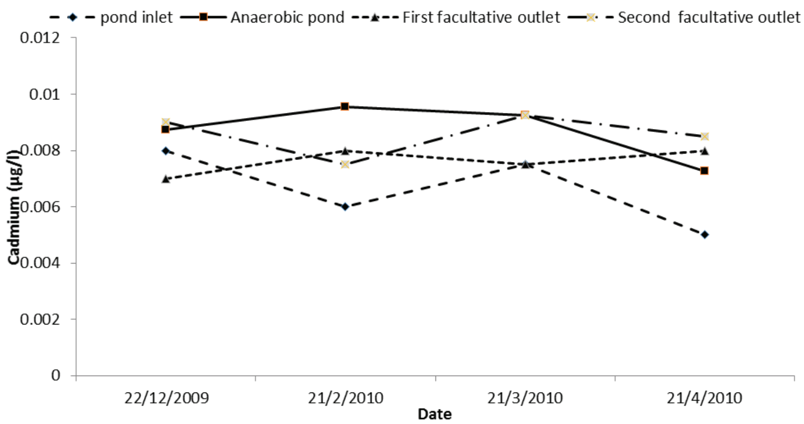

Figure 2: Chromium concentrations in Yazd wastewater stabilization ponds.

14.4% and 33.8%, respectively. No removal occurred in the second facultative pond, but some increase was observed. This is due to solar radiation and high evaporation in this pond. Regarding cadmium, the removal was just observed in the first facultative pond with a removal level of 12.64%. In the second facultative pond, as mentioned, with the increase in solar radiation and evaporation, the amount of cadmium condensed and increased.

Discussion

In a study by Mansouri and Ebrahimpur on heavy metals in stabilization ponds, the amounts of heavy metals of arsenic, chromium, copper, lead, zinc and mercury were1.14, 11.7, 71.6, 36.9, 6.8, 50.3, and 5µg/l, respectively. These values were used to check whether the wastewater was suitable for crop irrigation or not. The results showed that it was suitable for irrigation. These were below the EPA standards and were thus reported as suitable for irrigation.[17]

Nasr and colleagues carried out a study on waste stabilization ponds for wastewater treatment and reuse in Egypt. The purpose was to determine whether the effluent is suitable for irrigation. They concluded that the effluent was not suitable for restricted irrigation but can be used for non-restricted irrigation.[18]

According to a study by Kaplan and colleagues on the treatment of domestic wastewater with stabilization ponds, the concentrations of heavy metals of zinc, cadmium, lead and copper in raw domestic wastewater were 224.2, 2, 53.5, and 34.3 µg/l. These concentrations in tap water were 92.2, 0.3, and 6.6. The rates of zinc removal from raw wastewater, settling ponds, anaerobic ponds, facultative ponds and tanks were 0, 24, 22, 9, and 42%, respectively. Cadmium removal rates for raw wastewater, settling ponds and tanks were 0, 5, and 45%, respectively. The rates of lead removal from raw wastewater, settling ponds, anaerobic ponds, facultative ponds and tanks were 0, 20, 28, 53, and, 41%, respectively. The rates of copper removal from raw wastewater, anaerobic ponds, facultative ponds and tanks were 0, 15, 30, and 30%, respectively.[19]

Several studies[12,20,21] have been studied waste stabilization pond in Yazd. Samaei and colleagues (2008) have studied heavy metals in Yazd stabilization ponds. The results showed that among all metals, arsenic removal rate was the (94.86%) followed by Pb (80.54%), cadmium (70/59%) and mercury (55.39%).[21]

Also, in a study by Ling and colleagues on stabilization ponds in Malaysia, heavy metals in wastewater and sediment from pond inflow and outflow of farms with one pond, two ponds, two ponds with separator and three ponds in series were investigated. Reduction of heavy metals in the wastewater was Cu [62%] >Zn [36%] >Ni [34%] > Pb [[31%] >Cd [1 6%] >Cr [9%]. The reductions were significantly higher in the 3-ponds system than the other systems. Copper and zinc were the highest in concentrations. The outflow of all the pond systems studied exceeded the 0.02 mg/l Malaysian standard for the discharge downstream of water intake, indicating its mobility and thus the need for other methods to polish the effluent for compliance.[22]

Contamination of soil, groundwater, sediment and surface water with toxic and hazardous chemicals is a serious problem to which the world is facing today.[23] If we compare these results with Iranian national standard, it is observed that the concentration of cadmium is more higher than the mentioned levels in these studies but chromium is not. Irrigation with such effluent can lead to the accumulation of these metals in the soil and crops. The amount of chromium in the effluent from the WWTP in Yazd is suitable for agriculture based on the World Health Organization standards. But the biggest problem is with cadmium، the value of which is greater than the Iranian standard and especially the WHO threshold. In general, the effluent is suitable for irrigation, but not for crop farms. For crop irrigation, pretreatment methods should be used before the stabilization ponds.

Also, this study showed that the percentage of metal removal in the second facultative pond was less than the first pond. Cadmium and chromium concentrations were higher in the second facultative pond. This is due to the increased evaporation. Anaerobic pond had the lowest removal percentage. The cadmium concentration in the anaerobic pond increased; this can be due to an increase in pH to above 8. Metals deposit in the anaerobic pond and disrupt the treatment process. Also, short-circuits can create a dead space which reduces the pond volume and can cause excessive load. This indicates that the facultative ponds outperformed the anaerobic ponds in removing heavy metals.

According to previous studies, facultative ponds are more responsible for removal of heavy metals than the anaerobic ones. Removal of cadmium and chromium was lower in the Ling's study,[22] which is consistent with the results of the present study.

Overall, the results of measurement of heavy metals in Yazd WSPs indicate that this wastewater treatment system can remove heavy metals such as cadmium and chromium, but it has not been able to reduce concentrations of cadmium to the standard level. In the present conditions, the use of effluent for irrigation of green spaces in the area is appropriate according to Iranian standards, but it is not suitable for crop irrigation. Cadmium can cause damage to the kidneys, lungs, liver, cardiovascular, immune, and reproductive systems.[24] So in order to prevent the harm to humans and the environment, industrial wastewater treatment plans should be considered. Modification of methods, use of other methods of wastewater treatment and waste management in industries that discharge sewage in the municipal wastewater collection network are among solutions to the issue. It seems that industries are the main sources of heavy metals entering the Yazd WWTP. Therefore, the Iranian department on environmental protection (DOE) must compel Yazd industries to do pretreatment, thereby reducing the metals in wastewater. This will improve living conditions for algae and bacteria and ultimately increase the efficiency of the ponds in Yazd. It should be noted that wastewater stabilization ponds are mostly effective in warm climates.[5] Thus, attempts should be made to modify the system in order to adapt it to local requirements and increase its performance. In all ponds, changing the dissolved oxygen concentration or increasing the pH values to above 8 leads to the increased treatment efficiency of WSP. Oxygen concentration in WSP was supersaturation due to high activity of algae in sunlight.

In recent years, biological absorption has been considered as an effective and affordable option for removal of heavy metals.[25] This method involves the use of biological materials, such as algae and bacteria, in the removal of heavy metals. Further research is recommended on algae and bacteria species that can be used to remove heavy metals in WSPs.

Globally, agriculture is the largest consumer of water and according to UNEP, in Africa and Asia, an estimated 85-90% of all freshwater is used for agriculture.[7] This is 92% in Iran. Agriculture is expected to increase its water requirements by 1.2 times by 2025.[26] A large part of the Yazd drinking water supplies is from underground sources[27] and may be polluted with heavy metals. Therefore, reuse of treated wastewater is one of the good options for agricultural water management[4] and should be taken seriously.

Since treatment of small amounts of wastewater containing large amounts of heavy metals is much easier than that of large amounts of wastewater containing small amounts of heavy metals,[13] it is recommended that first, a pretreatment should be designed for industrial towns to prevent the imposition of economic and environmental costs and help the country take stronger measures towards sustainable development. The use of coagulants is appropriate to reduce suspended solids and turbidity of WSPs that is suitable for agricultural purposes and complies with environmental standards. For the prevention of heavy metal pollution, biological methods can be used for creation of rural wastewater collection system.

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Conflict of Interest: None declared.

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