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Removal of heavy metals using food industry waste as a cheap adsorbent

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Abstract

Due to the high capacity of food factories, a lot of waste is generated. Due to the presence of nutrients in them can increase pollution in the sewerage network and cause environmental problems. To animal feed, grain waste can be used to produce fertilizer, compost, fuel, soil cover, etc. The natural pigment lycopene, thickeners, proteins, etc., can be produced from the seeds and skin of the tomato paste factory waste. In the present paper, soybean oil residue was used to remove cadmium, zinc, and lead ions from aqueous solutions. Discontinuous experiments to investigate the effect of initial concentration (100-300 ppm), solution pH (1-5), contact time (1-60 min), adsorbent amount (0.02-2 g) on the uptake of cadmium, zinc, and lead ions by soybean oil residues. The results showed that with increasing the pH, the value of the contact time, the amount of adsorbent, and the adsorption rate increases with increasing the initial concentration of metal ions, the adsorption rate decreases. According to the results, the best pH for adsorption of metal ions is about 3-5, and the equilibrium time for cadmium ions is 40 minutes, for zinc ions is 20 minutes, and for lead, the ion is 10 minutes.

Keywords: soybean oil waste; heavy metals; absorbents; adsorption; food industry waste.

Practical Application: Soybean oil residue is used to remove cadmium, zinc, and lead ions from aqueous solutions.

1 Introduction

Industrial development and subsequent production of various industrial products in the world have led to many environmental pollutions, which is one of the worrying problems of this century (Seyyedi & Ayati, 2021). Untreated effluents in industries and mines are often the most dangerous types of effluents (Fan et al., 2019). Heavy elements entering water and soil resources are absorbed by plants and animals and enter the human food chain, leading to dangerous and incurable diseases (Youssef et al., 2018). Heavy metals are one of the dozens of sustainable materials that do not decompose in nature and can enter the environment with wastewater or sewage from various industries (Odobašić et al., 2020). These metals are usually needed in small quantities for normal body function, but their excessive entry into the body will cause poisoning (Seğmenoğlu & Baydan, 2021). Studies show that heavy metals can affect human health in India, so the removal of heavy metals is essential, and various methods for the removal of heavy metals in the form of physical, chemical, and biological methods such as membrane methods are used, chemical precipitation, electrochemical purification, ion therapy, surface adsorption and bioremediation (Herrera-Barros et al., 2021). Researchers have always stated that heavy metals have destructive effects and that it is necessary to remove and purify these metals from water and soil (Hamid et al., 2021). Offering the advantages and disadvantages of heavy metal removal methods, it is possible to easily choose the appropriate method in terms of cost and access to technical knowledge (Onac et al., 2021). Excessive amounts of heavy metals in soil and water are important issues that can threaten ten aquatic ecosystems, agriculture, and public health (Singh Sankhla et al., 2016). Environment through human activities such as mining, production of metal ingots such as lead, zinc, copper, cadmium, etc., production of fuel and energy, use of agricultural pesticides, battery industry,

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and dyeing with heavy metals it is possible (Sheng et al., 2021). These metals can enter the body directly through water, air, and soil (drinking water and inhaling heavy metal-contaminated air) or indirectly (eating products, fruits, and meat of heavy metal-fed animals) be human. Due to the lack of decomposition and decomposition, these metals accumulate in the body and cause many problems in the body (Tadesse et al., 2018). The most important toxicity properties of heavy metals include A) these toxic elements are abundant in the environment and in the body, b) the toxicity of some heavy metals such as mercury in a particular environment increases over time, c) accumulation of heavy metals and increasing the concentration of heavy metals in the body increases their toxicity and damages the body's physiological activities, d) the concentration and toxicity of heavy metals are different; but arsenic, cadmium, and mercury can be toxic even at very low levels (Fomina & Gadd, 2014). Contact with heavy metals can cause skin, digestive, respiratory, kidney, liver, and cancer problems (Jan et al., 2015). Heavy metals such as chromium, arsenic, cadmium, mercury, and lead have a greater potential for harm to health (Matta & Gjyli, 2016). Due to the destructive effects and serious problems of heavy metals in drinking water and agriculture for human health, action should be taken to eliminate and reduce heavy metals. There are several methods used to remove heavy metals in the world (Hamid et al., 2020).

Due to the side effects of these effluents, removal, and control of some heavy metals from these effluents are recommended (Abbas, 2020). In order to remove heavy metals from the factory output, different methods such as reverse osmosis, chemical deposition, ion exchange, membrane processes, evaporation, and solvent extraction are suggested. Most of these methods face disadvantages such as the cost of equipment and sludge production operations. Also, the need for energy and a lot of space is another disadvantage of these methods, which has led to their limited use. Therefore, recognizing and diagnosing inexpensive methods to eliminate water pollution is very appropriate for this reason; the use of adsorbents to remove heavy metals is a cheap and convenient method that has attracted the attention of many researchers today (Xu et al., 2018). In the past decades, activated carbon was the most common and efficient adsorbent used to adsorb pollutants, but due to orientation and problems in its preparation, it forced researchers to replace it with other adsorbents that, in addition to it is cheaper, cheaper, and easier to prepare. In this regard, mineral, natural adsorbents, and food industry and agricultural wastes such as diatomite, pulp, olive, chitosan, sawdust, red mud, etc., are used to remove heavy metal contamination. In this study, soybean, which is one of the absorbers of the food industry, was used. Oil extracted from soybeans is one of the most important types of oils. This oil contains very high linoleic acid; soybean oil waste is a by-product of the lubrication industry and is used for human and animal consumption. It also contains a significant amount of linoleic acid. With different hydroxyl groups and fatty acids, this material has a good potential for adsorption of metal ions (Bitonto et al., 2019). In this study, soybean oil residue has been used to remove cadmium, zinc, and lead metals from aqueous samples, and the influence of various factors such as metal concentration, adsorbent amount, contact pH, etc., in the adsorption process has been investigated.

Heavy metals are commonly found in wastewater from various industries. Plating has resulted in significant amounts of effluents containing heavy metals such as cadmium, zinc, lead, chromium, nickel, copper, vitamin A, platinum, silver, and titanium. Metals such as cadmium, zinc, copper, nickel, lead, mercury, and chromium there are several examples of heavy metals that originate not only from metal plating activities but also from mining activities, battery production, oil refining, and paint production. In addition, wastewater from the leather, textile, pigment, and paint industries, products, wood, and photographic film production contain significant amounts of heavy metals, which are toxic and harmful to humans and animals. Low-cost attractions in general, an adsorbent is called low-cost because it requires few processing methods or is abundant in nature and can even be a by-product of industry. Natural materials or effluents from industrial or agricultural operations are one of the important sources of low-cost absorbers (Wang et al., 2019). In general, these materials are available in large quantities and are cheap. The removal of heavy metals using low-cost adsorbents is very practical; the development of these attractions has been done using agricultural and industrial wastes (Guo et al., 2018). Commercially, an adsorbent should have high selectivity to facilitate separation, easy transport, kinetic properties, heat and chemical stability, mechanical strength, deposition resistance, regenerative capacity, and low solubility in the liquid. The adsorption process has many advantages over conventional heavy metal removal methods. The advantages of the adsorption process include economic efficiency, metal selectivity, playability, naught of toxic algae, metal recovery, and, most importantly, the effectiveness of this method. Absorbents are mainly agricultural wastes, industrial by-products, natural materials, or modified biopolymers. (Rangabhashiyam & Balasubramanian, 2019).

2 Material and methods

To prepare other solutions, dilute an appropriate amount of the initial solution of cadmium, zinc, and lead, which was prepared by dissolving their nitrate salts in distilled water, was used. A five-digit decomposition scale was used for weighing in this study. Dilute hydrochloric acid, and sodium hydroxide solutions were also used to adjust the pH.

In the present paper, the soybean oil residue was first washed two to three times with distilled water and then dried at a temperature of 60 °C. It was then ground to the exact size of the particles and used in an aqueous solution for heavy metal adsorption experiments.

2.1 Adsorption method

Methods for removing heavy metals from aqueous solutions include physical, chemical, and biological processes (Gunatilake, 2015). Adsorption is the process of adsorption of atoms and molecules in a fluid by a solid surface away from equilibrium, in which the solid tends to capture some of these ions to reach equilibrium. The adsorption process usually begins with the blade force of the rolling board and ends with the short force such as metal and ionic bonds. The surface adsorption method is one of the most widely used methods for the removal of heavy metals due to its high yield and ease of application. In this process, the contaminated water is passed through a substrate or filter, and the arsenic and heavy metal are separated from the water by the bonds they make with the adsorbent. Activated alumina, activated carbon, and iron oxide are among the solids that are widely used as adsorbents (Azimi et al., 2017). The greater the temperature difference between the solid surface and the adsorbent, the faster the adsorption occurs because the thermal energy of the material is the driving force of the adsorption on the surface. In general, ten adsorption pads occur due to their properties on the solid surface (Marczewski et al., 2016). Advantages of the adsorption method include the extraction of the removed metal in case of recovery from the adsorbent surface, a suitable method for the removal of heavy metals in dilute solutions, low cost, and simple process design. Disadvantages of this method include the loss of adsorbent efficiency over time and the inability to activate dozens of adsorbents in many cases (Rahel & Bhatnagar, 2017).

2.2 Method of performing adsorption tests

All adsorption experiments were performed intermittently. To do this, adsorbent and solution containing metal ions with a certain concentration were poured into a human and placed on a shaker at a suitable speed, after the required time, the adsorbent particles. It was separated from the solution using a strainer and an atomic absorption device; it was used to determine the concentration of metal ions in the initial solution and after adsorption. The adsorption capacity or the amount of adsorbed material on the adsorbent surface in milligrams per gram of adsorbent, as well as the adsorption percentage, are obtained from Equation 1.

$$q_t = \frac{(c_0 - c_t)v}{w} \quad (1)$$

In this regard, " q_t " with adsorption capacity, the amount of adsorbed material in equilibrium in mg/g of adsorbent, " c_t " the equilibrium concentration of metal in mg/L, " c_0 " its initial concentration in mg/L, " v " the volume of the solution in liters, " w " is the mass of adsorbent used in grams.

3 Results and Discussion

In this section, the results related to the effect of pH, contact time, solution concentration, and adsorbent amount are discussed.

3.1 The effect of pH

Changes in the concentration of hydronium ions are a very important factor in the adsorption capacity, and the adsorption dependence is due to the competition for surface locations between metal ions and hydrogen ions. Figures 1 to 3 shows that as the pH increases, the adsorption of metal ions increases. Hydrogen ions compete with metal ions at low pH to occupy active sites on the adsorbent surface, so adsorption efficiencies are very low. As these results show, for all the studied pounds, the best pH for adsorption of metal ions is about 3-5, and with increasing the concentration of metal ions, the amount

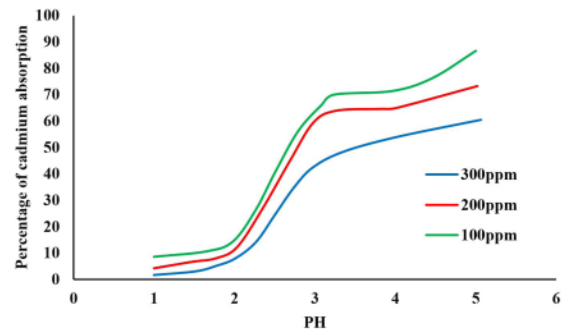

Figure 1. Effect of pH on the absorption of cadmium.

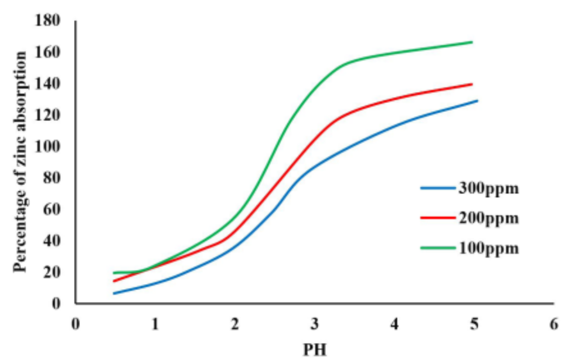

Figure 2. Effect of pH on the absorption of zinc.

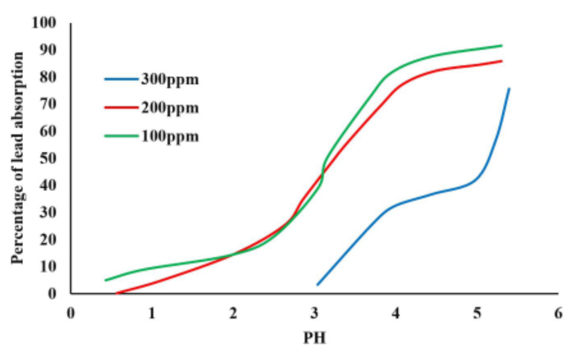

Figure 3. Effect of pH on the absorption of lead.

of adsorption decreases. According to the Figures, zinc has a higher adsorption rate than other ions. The effect of pH on the absorption of cadmium, zinc, and lead by soybean oil residues has been investigated, and test conditions are stirring speed 1000 rpm, adsorbent value 0.6 g, stirring time 40 min, solution volume 60 mL, and test temperature 25 °C.

3.2 The effect of the contact time of the heavy metal solution with the adsorbent

Increasing the contact time of the adsorbent with the solution increases the amount of adsorption due to the possibility of more contact of the adsorbent material with the adsorbent. To study the effect of contact time on the amount of adsorption, adsorption tests were performed in the presence of a certain amount of adsorbent at different times, and other effective factors were kept constant.

The effect of time on the absorption of cadmium, zinc, and lead by soybean oil residues has been investigated. Test conditions are stirring speed 1000 rpm, pH of 5, solution volume 60 mL, adsorbent amount 2 g, and test temperature 25 °C.

The results of the experiments showed that the amount of adsorption increased with increasing contact time. Then, after a certain period of time, it reached equilibrium. The equilibrium time for cadmium ions is 40 minutes, for zinc ions is 20 minutes, and for lead, the ion is 10 minutes, after which time the amount of adsorption does not increase significantly (Figures 4 to 6).

3.3 The effect of the amount of adsorbent and concentration of heavy metals

According to the results, as the amount of adsorbent increases, more surface area of the active adsorbent sites is available, and the adsorption efficiency increases. Figures 7 to 9 show that the percentage of adsorption decreases with the increasing concentration of metal ions. The amount of adsorption increases with increasing the amount of adsorbent at a constant concentration. According to the results of this section, lead has the least impact.

The effect of the initial concentration of cadmium, zinc, and lead on their absorption by soybean oil residues has been

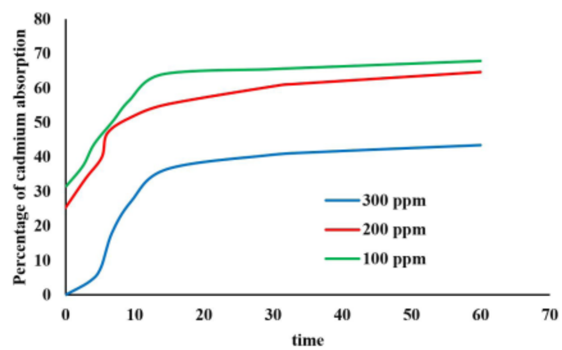

Figure 4. Effect of time on the absorption of cadmium.

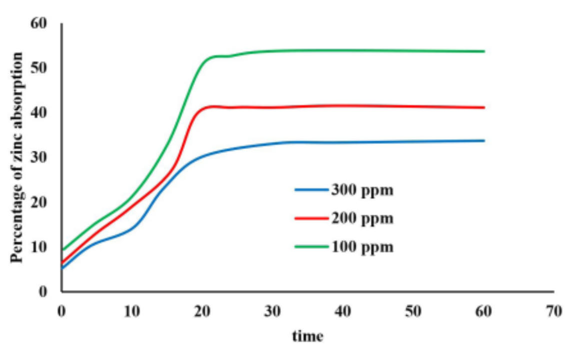

Figure 5. Effect of time on the absorption of zinc.

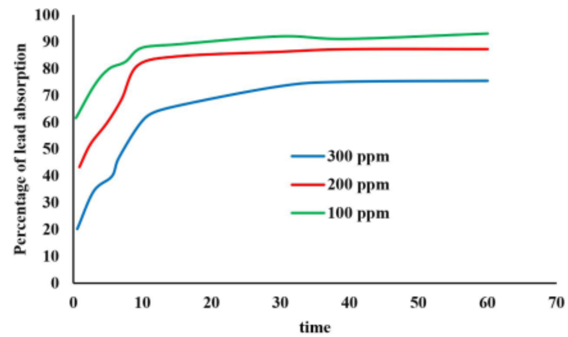

Figure 6. Effect of time on the absorption of lead.

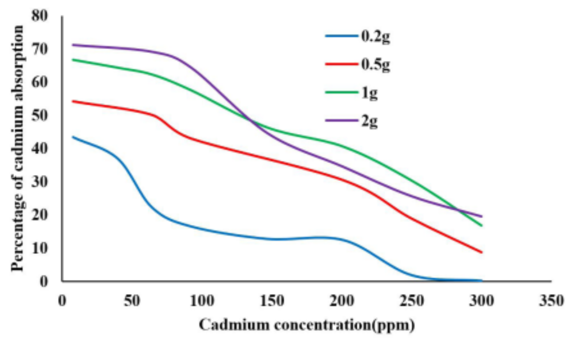

Figure 7. Effect of initial concentration of cadmium.

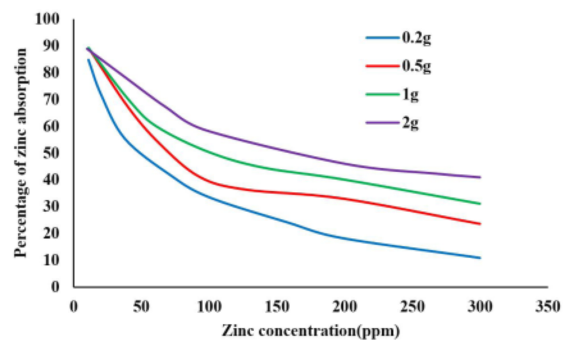

Figure 8. Effect of initial concentration of zinc.

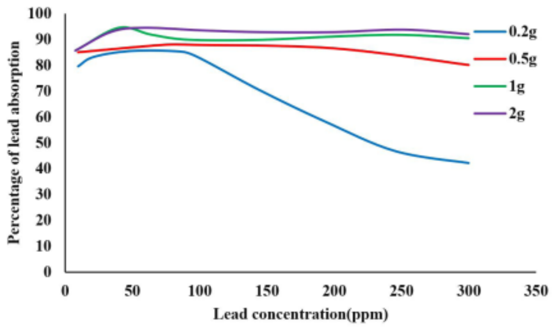

Figure 9. Effect of initial concentration of lead.

investigated. Test conditions are stirring speed 1000 rpm, time 40 minutes, pH of 5, solution volume 55 mL, and test temperature 25 °C.

4 Conclusion

The results of experiments proved that biosorbents have a high ability to remove heavy metals from contaminated water. Also, these results showed that changes in the concentration of hydronium ions are a very important factor in adsorption capacity. It is the surface between metal ions and hydrogen ions. As the pH increases, the adsorption of metal ions increases. For all studied pounds, the best pH for absorption of metal ions is about 3-5 may, and with increasing the concentration of metal ions, the amount of absorption decreases. Increasing the contact time of the adsorbent with the solution increases the amount of absorption due to the possibility of more contact of the adsorbent material with the adsorbent. To study the effect of contact time on the amount of adsorption, adsorption tests were performed in the presence of a certain amount of adsorbent at different times, and other effective factors were kept constant. The results of these experiments showed that the amount of adsorption increased with increasing contact time. Then, after a certain period of time, they reach equilibrium; also, with increasing the concentration of metal ions, it decreases, and with increasing the amount of adsorbent at a constant concentration, the amount of absorption increases.

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References

Abbas, M. (2020). Experimental investigation of activated carbon prepared from apricot stones material (ASM) adsorbent for removal of malachite green (MG) from aqueous solution. *Adsorption Science and Technology*, 38(1-2), 24-45. http://dx.doi.org/10.1177/0263617420904476.

Azimi, A., Azari, A., Rezakazemi, M., &Ansarpour, M. (2017). Removal of heavy metals from industrial wastewaters: a review. *ChemBioEng Reviews*, 4(1), 37-59. http://dx.doi.org/10.1002/cben.201600010.

Bitonto, L., Reynel-Avila, H. E., Mendoza-Castillo, D. I., Pastore, C., &Bonilla-Petriciolet, A. (2019). Mexican biomass wastes: valorization for potential application in bioenergy. *Bulgarian Chemical Communications*, 51, 99-102.

Fan, X., Ming, W., Zeng, H., Zhang, Z., &Lu, H. (2019). Deep learning-based component identification for the Raman spectra of mixtures. *Analyst*, 144(5), 1789-1798. http://dx.doi.org/10.1039/C8AN02212G. PMid:30672931.

Fomina, M., &Gadd, G. M. (2014). Biosorption: current perspectives on concept, definition and application. *Bioresource Technology*, 160, 3-14. http://dx.doi.org/10.1016/j.biortech.2013.12.102. PMid:24468322.

Gunatilake, S. K. (2015). Methods of removing heavy metals from industrial wastewater. *Journal of Multidisciplinary Engineering Science Studies*, 1(1), 12-18.

Guo, X., Tang, S., Song, Y., &Nan, J. (2018). Adsorptive removal of Ni2+ and Cd2+ from wastewater using a green longan hull adsorbent. *Adsorption Science and Technology*, 36(1-2), 762-773. http://dx.doi.org/10.1177/0263617417722254.

Hamid, A., Wasim, A., Azfar, A., Amjad, R., &Nazir, R. (2020). Monitoring and health risk assessment of selected trace metals in wheat rice and soil samples. *Food Science and Technology*, 40(4), 917-923. http://dx.doi.org/10.1590/fst.23319.

Hamid, A., Yaqub, G., Ayub, M., &Naeem, M. (2021). Determination of malathion, chlorpyrifos, λ-cyhalothrin and arsenic in rice. *Food Science and Technology*, 41(2), 461-466. http://dx.doi.org/10.1590/fst.01020.

Herrera-Barros, A., Tejada-Tovar, C., &Gonzalez-Delgado, A. D. (2021). Comparative assessment of Al_2O_3 modified biomasses from agricultural residues for nickel and cadmium removal. *Journal of Water and Land Development*, 49, 29-34.

Jan, A. T., Azam, M., Siddiqui, K., Ali, A., Choi, I., &Haq, Q. M. (2015). Heavy metals and human health: mechanistic insight into toxicity and counter defense system of antioxidants. *International Journal of Molecular Sciences*, 16(12), 29592-29630. http://dx.doi.org/10.3390/ijms161226183. PMid:26690422.

Marczewski, A. W., Seczkowska, M., Deryło-Marczewska, A., &Blachnio, M. (2016). Adsorption equilibrium and kinetics of selected phenoxyacid pesticides on activated carbon: effect of temperature. *Adsorption*, 22(4-6), 777-790. http://dx.doi.org/10.1007/s10450-016-9774-0.

Matta, G., &Gjyli, L. (2016). Mercury, lead and arsenic: Impact on environment and human health. *Journal of Chemical and Pharmaceutical Sciences*, 9(2), 718-725.

Odobašić, A., Ahmetović, M., Šestan, I., &Kovačević, L. (2020). Removal of Cd and Ni Ions from water using biosorbent based on corn residues. *International Journal for Research in Applied Sciences and Biotechnology*, 7(6), 12-18. http://dx.doi.org/10.31033/ijrasb.7.6.3.

Onac, C., Topal, T., &Akdogan, A. (2021). Investigation of the nutritional environment of the differences in toxicity levels of some heavy metals and pesticides examined in gilthead bream fishes. *Food Science and Technology*. In press. http://dx.doi.org/10.1590/fst.27921.

Rahel, C., &Bhatnagar, M. (2017). Adsorption of heavy metals and phenol from aqueous solution onto fly ash as low cost adsorbent: a review. *International Journal of Innovative Research in Science, Engineering and Technology*, 6(2), 2479-2497.

Rangabhashiyam, S., &Balasubramanian, P. (2019). The potential of lignocellulosic biomass precursors for biochar production: performance, mechanism and wastewater application: a review. *Industrial Crops and Products*, 128, 405-423. http://dx.doi.org/10.1016/j.indcrop.2018.11.041.

Seğmenoğlu, M. S., &Baydan, E. (2021). Comparison of heavy metal levels of organic and conventional milk and milk products in Turkey. *Food Science and Technology*, 9(4), 696-700.

Seyyedi, M., &Ayati, B. (2021). Treatment of petroleum wastewater using a sequential hybrid system of electro-Fenton and NZVI slurry reactors, future prospects for an emerging wastewater treatment technology. *International Journal of Environment and Waste Management*, 28(3), 328-348. http://dx.doi.org/10.1504/IJEWM.2021.118369.

Sheng, J., Zuo, J., Liu, K., Ma, L., Li, C., Li, Y., &Kong, D. (2021). Highly selective enrichment of aflatoxin B1 from edible oil using polydopamine-modified magnetic nanomaterials.*Food Science and Technology*, 41(2), 321-327. http://dx.doi.org/10.1590/fst.34619.

Singh Sankhla, M., Kumari, M., Nandan, M., &Kumar, R. (2016). Heavy metal contamination in soil and their toxic effect on human health: a review study.*International Journal of All Research Education and Scientific Methods*, 4(10), 13-19.

Tadesse, M., Tsegaye, D., &Girma, G. (2018). Assessment of the level of some physico-chemical parameters and heavy metals of Rebu River in oromia region, Ethiopia.*MOJ Biology and Medicine*, 3(3), 99-118. http://dx.doi.org/10.15406/mojbm.2018.03.00085.

Wang, Z., Yang, X., Qin, T., Liang, G., Li, Y., &Xie, X. (2019). Efficient removal of oxytetracycline from aqueous solution by a novel magnetic clay-biochar composite using natural attapulgite and cauliflower leaves.*Environmental Science and Pollution Research International*, 26(8), 7463-7475. http://dx.doi.org/10.1007/s11356-019-04172-8. PMid:30656586.

Xu, A. R., Chen, L., Guo, X., Xiao, Z., &Liu, R. (2018). Biodegradable lignocellulosic porous materials: fabrication, characterization and its application in water processing.*International Journal of Biological Macromolecules*, 115, 846-852. http://dx.doi.org/10.1016/j.ijbiomac.2018.04.133. PMid:29704601.

Youssef, M., Hagag, A., &Ali, A. H. (2018). Synthesis, characterization and application of composite derived from rice husk ash with aluminium oxide for sorption of uranium.*Adsorption Science and Technology*, 36(5-6), 1274-1293. http://dx.doi.org/10.1177/0263617418768920.

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