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REMOVAL OF LEAD(II) AND ZINC(II) FROM AQUEOUS SOLUTIONS APPLYING FIBBER HEMP (*Cannabis sativa* L.)

Abstract: Lead and zinc are heavy metals with toxic properties. These chemical elements are found in wastewater. The article deals with the removal of lead(II) and zinc(II) ions from polluted water using adsorption. As object of researches was selected natural polymer - fibber hemp (*Cannabis sativa* L.). Big quantities of fibber hemp are produced as waste in textile, agricultural industry, and therefore their usage could help to solve two problems - reducing quantity of fibber hemp as waste and reducing of water pollution by heavy metals. Pb(II) and Zn(II) ions adsorption with fibber hemp was investigated for contact time, pH, and heavy metal ions concentration impact. Pb(II) and Zn(II) ions biosorption rate was highest within the first hour, with optimal their biosorption recorded at pH = 5.0. Highest lead and zinc ions removal efficiency was recorded after 240-480 min and reached 60.5 and 61.7 % respectively. This study demonstrated the applicability and effectiveness of fibber hemp in lead and zinc ions removal, which could be applied for the sewage treatment plant in small scale.

Keywords: fibber hemp, adsorption, zinc, lead, heavy metals

Introduction

Heavy metals are one of the most harmful types of pollution. They are one of the dangerous pollutants in soil, marine and even purified industrial wastewater. Heavy metals are non-biodegradable and can easily penetrate into various ecosystems due to their water solubility [1]. Wastewater of modern industries, chemistry, electroplating (including battery production), fertilisers, mining, paper, pesticides, metallurgy, fossil fuels, leather processing and rapid increasing of production, especially in developing countries strongly affect the release of heavy metals [2]. Heavy metals in Lithuania enter industrial wastewater in electroplating, textile, plastics processing, organic paint production and non-ferrous metals industries. In industrial wastewater the highest amounts of heavy metals includes lead, zinc and etc. The cost of maintaining existing industrial wastewater treatment plants is high, and so far there has been a strong focus on the implementing of innovative technologies that are low in cost, low maintenance and energy in comparison with existing technologies [3]. Although chemical precipitation, coagulation, ion exchange, filtration, membrane and other methods have been applied in this purpose, most techniques have some limitations such as requirement of several pre-treatments, some of them are less effective or require high capital costs. Therefore many scientists have applied natural wastes to remove heavy metals from aqueous solutions [4-6]. At present, adsorption is one of the economically advantageous methods of wastewater treatment. Adsorption is reversible and

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adsorbents can be regenerated by suitable desorption techniques [7]. Adsorption has wide pH range, high metal binding capacities, and easy operating conditions addition to its low-cost. However, the adsorption efficiency depends on the adsorbent materials [8]. For the adsorption of heavy metals from contaminated water, cheap natural adsorbents such as zeolites, opoca, peat and others can be applied. Natural organic adsorbents are commonly used to remove heavy metals and organic pollutants from surface water. They have good adsorption properties and abundant natural resources, but some of them used once must be disposed [9]. Currently, adsorbents from industrial and agricultural wastes have been the focus of attention: crab shells, activated sludge, rice straw, peanut shells, papaya trunk, rice husks, nymphs, goose-foot leaves, egg shells, swamp mosses, cumin, flax [10]. Agricultural by-products may be heavy metal adsorbents that may be specifically oriented for some metal ions [11]. A lot of lead and zinc ions removal techniques are used in the world, the most common one being the adsorption process, but there is a lack of research of the uses of adsorbents that are easy to obtain and cheap, such as fiber of hemp. As object of researches was selected natural polymer - fiber hemp (*Cannabis sativa* L.). Big quantities of fiber hemp are produced as waste in textile, agricultural industry, and therefore their usage could help to solve two problems - reducing quantity of fiber hemp as waste and reducing of water pollution by heavy metals. Cannabis belongs to the genus Cannabis in the family Cannabaceae and may include three species, *Cannabis sativa*, *Cannabis indica*, and *Cannabis ruderalis*. According to the data of European Industrial Hemp Association (EIHA), around 42 500 hectares of hemp was grown in the European Union in 2017, and compared to 2016, the area increased by about 30 % (compared to 33 300 ha in 2016). According to the data of the Agricultural Information and Rural Business Center, the area declared for fiber hemp in Lithuania in 2014 was 1062.89 ha, in 2015 - 2348.12 ha, in 2016 - 2453.84 ha, in 2017 - 2479.39 ha. In 2018, JSC Naturalus pluostas was established in Lithuania, which hemp stems processed into fibers suitable for the textile, paper, construction industry, and the remaining materials - spikes and fine particles - were used in agriculture and industry, as well as in fuel production. Hemp fiber raw material is supplied to Lithuanian and foreign markets [12].

Cellulose in fiber hemp (*Cannabis sativa* L.) can be chemically activated and adapted for heavy metal ion adsorption, but the use of this adsorbent for the removal of heavy metal ions from aqueous solutions has not been studied widely. In this study was investigated the application of the fiber hemp for heavy metals adsorption. The purpose of this article is to investigate the dependence efficiency of the removal of lead(II) and zinc(II) ions from polluted water on contact time, heavy metal concentration and solution pH using fiber hemp as adsorbent.

Materials and methods

Preparation of adsorbent. The low-cost fiber hemp was used as an adsorbent. Fiber hemp was washed 3 times with deionised water (Demiwa 3 roi system). The washed biosorbent was dried at room temperature (21 °C) for 72 hours. The dried mass of adsorbent was crushed in a porcelain mortar to a homogeneous mass and spread through a 0.2 mm sieve with vibratory sieve shaker Retsch AS 200 [13]. Fraction with fiber hemp diameter < 200 µm was selected for experimental research. The prepared adsorbents were stored in plastic containers at constant temperature (21 °C) to minimise the influence of moisture [13]. Surface images of fiber hemp were obtained by microscopy.

Effect of heavy metal concentrations on removal of heavy metals. AAS standard solutions of lead and zinc (ROTI® STAR) were used as the source of Zn(II) and Pb(II) ions in the polluted water. The aqueous solutions containing cations of Zn^{2+} (3.0; 6.0; 15.0; 30.0; 60.0 mg/L) and Pb^{2+} (0.5; 1.0; 2.5; 5.0; 10.0 mg/L) were used in experimental adsorption studies. The concentrations of both selected heavy metals were chosen as follows: 1·MAC, 2·MAC, 5·MAC, 10·MAC, 20·MAC. The maximum allowable concentration (MAC) of lead and zinc ions in wastewater which is allowed to discharge to wastewater collection system is 0.5 and 3.0 mg/L, respectively [14]. These heavy metal solutions were prepared by diluting the standard metal solution (1000 ± 2 mg/L, 2 % HNO_3) to the 0.1 L with deionised water.

Effect of adsorption time on removal of heavy metals. The adsorption time is assessed by analysing the static heavy metals adsorption from the aqueous solution. The aim of these experiments was to determine the time when the equilibrium of adsorption is achieved. The following durations (5, 15, 30, 60, 240 and 480 min) were selected for adsorption research. The experiments of static heavy metals adsorption from aqueous solution were performed by mixing an adsorbent with the heavy metal solution on a 1:100 ratio (1 g of adsorbent and 0.1 L of aqueous solution) using capped bottles (0.2 L). The suspensions were shaken at 20 rpm for mentioned contact time, at 21 °C applying Rotashake RS12. The samples were filtered (using glass filter with 0.45 µm pores) and heavy metal concentrations were measured in solutions by AAS method [15].

Effect of pH on removal of heavy metals. The analysis of adsorption efficiency of lead(II) and zinc(II) ions in different media had been performed. Adsorption efficiency was tested at pH 2, 3, 4, 5 and 6. pH was adjusted with 0.01 N (HNO_3) and 0.01 N (NaOH) solutions. pH was measured with mettler toledo seven Multi pH meter. In order to avoid the formation of any hydroxide precipitation of Pb(II) to obstruct the adsorption process, the initial solution pH should be in the range of 2.0-6.0 [6].

Measurement of heavy metals concentration. The concentration of Zn(II) and Pb(II) ions was assessed by analysing the static heavy metals adsorption from the aqueous solution. The concentrations of lead(II) and zinc(II) ions were determined by using atomic absorption spectrometry (AAS; model Buck Scientific 210 VGP, USA) operated with graphite furnace, a slit of 0.7 mm at 283.2 and 213.9 nm wavelength, respectively. GFAAS samples are placed in a small graphite tube, which can then be heated to evaporate and decompose the analyte [16, 17]. A chemical modifier ($\text{NH}_4\text{H}_2\text{PO}_4$) was used for possible alleviation of matrix interferences, which are normally severe during graphite furnace analysis for heavy metals.

Evaluation of adsorption efficiency and adsorption capacity. The adsorption efficiency was calculated evaluating initial concentration of metal and its concentration after adsorption. The adsorption capacity, Q , of adsorbent was calculated by using the following equation [18, 19]:

$$Q = \frac{(C_i - C_f) \cdot V}{m} \left[\frac{\text{mg}}{\text{g}} \right] \quad (1)$$

where C_i - the concentration of metal ion before adsorption [mg/L]; C_f - the concentration of metal ion after adsorption at the equilibrium state [mg/L]; V - the volume of solution [L]; m - the adsorbent mass [g].

Quality control. All chemicals and reagents were of analytical grade or higher purity and were used in the experiments as received without further purification. The solutions

were prepared by mixing standards in deionised water from the water purification system - Demiwa 3 roi (Watek, Czech Republic). Deionised water used in experiments meets the requirements of ISO standard [20]. All volumetric flasks used in the experiments were soaked for 24 h in 5M HNO₃ and then rinsed 3-4 times carefully with deionised water. All the volumetric flasks were only the highest accuracy class. High accuracy analytical balance AS 60/220.R2 (Radwag, Poland) was used for weighting. The blank solution was used for calibration. Calibration curves for heavy metal analysis using AAS were created from 5 different concentration solutions of metals. All experiments were conducted in triplicate and the mean of the three was calculated.

Statistical analysis. Statistical analysis of data was carried out. Mean, standard deviation, confidence intervals were calculated. A single factor (one-way) ANOVA was used to test the null hypothesis that the means of adsorption efficiency are equal using as criteria *p* value. Excel 2016 software was used for Statistical parameters were estimated at *p* < 0.05.

Analysis methods. The following standards were used in experiments:

- Determination of lead and zinc concentration in water was carried out according to ISO 15586:2003. Water quality - Determination of trace elements using atomic absorption spectrometry with graphite furnace [21].
- Water pH was determined according to ISO 10523:2008. Water quality - Determination of pH [22].

According to "Council Directive 98/83/EC of 3 November 1998 on the quality of water intended for human consumption" [23] the result is acceptable, when trueness and precision of method is less than 10 %. Trueness is a measure of systematic error, i.e. the difference between the mean value of the large number (10 measurements) of repeated measurements and the true value. Precision is a measure of random error and is usually expressed as the standard deviation (within and between batches) of the spread of results from the mean. Acceptable precision is twice the relative standard deviation. Trueness and precision of method was tested and results for Zn (6 mg/L) and Pb (5 mg/L) are presented.

Table 1

Trueness and precision of method

Parameter	Trueness	Precision
Pb		
Average value [mg/L]	4.9	5.1
Assigned value [mg/L]	5.0	5.0
Standard deviation [mg/L]	0.15	0.14
Relative standard deviation [%]	3.0	2.8
Acceptable trueness [%]	6.0	5.6
Zn		
Average value [mg/L]	6.1	5.85
Assigned value [mg/L]	6.0	6.0
Standard deviation [mg/L]	0.16	0.14
Relative standard deviation [%]	2.7	2.3
Acceptable trueness [%]	5.4	4.6

The obtained result of the analysis is the arithmetical average of concentrations of three samples, when distribution does not exceed 6 %, if higher tested were repeated. 95 % confidence interval was calculated.

Results and discussion

Hemp fiber consists of cellulose (55-72 %), hemicellulose (7-19 %), lignin (2-5 %), pectin (up to 1 %), fats and waxes (0.7-1.3 %), dust (up to 4 %) [24]. The cellulose, hemicellulose and lignin content in plant fibres vary depending on the plant species, origin, quality and conditioning [25]. Adsorption occurs on the surface and pores of the adsorbent, therefore it is important to evaluate the surface of hemp fiber. Images of the fiber hemp with microscope is presented in Figure 1.

Fig. 1. Images of the fiber hemp with microscope: a) hemp fiber particle (magnification $\times 100$); b) hemp fiber particle (magnification $\times 300$); c) a wall separating the pores using MOTIC K-400 L digital microscope with a video camera Pixera VSC

The hemp fiber particle cut (Fig. 1a and b) shows that the porous structure of hemp fiber is determined by two types of voids, large and smaller. The part of larger voids are smaller than the smaller voids and occupy a smaller volume of particle. The shape of the large cells was found to be close to an ellipse with a shorter diagonal of $\sim 50 \mu\text{m}$ and an elongated $\sim 70 \mu\text{m}$. Smaller voids exhibit irregular shape comparing to large voids: rectangular, square, and irregularly shaped eyes with an average diameter of $\sim 15 \mu\text{m}$. The voids are separated by a thin film that forms pores. The walls of the large pores are porous (Fig. 1c).

The effective parameter on heavy metals ions adsorption is size of adsorbent. Pollutant uptake during adsorption process is a function of surface of adsorbent. The fraction of fiber hemp with diameter $< 200 \mu\text{m}$ was selected for researches. The adsorption takes place at the surface of the adsorbent and the functional groups are responsible for the adsorption of heavy metal ions on the selected biosorbent. Functional groups of the adsorbent, such as hydroxyl, carboxyl, carbonyl, phenol, etc., play an important role in adsorption processes [26]. Cellulose has many hydroxyl groups which can be involved in various chemical reactions as it can form an insoluble, stationary phase. The chemical composition of fiber hemp depends on the type of plant and its growth conditions [27].

The biosorption of heavy metal ions (Pb^{2+} , Cd^{2+} and Zn^{2+}) from aqueous solution by lignocellulosic material (chemically modified hemp fibers) was investigated by scientists. Obtained results show that the biosorption process is very fast at the beginning and mainly

determined by diffusion of the ions through the porous fiber structure. However, over a period of time the biosorption slows down due to the increase of the resistance to the further transport of metal ions through the fibers (i.e. the electrostatic repulsive interactions between ions into the fibers increase with the increase of the ion concentration in the fibers) [28].

Fig. 2. Dependence of heavy metal removal efficiency on contact time, when concentration of lead(II) is 0.5 mg/L, zinc(II) concentration is 3.0 mg/L: a) pH = 2.0; b) pH = 3.0; c) pH = 4.0, d) pH = 5.0; e) pH = 6.0

Effect of contact time. In order to define the kinetics of the zinc(II) and lead(II) ions adsorption, the parameters for the adsorption process were studied for contact time ranging between 5 and 240 min, by monitoring the percent removal of zinc and lead ions by

bioadsorbent. The efficiency of metals adsorption was calculated. The adsorption conditions were given in the figure legends. Figure 2 depicts the effect of contact time on the adsorption of Zn(II) and Pb(II) ions onto fiber hemp, when pH is constant, adsorbent solution ratio 1 : 100 (w : v), temperature 21 °C.

Fig. 3. Dependence of heavy metal removal efficiency on solution pH when: a) concentration of lead(II) is 0.5 mg/L and zinc(II) concentration is 3.0 mg/L; b) concentration of lead(II) is 1.0 mg/L and zinc(II) concentration is 6.0 mg/L; c) concentration of lead(II) is 2.5 mg/L and zinc(II) concentration is 15.0 mg/L; d) concentration of lead(II) is 5.0 mg/L and zinc(II) concentration is 30.0 mg/L; e) concentration of lead(II) is 10.0 mg/L and zinc(II) concentration is 60.0 mg/L

The plots could be split to three distinct regions:

- 0-30 min, which indicates the instantaneous adsorption of heavy metal ions, suggesting rapid external diffusion and surface adsorption;
- 30-60 min, shows a gradual equilibrium;
- 60-240 min, indicates the equilibrium state.

The adsorption equilibrium time depends on heavy metal concentration and adsorbent dose. It can be seen that the adsorbed amount of Pb(II) and Zn(II) ions increases with contact time up to 60 min, after that a maximum removal is attained. 240 min was selected as the optimum contact time for further experiments.

After comparison of the obtained results with those of other scientists [9] who studied flax as an adsorbent for the removal of zinc(II) ions from aqueous solutions, it can be shown that cellulose-containing adsorbents adsorb best, when the contact time is at least 60 min.

Figure 3 depicts the effect of solution pH on the adsorption of Zn(II) and Pb(II) onto fiber hemp, when contact time is 480 min, adsorbent : solution ratio 1 : 100 (w : v), temperature 21 °C.

Effect of pH and heavy metal concentration

Adsorption studies of Pb(II) and Zn(II) ions removal from aqueous solutions showed that at strong acidic solution ($\text{pH} = 2$), the adsorption efficiency reached from 9.3 to 20.3 % and from 9.4 to 19.4 % accordingly, when Pb(II) concentration was 0.5-10.0 mg/L and Zn(II) ion concentration was 3.0-60.0 mg/L. When pH was 3.0 the adsorption efficiency reached from 11.4 to 23.6 % and from 12.9 to 29.5 % accordingly, when Pb(II) concentration was 0.5-10 mg/L and Zn(II) ion concentration was 3.0-60 mg/L. When pH was 4, the adsorption efficiency reached from 18.3 to 34.4 % and from 20.5 to 35.7 % accordingly, when Pb(II) concentration was 0.5-10 mg/L and Zn(II) ion concentration was 3.0-60 mg/L. Maximum adsorption efficiency was achieved at pH 5.0, and reached from 43.1 to 60.5 % and from 45.2 to 61.7 % accordingly, when Pb(II) concentration was 0.5-10 mg/L and Zn(II) ion concentration was 3.0-60 mg/L. When pH was 6 the adsorption efficiency reached from 42.7 to 57.1 % and from 44.5 to 57.6 % accordingly, when Pb(II) concentration was 0.5-10 mg/L and Zn(II) ion concentration was 3.0-60 mg/L.

The highest fiber hemp adsorption capacity for Pb(II) was 0.53 mg/g and for Zn(II) 3.31 mg/g at pH 5.0 and contact time of 240-480 min. Maximum sorption for lead ion was found also at pH 5, studying adsorption on bamboo activated carbon [29].

Researchers carried out a study on the use of flax as an adsorbent in acidic solutions for removal of heavy metals from aqueous solutions (Cd, Zn, Pb). In an experimental study at pH 5.0 and lead(II) concentration of 10 mg/L, the flax adsorption capacity was 0.189 mg/g. The adsorption capacity in this experiment for lead(II) ions was similar and reached 0.194 mg/g when contact time was 480 min. Maximum adsorption capacity of adsorbent depends on initial concentration of metal and adsorbent dosage.

The adsorption of metal ions was very small for pH 2.0 according to research data. The results showed that pH is an important parameter affecting the adsorption of heavy metals. The amount of zinc and lead ions adsorbed by fiber hemp increases with the increasing in pH from 2.0 to 5.0.

Adsorption mechanism of fiber hemp could be explained. In the case of cations (as zinc or lead). The fiber hemp primarily contain weak acidic and basic functional

groups. It follows from the theory of acid-base equilibria that at $2.0 < \text{pH} < 7.0$ the binding of heavy metals cations is determined primarily by the state of dissociation of the weak acidic groups. Carboxyl groups ($-\text{COOH}$) are the important (but not the unique) groups for metal uptake by these materials. When pH is below 3.5 most of carboxylate groups are less reactive groups for the binding of metal ions, while above pH 3.5 the carboxylate groups are more favourable for metal ions binding [6]. The minimal adsorption at low pH may be due to the higher concentration and high mobility of H^+ , which are preferentially adsorbed rather than metal ions. Increasing the pH of the solution, the lower number of H^+ (with higher negative surface charge) results in more heavy metal adsorption. Nevertheless, at higher pH values determination of metal sorbed is overvalued because of metal precipitation [27]. This pH value depends on heavy metal concentration in solution. It can be seen that the adsorption percentages are very low at strong acidic medium for the fibber hemp.

The optimum pH was 5.0 for adsorption of Zn(II) and Pb(II) ions. The pH of the aqueous medium not only affects the solubility of the metal ions but also the ionic form in which it will be present in the solution and the type and ionic state of the functional groups at the biosorbent surface. The choice of pH range (2.0-6.0) evaluated in the present study was based on the fact that since approximately 5.5 pH precipitation of Pb ions starts in aqueous solution [19, 28]. Therefore, it is assumed that adsorption involves a direct contact of metal ions onto the surface of fibber hemp and thus proceeds up to monolayer coverage. In all cases, the adsorption capacity of Zn(II) ions onto fibber hemp was higher comparing to Pb(II) despite the fact that its concentration was 6 times higher in solution. Aqueous phase pH governs the speciation of metals and also the dissociation of active functional sites on the sorbent. It has been identified as the most important variable affecting metal adsorption onto adsorbent, this partly because hydrogen ions themselves are strongly competing with adsorbate. The adsorption efficiency depends on the pH of the solution containing lead(II) and zinc(II) ions. The pH can effect on the ionization state of the adsorbent functional groups.

Studies have shown (Figs. 2 and 3) that adsorption process efficiency of zinc and lead ions onto fibber hemp depends not only on contact time and concentration, but also on the pH of the solution. The remarkable results obtained in this study prompt to use the fibber hemp waste as an adsorbent for the treatment of wastewater polluted with heavy metals.

The efficiency of the adsorption process depends on the properties of metal ions, such as different molecular weights, shapes, size or polarities [30].

The adsorption capacity of the bioadsorbent increased significantly with the growth of initial concentration even though there is decrease in the adsorption efficiency. The increase of adsorption capacity can be due to growth of concentration gradient, which causes an increase in the number of metal ions coming in contact with the adsorbent. On the other hand, the number of existing adsorption sites in the adsorbent is the same for all initial concentrations. Therefore, as the initial concentration increases, more ions has to compete for the same adsorption site. This may cause many metal ions to be left without being adsorbed, thus decreasing the efficiency of the removal upon increasing the concentration of metal ions [31].

Comparison of the adsorption study results with the allowable concentrations of the selected heavy metals according to the Wastewater Testing Regulation showed that hemp fibber achieves allowable concentrations at Zn(II) concentration of 3.0 mg/L and Pb(II) concentration of 0.5 mg/L. A single factor (one-way) ANOVA was used to test the null

hypothesis that the means of adsorption efficiency for selected heavy metal (Zn and Pb) are equal using as criteria p value. Results of calculation are presented in Table 2.

Table 2

 p value

Parameter	Pb	Zn
Contact time, pH from 2 till 6		
5 min	$3.13 \cdot 10^{-5}$	$7.53 \cdot 10^{-6}$
15 min	$3.87 \cdot 10^{-6}$	$1.26 \cdot 10^{-5}$
30 min	$3.25 \cdot 10^{-6}$	$6.2 \cdot 10^{-7}$
60 min	$2.43 \cdot 10^{-7}$	$1.02 \cdot 10^{-5}$
240 min	$2.62 \cdot 10^{-7}$	$1.2 \cdot 10^{-6}$
pH, concentration of metal from 1 MAC till 20 MAC		
pH = 2	$1.29 \cdot 10^{-5}$	$4.65 \cdot 10^{-5}$
pH = 3	$2.07 \cdot 10^{-5}$	$4.8 \cdot 10^{-6}$
pH = 4	0.000147	$6.59 \cdot 10^{-6}$
pH = 5	0.000163	0.000191
pH = 6	0.005218	0.001224

Because the all p -values presented in Table 2 are lower than the significance level of 0.05, the null hypothesis was rejected and concluded that all presented in Figures 2 and 3 values of adsorption efficiency have different means.

This adsorbent can be used in industries with low concentrations of heavy metals in wastewater, such as textiles industry. Used in adsorption fibber hemp can be regenerated and used again; burned and according to heavy metal content in ash - heavy metals could be recovered, used as fertiliser (if it meets national requirements) or ash could be utilised as dangerous waste in accordance with the laws of the Republic of Lithuania on waste management.

Conclusion

1. Metal uptake increases with an increasing of contact time. When contact time increased from 5 to 480 min, adsorption efficiency of Zn(II) and Pb(II) increases from 10.9 to 45.2 % and from 9.5 to 43.1%, when solution pH was 5.0, concentration of Zn(II) ions was 3.0 and concentration of Pb(II) ions was 0.5 mg/L. The adsorption equilibrium of investigated heavy metals was achieved after 60-240 min.
2. Experimental studies have shown that pH of the solution has impact on adsorption process efficiency. Zinc(II) and lead(II) ions adsorption from aqueous solutions process is most effective when the solution is weakly acidic, i.e., pH = 5.0. The highest fibber hemp adsorption capacity for Pb(II) was 0.53 mg/g and for Zn(II) 3.31 mg/g at pH 5 and contact time of 240-480 min.
3. Comparison of the adsorption study results with the allowable concentrations of the selected heavy metals according to the Wastewater Testing Regulation showed that hemp fibber achieves allowable concentrations at Zn(II) concentration of 6.0 mg/L and Pb(II) concentration of 1.0 mg/L at pH of 5.0.
4. This study showed that fibber hemp can be used for lead(II) and zinc(II) ions removal from polluted water as eco-friendly potential biosorbent.
5. The regeneration of the selected biosorbent could be an object for further experimental studies.

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