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EXPERIMENTAL RESEARCH ON APPLICATION OF YEAST IN HEAVY METAL REMOVAL FROM POLLUTED WATER

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Abstract. Both surface and groundwater can be contaminated with a variety of chemicals, making it dangerous to use water for domestic usage. Water can be contaminated with heavy metals (HM), petroleum products, detergents, radioactive isotopes, mineral or organic fertilizers. Copper, cadmium and lead are some of the most commonly emitted heavy metals from various industries. Adsorption is considered to be one of the alternative methods of treatment of wastewater contaminated with heavy metals. The use of adsorbents of biological origin for the removal of heavy metals from wastewater is a promising method due to the low costs, rapid biodegradation and easy availability of adsorbents.

Keywords: Saccharomyces cerevisiae, adsorption capacity, heavy metals, adsorption efficiency, lead, copper, cadmium.

Introduction

Both surface and groundwater can be contaminated with a variety of chemicals, making it dangerous to use water for domestic usage. Pollutants can enter the water with precipitation, sewage, transport exhaust gasses, fertilizers, industrial dust and snowmelt water. Contamination of surface and groundwater with oil products or landfill leachate is also possible (Ojo et al., 2012).

Water can be contaminated with heavy metals (HM), petroleum products, detergents, radioactive isotopes, mineral or organic fertilizers (Pazand et al., 2018). Heavy metals can enter the environment through natural processes, such as volcanic eruptions or weathering of rocks (Motuza, 2013).

Toxic metals are largely distributed in the environment through industrial effluents, organic waste, waste incineration and transportation and energy production. Heavy metals can disperse far from sources, depending on whether they are in the form of gaseous compounds or solid particles. These pollutants are leached from the air to land or water surfaces (Mahurpawar, 2015).

Heavy metal ions are non–biodegradable, toxic, carcinogenic even at very low concentrations and therefore generally pose a serious threat to the environment and public health (Liu et al., 2008). Heavy metals tend to accumulate in the environment, so they are termed “perpetual pollutants” and fall into the class of important environmental pollutants.

Copper (Cu), cadmium (Cd) and lead (Pb) are some of the most commonly emitted heavy metals from various industries. Copper is found in several forms in the soil. In the soil solution as copper chloride, copper nitrate, copper sulfate and its concentration is low and depends on the immobilization of copper with organic compounds (Carvalho et al., 2015). Health problems are caused by oxidative stress caused by cadmium in the body’s cells. Long–term cadmium poisoning causes Fanconi syndrome (Martin & Griswold, 2009). Increased Pb content in soil can reduce soil productivity and very low Pb concentrations can inhibit some vital plant processes, like photosynthesis, mitosis, and water absorption (Jiwan & Ajay, 2011).

Heavy metals are characterized by carcinogenic, mutagenic and teratogenic effects, which manifest themselves not only in oncological diseases, but also in developmental disorders of the organism, weakened immunity and impaired reproductive functions (Jan et al., 2015). The negative effects of heavy metals are not only recorded in humans or animals, their toxic effects can also occur in plants.

Heavy metals tend to accumulate and migrate from one ecological niche to another. Heavy metal pollution is a major ecological problem worldwide, so eliminating it is particularly important (Bhat et al., 2019).

Adsorption is considered to be one of the alternative methods of treatment of wastewater contaminated with heavy metals. Adsorption has been shown to be a cheap and effective method to remove many heavy metals from water (Edet & Ifelebuegu, 2020).

The use of adsorbents of biological origin for the removal of heavy metals from wastewater is a promising method due to the low costs, rapid biodegradation and easy availability of adsorbents (Halnor, 2015). The application of yeast (*Saccharomyces cerevisiae*) as a removal agent of heavy metals from contaminated aqueous solutions has been little studied.

Yeast usually grows in an acidic environment with a pH of 5.0 to 6.0 and an optimal growth temperature of 25 to 30 °C (Qadir, 2019). This type yeast can withstand stressful conditions; they are characterized by high fermentation efficiency, rapid growth, efficient sugar consumption, the ability to produce and consume ethanol (Reis et al., 2013). Yeast *S. cerevisiae* is not difficult to grow in large quantities. They can be easily grown using simple fermentation methods and inexpensive growth medium (Can & Jianlong, 2010).

The performed experimental studies and the results of those studies will allow to determine whether yeast can be used for the removal of heavy metals from contaminated water. The efficiency of yeast sorption properties at different concentrations of heavy metals in solution will be determined using different yeast and heavy metal contact times, sorbent content and pH.

The aim of the study was to investigate the application of yeast (*Saccharomyces cerevisiae*) to the removal of heavy metals from contaminated water and the factors influencing it‘s efficiency.

Methodology

The natural biological material chosen for the preparation of the adsorbent was the yeast species *Saccharomyces cerevisiae* obtained from the Vilnius Nature Research Center.

During the research work, experiments were performed with artificially contaminated deionized water, in which the concentrations of metals (copper, lead and cadmium) ions exceeded the maximum permissible concentrations.

The aim of the experimental research was to determine the optimal conditions under which the highest efficiency of heavy metal ion removal from aqueous solutions using yeast is recorded. Experimental studies were performed at different pH values: pH 2, 3, 4, 5, 6, as some heavy metals, such as lead, settle in the sediment from about pH 6 (depending on its concentration in solution).

The dependence of the adsorption capacity on the contact time was also investigated: the biosorbent prepared from yeast was in contact with the contaminated aqueous solution for 5 min, 30 min, 1 h.

Test substances, mixtures and chemical reagents: heat–treated *Saccharomyces cerevisiae* yeast species, sodium hydroxide (NaOH), deionized water (meeting the quality requirements of LST EN ISO 3696), nitric acid (HNO_3), standard solutions of copper, cadmium and lead (1000 mg/l). 0.1 N NaOH and 0.1 N HNO_3 solutions were used to adjust the pH of copper / cadmium / lead aqueous solutions.

The initial concentration of heavy metals in the solution was an important parameter for the examination of adsorption process. Standard metal solutions and deionized water were used prepare solutions of different concentrations of the selected heavy metals in an Elenmeyer flask (100 ml).

Aqueous solutions of 2 different metal concentrations were prepared: 5 mg/l and 10 mg/l. Added 0.5 ml or 1.0 ml of the chosen metal standard solution to 100 ml flasks.

After adding the required amount of heavy metal, the rest of the solution (up to 80%) was prepared with deionised water. A 0.1 N solution of nitric acid or alkali is then carefully added using a digital pipette, mixed and measured until the required pH is reached.

The pH of the solution is determined using a pH-meter. Before starting the experimental tests, the instrument was calibrated using two buffer solutions with different pH values, pH 4.0 and 7.0. The pH of the solution was adjusted with 0.1 N HNO_3 and 0.1 N NaOH.

After preparation of aqueous solutions of appropriate heavy metals concentration, the required amount of yeast was added. 6 different amounts of yeasts were used for the studies: 0.1 g, 0.2 g, 0.5 g, 1.0 g, 2.0 g and 5.0 g (+/–0.01 g). Then, the selected amount of yeast was transfered to each volumetric flask. To make the yeast active, 0,1 g of sugar or agar was added to each sample. The first tests were performed using agar, but due to the more complex filtration process, this solution was later abandoned and sugar was used instead.

The prepared samples were then transferred to screw–on glass 100 ml volumetric flasks, which were thoroughly mixed. Sample mixing was performed at the selected contact time.

To avoid measurement errors, pre–filtration using "VWR Qualitative filter paper 413" filter paper was started before the end of the contact time, as the sorption process is not stopped during the filtration process. After the primary filtration, a secondary one was performed using a vacuum pump.

Filtered samples were then transferred to prepared (numbered) flasks. It is necessary to add 1.0% by volume of concentrated nitric acid to each container. This preserves the samples. Until measurements, the samples were kept refrigerated at 5 °C.

The residual concentration of metals in the solutions was determined by atomic adsorption spectral analysis using a Buck Scientific 210 VGP spectrometer with an air–acetylene flame and a graphite furnace.

Calibration curves, that are prepared for each heavy metal separately, were used to determine the concentrations of heavy metals. Solutions of the investigated heavy metals (copper, cadmium and lead) prepared from standard metal solutions (~1000 mg/l metal, 2% HNO_3) are used to form the data curves.

Results

Based on the data presented in Table 1, it can be concluded that with increasing pH values from 2 to 5, a significant increase in adsorption efficiency from 41.10% (at pH 2) to 95.91% (at pH 5) is observed. Meanwhile, when evaluating the adsorption efficiency values at pH 5 and pH 6, it was observed that at pH 6 the adsorption efficiency slightly decreased.

Table 1. Influence of aqueous solution pH on lead removal efficiency

Parameters	Initial pH level				
	2	3	4	5	6
Residual lead concentration, mg/l	2.94	1.74	0.21	0.21	0.26
Adsorption efficiency, %	41.10	65.30	95.83	95.91	94.93

Based on the results of the performed experimental studies and the data presented in scientific publications (Parvathi et al., 2007), it was decided to perform further studies only at one pH value i.e., 5.0.

The highest lead adsorption efficiency at 5.0 mg/l and 10.0 mg/l aqueous solutions was found using yeast amount of 5.0 g. However, at a lower concentration of the solution, a higher adsorption efficiency was recorded – 84.0% (Fig. 1). At a concentration of 10.0 mg/l of lead ions, an adsorption efficiency of 71.0% was recorded.

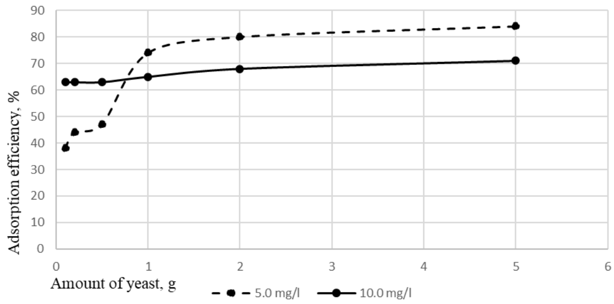

Figure 1. Graph of the dependence of lead adsorption efficiency on yeast content (5 min)

It should be noted that in solutions with a concentration of 10.0 mg/l of lead ions and at 0.1 g, 0.2 g and 0.5 g of yeast, the adsorption efficiency did not change, the same value of 63.0% was recorded in all samples.

On the other hand, the highest adsorption efficiency of copper was recorded in samples with 5.0 g. At 5.0 mg/l copper ion concentration, 24.0% adsorption efficiency value was recorded, and at 10.0 mg/l concentration, 50.0% adsorption efficiency was observed (Fig. 2). At yeast amount of 0.1 g to 0.5 g, a slight change in sorption capacity was observed in the samples. For instance, at 5.0 mg/l, the residual concentration of copper ions in the sample was 5.0 mg/l. Thus, sorption capacity was 0.0 mg/g – adsorption efficiency 0.0%. Moreover, sorption capacity of 0.35 mg/g and 0.16 mg/g was recorded at 0.2 g and 0.5 g of yeast amount.

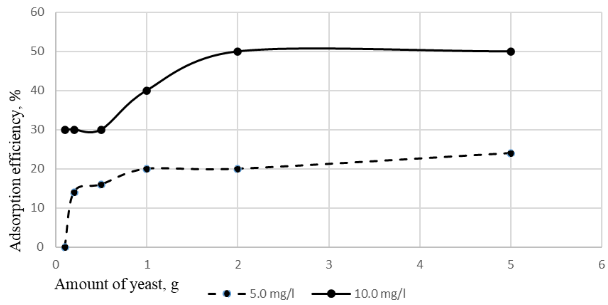

Figure 2. Graph of the dependence of copper adsorption efficiency on yeast content (5 min)

Studies with samples containing 0.1 g, 0.2 g and 0.5 g of yeast with a solution concentration of 10 mg/l showed a uniform adsorption efficiency of 30.0%. It can be assumed that at higher concentrations of heavy metal, a small amount of yeast in the sample is not sufficient to ensure larger changes in adsorption efficiency.

In studies of cadmium, more deviations from previously observed trends were recorded. Such as, an increase in adsorption efficiency from 0.1 g of yeast to 0.5 g of yeast at 5.0 mg/l, but in an aqueous solution of cadmium containing 1.0 g of yeast, a decrease, albeit slight, was observed in the adsorption efficiency compared to the first values in this order. Meanwhile, increasing the yeast content from 2.0 g to 5.0 g again showed an increased value of the adsorption efficiency (Fig. 3).

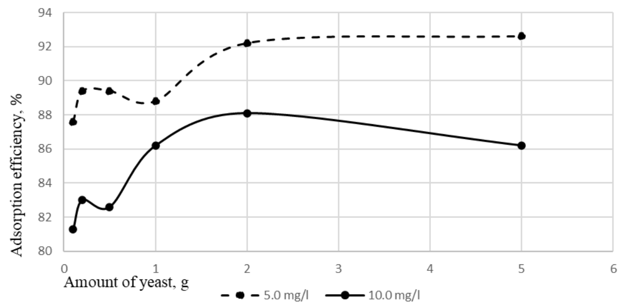

Figure 3. Graph of cadmium adsorption efficiency dependency on yeast amount (5 min contact time)

The initial concentration of lead, copper and cadmium ions in the solutions was found to affect the adsorption efficiency of *Saccharomyces cerevisiae* yeast. The highest adsorption efficiency of lead and copper at 5.0 mg/l and 10.0 mg/l aqueous solutions was recorded at a yeast amount of 5.0 g. At concentration of 5.0 mg/l with the samples of 5.0 g of yeast, the value of adsorption efficiency of 84.0% was recorded, and at the concentration of 10.0 mg/l, the adsorption efficiency of 71.0% was observed. Adsorption efficiency of 24.0% was recorded in samples with 5.0 g of yeast and copper samples at a concentration of 5.0 mg/l, and adsorption efficiency of as much as 50.0% was observed at a concentration of 10.0 mg/l.

At contact time of 30 min, sorption experiments of lead ions from aqueous solutions using yeast showed that at higher concentrations of lead ions, i.e., 10.0 mg/l, higher adsorption efficiency was achieved compared to 5.0 mg/l concentration studies.

It should be noted that in solutions of 5.0 mg/l and 10.0 mg/l at 0.1 g, 0.2 g and 0.5 g of yeast amount, the adsorption efficiency change was minimal, 58.0–59.0% adsorption efficiency value was recorded in all of the samples tested (Fig. 4).

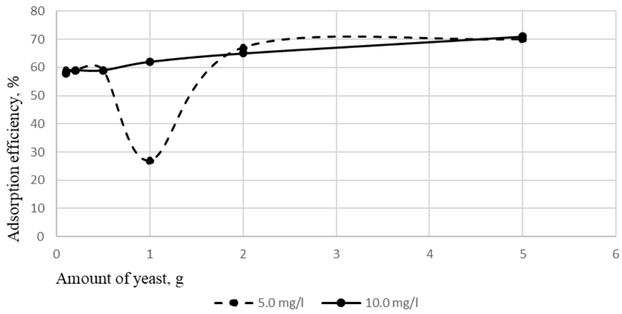

Figure 4. Graph of the dependence of lead adsorption efficiency on yeast amount (30 min contact time)

The highest lead adsorption efficiencies at 5.0 mg/l and 10.0 mg/l aqueous solutions were recorded at a yeast amount of 5.0 g. At a lower concentration of the solution, the adsorption efficiency of 70.0% was observed, while at a concentration of 10.0 mg/l, the adsorption efficiency of 71.0% was recorded (same as after 5 minutes of contact time).

Comparing the results of copper sorption of 5 min and 30 min contact time, it was observed that yeast, which remained in the samples for a longer period of time, sorbed more copper ions (Fig. 5). For example, at concentration of 10.0 mg/l with 5 min of contact time, the value of adsorption efficiency ranged from 30.0% to 50.0%, and when the contact time was extended from 5 min to 30 min, the value of adsorption efficiency was recorded from 55.0% to 71.5%.

Studies on the adsorption of cadmium ions by yeast have shown that at lower concentrations of cadmium ions, i.e., 5.0 mg/l, maximum adsorption efficiency of 90.15% was achieved.

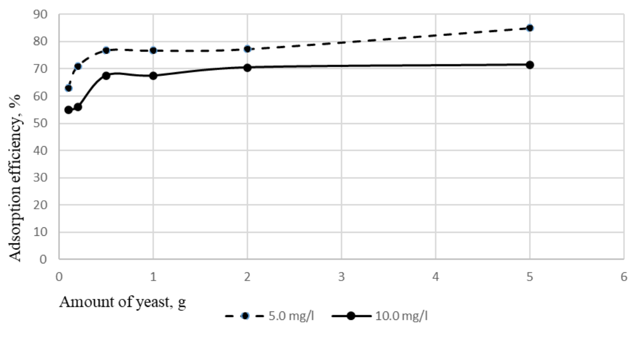

Figure 5. Graph of the dependence of copper adsorption efficiency on yeast amount (30 min of contact time)

The highest adsorption efficiency was recorded at of 5.0 g of yeast amount in samples: at concentration of 5.0 mg/l, the adsorption efficiency of 85.0% was recorded, and at concentration of 10.0 mg/l, the adsorption efficiency of 71.5% was observed.

The last, but not least cadmium: the highest adsorption efficiency was recorded at yeast amount of 1.0 g with samples with cadmium concentration of 5.0 mg/l (Fig. 6). In cadmium 30 min studies, number of deviations from previously observed trends were also observed. For example, at cadmium concentration of 5.0 mg/l, an increase in adsorption efficiency from 0.1 g to 1.0 g of yeast was observed, but in cadmium aqueous solutions containing 2.0 g and 5.0 g of yeast, although a small, but a decrease in adsorption efficiency compared to the first values in this order.

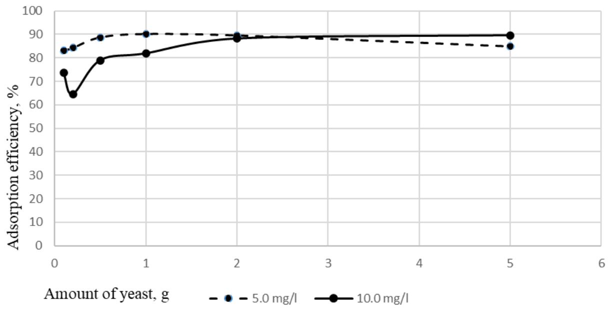

Figure 6. Graph of cadmium adsorption efficiency as a function of yeast amount (30 min contact time)

Studies have shown that with an increase of yeast amount in samples, higher values of adsorption efficiency were recorded (several exceptions were observed). Meanwhile, while comparing the different contact time of the sorption process of the same heavy metal, it was found out that at 10.0 mg/l solutions after 30 min of yeast and heavy metal contact time a higher sorption capacity values were recorded compared to the same concentration, but 5 min contact time samples.

Conclusion

1. Experimental studies have shown that the pH of the solution has a significant effect on the adsorption efficiency. Maximum of adsorption efficiency was recorded when the pH of the solution was at 5.0.

2. After measurements with 5 min of contact time, it was observed that the highest values of adsorption efficiency were recorded for cadmium ions (88.1–92.6%), and the lowest purification efficiency was typical for copper ions (24.0–50.0%).

3. After the contact time of 30 minutes, evaluation of the residual concentration of heavy metal ions in the samples showed that cadmium ions have the highest values of adsorption efficiency (89.6–90.15%). The lowest values of adsorption efficiency were found in aqueous lead solutions (70.0–71.0%).

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MIELIŲ NAUDOJIMO SUNKIESIEMS METALAMS ŠALINTI IŠ UŽTERŠTO VANDENS EKSPERIMENTINIAI TYRIMAI

M. Stonkutė

Santrauka

Tiek paviršinis, tiek požeminis vanduo gali būti užterštas įvairiomis cheminėmis medžiagomis, tad vandens vartojimas buitinėms reikmėms tampa pavojingas. Vanduo gali būti užterštas sunkiaisiais metalais (SM), naftos produktais, detergentais, radioaktyviaisiais izotopais, mineralinėmis arba organinėmis trąšomis. Varis, kadmis ir švinas – vieni dažniausiai su nuotekomis išleidžiamų sunkiųjų metalų iš įvairių pramonės įmonių. Adsorbcija yra vienas iš alternatyvių nuotekų, užterštų sunkiaisiais metalais, valymo būdų. Biologinės kilmės adsorbentų naudojimas sunkiesiems metalams šalinti iš nuotekų yra perspektyvus metodas dėl adsorbentų pigumo, sparčios biodegradacijos ir lengvo prieinamumo.

Raktiniai žodžiai: „Saccharomyces cerevisiae“, adsorbcijos pajėgumas, sunkieji metalai, adsorbcijos efektyvumas, švinas, varis, kadmis.