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WOOL-BASED FILTERS FOR THE RETAINING OF HEAVY METALS FROM INDUSTRIAL AND CONTAMINATED WASTEWATER

Bianca-Denisa CHEREJI, Florentina-Daniela MUNTEANU

"Aurel Vlaicu" University of Arad, Faculty of Food Engineering, Tourism and Environmental Protection, 2 Elena Dragoi Street, 310330, Arad, Romania

Corresponding author email: florentina.munteanu@uav.ro

Abstract

Water pollution occurs when chemical, physical, and biological elements exceed set limits. This phenomenon is primarily a result of various human activities, with industrial and municipal landfills playing a significant role in polluting the environment. Industries heavily dependent on chemicals, especially those that discharge metal-contaminated wastewater, pose a significant environmental concern because of the potential for bioaccumulation in organisms. The bioaccumulation of heavy metals in the food chain highlights the significance of this issue and its potential impact on consumer and public health. With various distinctive properties of α-keratin, wool-based filter systems can effectively manage heavy metal pollution. This paper will discuss the preliminary studies of the efficiency of wool-based filters for retaining heavy metals from different water sources, including wastewater, industrial water, and contaminated water.

Key words: *contaminated, filters, heavy metals, waste, wool.*

INTRODUCTION

Water is a crucial natural resource in any economic system since it serves as the basis for life and the growth of civilisation. Life on Earth would be impossible since water is intrinsically linked to life. People depend on water for their subsistence and progress because it is essential for agriculture, food, drink, and energy production (Afzaal et al., 2022).

Water constitutes around 75% of the human body and approximately 90% of the content of plants. It is indisputable that water is an essential component of life, and as people advance in their lives, their need for water becomes more demanding (Hassan Al-Taai et al., 2021).

Water was essential to the growth and prosperity of ancient human civilisations that progressed for millennia.

Records from the past make it abundantly clear that many civilisations flourished close to rivers. In addition to its fundamental significance, water plays an essential part in our world. It serves as the principal supply of fish, a vital food source all around the globe (Lin et al., 2022).

Additionally, water is used as a medium for linking diverse regions of the globe by utilising various techniques for marine transportation.

Pollution involves the harmful changes that may occur in several facets of the environment. It is an immediate result of human action, including both essential and industrial aspects, whether in whole or in part (Hassan Al-Taai et al., 2021).

The process commences with energy modifications, radiation levels, and unwanted biological, physical, and chemical changes in the biosphere, which is the habitat for all other animals. These alterations can influence the fragile ecological equilibrium, impacting the accessibility of sustenance, the purity of air and water, and the quality of agricultural commodities (Kaur et al., 2022).

A diverse array of environmental contaminants originates from several sources, each with its importance and influence. This phenomenon, known as environmental degradation, encompasses changes in the environment's quantity and quality, resulting in adverse effects on species and a reduction in the ecosystem's ability to support its production.

Drinking sediments and organic contaminants that reduce oxygen levels causes water pollution. These pollutants are emitted mainly by untreated urban sewers and industrial drains, exposing the environment to dangerous trace pollutants such as toxic compounds and heavy metals such as mercury, zinc, lead, and cadmium. Thermal pollution is a kind of water pollution caused by the discharge of power plants and industries and cooling water into water streams, causing increased temperatures and upsetting the natural balance of the aquatic ecosystem (Sonone et al., 2021).

Water pollution with heavy metals

Organic matter, nutrients, pharmaceuticals and personal care products, biocides, heavy metals, and nanoparticles are among the pollutants of significant concern.

Heavy metal ions are extensively discharged pollutants, and thus, they are of significant interest. Heavy metals are persistent, non-degradable, and non-soluble; therefore, they tend to bioaccumulate, increasing their concentration in living and aquatic organisms over time (Briffa et al., 2020).

Industrial activities often generate wastewater containing heavy metals, posing an increased environmental and health risk. Heavy metals such as lead, cadmium, mercury, and chromium are persistent and toxic substances that can accumulate in water and food chains.

Traditional methods such as chemical precipitation, ion exchange, and membrane filtration have cost, complexity, and efficiency limitations. Sustainable and cost-effective alternatives are therefore needed (Fu et al., 2011; Hezarjaribi et al., 2021).

Sheep wool has been found to be an excellent material for effectively retaining heavy metals from industrial wastewater because of its natural and renewable properties.

Wool's unique characteristics make it a favourable option for filtration systems (Enkhzaya et al., 2020).

This material's intricate structure features various functional groups, a significant surface area, and a remarkable ability to absorb substances.

Modifying wool chemically can improve its chemical and physical properties. Usually, these modifications are carried out on the mercapto (-SH) groups in sheep wool, leading to decreased disulfide bonds when exposed to alkaline reagents.

Sheep wool comprises 95% pure keratin, some hydrocarbons, and other compounds (Erdogan et al., 2020).

Sheep wool is a natural fibre obtained from keratin, a protein present in the hair of sheep. The chemical characteristics of sheep wool have a complex relationship linked to its partially crystallised protein polymer structure. This structure consists of a variety of amino acids that are linked together by peptide bonds. Sheep wool has specific characteristics that enable it to efficiently interact with and retain heavy metals in water pollution situations (Kuffner et al., 2012).

The working principle of sheep's wool filters

A better understanding of the working principle of sheep wool filters may be achieved by following the procedures that are provided below:

To complete the filtering process, the wastewater from industrial processes is passed through filters that include sheep wool.

While the water moves through the wool, heavy metal ions are absorbed into the fibres of the wool. Ultimately, the wool acts as a sorbent, capturing the heavy metals and retaining them from the water, as we can see in the figure below (Alyousef et al., 2020).

Advantages of using sheep wool filters

Sheep wool filters provide several significant benefits compared to more traditional approaches to removing heavy metals (Figure 1) (McNeil et al., 2015).

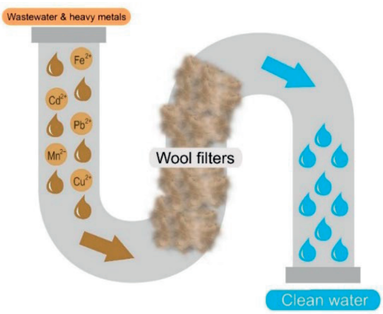

Figure 1. Working principle of wool filter

First, they are easily accessible and affordable, which is a significant factor in lowering treatment expenses.

Second, using of natural materials decreases the dependence on synthetic absorbents, decreasing the negative environmental impact. Wool's natural biodegradability also simplifies disposing of used filters, which provides an additional benefit.

The fact that sheep wool filters may be recycled and reused is another way they contribute to the product's sustainability (Doyle et al., 2021).

MATERIALS AND METHODS

For this analysis, we use sheep wool waste collected from a local farm, cleaned of contaminants or impurities and rinsed with distilled water.
The samples were analysed using the spectrophotometer Specord 200, (Analytik Jena, Jena, Germany). The heavy metal solution used was cadmium sulphate at 0.1 M concentration.
For its preparation, 2 grams of waste wool were cleaned and rinsed with distilled water.
A solution of 0.1 M/mL cadmium sulphate was applied to the wool in a total volume of 100 mL. After 30, 60, and 90 minutes, 10 mL of the sample was extracted and prepared for the spectrophotometric analysis, according to a method described by Ullah et al., 2011.

RESULTS AND DISCUSSIONS

Several scientific studies have been conducted to assess the efficacy of using sheep's wool filters to trap heavy metals (Enkhzaya et al., 2020).
The tests have yielded promising results, indicating significant retention rates for various heavy metals such as lead, copper, cadmium, and zinc (Figure 2) (Baltrenas et al., 2006).

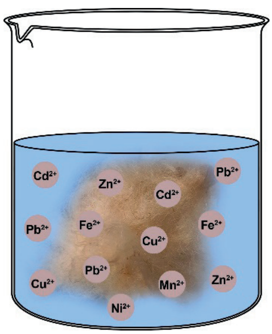

Figure 2. Heavy metals retention by the wool

Wool filters have interesting retaining capacities for heavy metals that make them highly suitable for various compositions of industrial wastewater (Babincev et al., 2020).
For this experimental study, we used a solution of cadmium sulphate as a heavy metal to demonstrate the efficacy of wool-based filters for retaining heavy metals.
The calibration curve for the heavy metal solution cadmium sulphate was generated by graphing the concentration against the sample's absorbance (Figure 3).

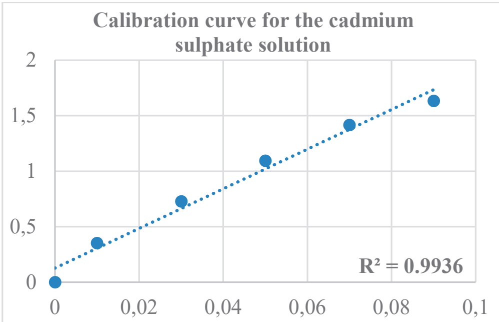

Figure 3. Calibration curve

The Table 1 illustrates the cadmium sulphate of sheep's wool filter over three separate measurements, 30, 60, and 90 minutes.

Table 1. Heavy metal solution in different contact time

Solution	Wool used	Contact time with heavy metal solution
Cadmium sulphate	2 g	30 min
	2 g	60 min
	2 g	90 min

These measurements are represented by vertical bars, each corresponding to a different value of retention capacity in percentage terms.
Based on the graphic data information, it is evident that sheep's wool filter demonstrates a significant capacity for retaining cadmium sulphate, with an efficiency that varies between approximately 70% and 77%.
As shown in Figure 4, the contact time between the wool and the heavy metal solution is an essential factor. After 60 minutes of contact, a higher retention is observed, while after 90 minutes, a decrease in retention (about 7% less) is registered.

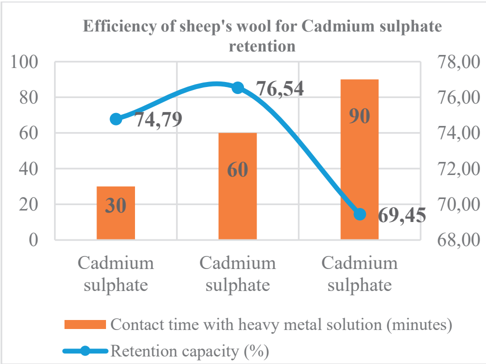

Figure 4. The efficiency of sheep's wool retaining for heavy metals

The measured maximum retention capacity is 76.54%. The ability to retain cadmium ions changes noticeably over different time intervals, indicating that wool's affinity for these ions might fluctuate during exposure.

The initial increase in retention capacity suggests a phase of accumulation, where the wool fibres demonstrate an increased ability to absorb cadmium ions.

The observed decline in the effectiveness of cadmium ion absorption may indicate a saturation threshold, at which point the wool's binding sites gradually become more inhabited.

When discussing these findings, it is important to consider the factors that could affect changes in retention capacity. These factors consider the rate at which the absorption process occurs, the point at which the wool's binding sites become saturated, and the possibility of cadmium ions being released back into the solution as time passes.

Including additional details about the specific time intervals during which these measurements were taken after the cadmium sulphate solution was administered will improve the overall understanding of the results.

Controlled experiments are essential to understand how these factors impact retention efficiency thoroughly. This could involve conducting experiments where one variable is deliberately changed while keeping all other factors constant.

This will allow for identifying the most effective methods to improve the efficiency of the filters.

CHALLENGES AND FUTURE PERSPECTIVES

Although the results obtained so far are encouraging, particular challenges are associated with sheep wool filters. More research is needed to evaluate the stability of the filters under different working settings, such as pH, temperature, contact time, initial metal concentration, and wool dosage, which significantly influence the absorption process. Furthermore, research on the regeneration and disposal of used wool filters is required to guarantee long-term usage (Hezarjaribi et al., 2021).

More research is needed to examine the possibilities of using new materials or changing wool fibers to increase their efficacy in retaining heavy metals.

To improve the retention efficiency of sheep's wool filters for cadmium sulphate or other heavy metal solutions, it considers the following approaches based on the following: (i) *Exposure time optimization.* The study reveals different levels of effectiveness at different time intervals. Investigating the optimal duration of contact to enhance absorption before reaching saturation could enhance retention efficiency;

(ii) *Modification of wool surface.* Through various treatments, the wool can acquire additional functional groups that can bind to heavy metals. This ultimately leads to increased accessible binding sites;

(iii) *pH adjustment.* The charge on wool fibers and heavy metal ions can be influenced by pH levels. Adjusting the pH of the solution could improve the bonding between heavy metal ions and wool, leading to better retention;

(iv) *Wool quantity.* Increasing the amount of wool in relation to the volume of the heavy metal solution could enhance retention by creating more binding sites;

(v) *Temperature control.* Optimizing the temperature to maximize the retention of heavy metal ions in wool can be beneficial, considering the impact of temperature on solubility and interaction;

(vi) *Regeneration of wool.* Investigating techniques to regenerate or purify the wool after it becomes saturated with heavy metal ions could make it reusable and maintain high retention rates over time (Condurache et al., 2022).

CONCLUSIONS

Sheep wool filers have shown considerable promise in efficiently retaining heavy metals from industrial wastewater activities. Sheep wool has remarkable attributes that make it a very effective filtering material and a notable ability to absorb heavy metals (Fu et al., 2011). Future studies should focus on enhancing the efficiency of wool modification procedures, incorporating sheep wool filters into wastewater treatment systems, and investigating combination filtering methods to improve the effectiveness of heavy metal removal (Gupta et al., 2021).

In conclusion, sheep wool filters have significant promise for efficiently eradicating heavy metals from industrial wastewater.

Due to ongoing technological advancements and research, these filters can significantly mitigate the environmental and health risks associated with heavy metal pollution in industrial activities.

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