

# THE EFFECTIVENESS AND EFFICIENCY OF OPUNTIA FICUS-INDICA (OFI) POWDER IN REMOVING Fe, Mn, AND As METAL CONTAMINATION IN WATER TREATMENT

Azyyati Ridha Alfian<sup>1,\*</sup>, Nindi Octaviani<sup>1</sup>, Aken Puti Nandi Nanti<sup>2</sup>, Muhammad Varrel Anandito<sup>3</sup>, Shirly Rizky<sup>1</sup>, and Trianda Nurlia Hidayat<sup>1</sup>

Received: October 06, 2023; Revised: December 18, 2023; Accepted: February 19, 2024

## Abstract

The use of Alum in water treatment has a negative impact on human health if used in the long term. The potential of *Opuntia ficus indica* (OFI) to be used as an organic coagulant that comes directly from nature can minimize metal contamination. Hence, OFI could be used as a new alternative in water treatment. The purpose of this study was to determine the effectiveness and efficiency of OFI in eliminating Fe, Mn, and As contamination. This research was conducted for four months at the University of Andalas. The research method was done by making metal-contaminated water samples, making OFI extract in the shape of powder form, then carrying out the FTIR test, providing treatment in the Laboratory of Organic Chemistry of Natural Materials Department of Chemistry Faculty of Mathematics and Natural Sciences, Universitas Andalas, then conducting Atomic Absorption Spectroscopy (AAS) testing for Fe metals and Mn metals and UV-Vis spectrophotometer test for metals as metals in the West Sumatra Regional Health Laboratory. Analysis of the results of the AAS test and UV-Vis spectrophotometer test showed that OFI powder is more effective and efficient than alum in removing metal contamination. OFI powder is optimal at a mass of 50 mg for removing Mn metal contamination and 100 mg for removing Fe metal contamination, while As metal cannot be identified because the before and after values are smaller than 0.01 mg/L. OFI powder is also more efficient because it is cheaper, easier to cultivate and use by the public, and does not cause side effects on health. It is hoped that the use of OFI powder as a natural coagulant can be used massively by the community.

**Keywords:** Bio-coagulant; effectivity and efficiency; *Opuntia-Ficus Indica* Powder; water treatment

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<sup>1</sup> Department of Public Health, Faculty of Public Health, Universitas Andalas, Padang, West Sumatra, Indonesia. E-mail: azyyatiRIDHAalfian@ph.unand.ac.id; nndoktavia46@gmail.com; shirlirizki6@gmail.com; triandahidayat@gmail.com

<sup>2</sup> Department of Chemistry, Faculty of Mathematics and Natural Sciences, Universitas Andalas, Padang, West Sumatra, Indonesia. E-mail: putiaken467@gmail.com

<sup>3</sup> Department of Environmental Engineering, Faculty of Engineering, Universitas Andalas, Padang, West Sumatra, Indonesia. E-mail: Anandhito25@gmail.com

\* Corresponding author

## Introduction

Based on data from the Badan Pusat Statistik Indonesia (2022) in Indonesia, there are still some areas that have not received proper drinking water, such as Papua (56.54%), South Kalimantan (65.60%), Bengkulu (67.90%), East Kalimantan (69.13%), Central Kalimantan (69.49%) and West Sumatra (77.53%), this percentage is still far from the SDG's Badan Pusat Statistik Indonesia (2022). In fact, water is a basic human need and most of the substances that make up the human body consist of water (Mane *et al.*, 2011). Decent drinking water is related to access to clean water, the difficulty of access to clean water causes the phenomenon of a clean water crisis caused by the growth in populations the exploitation of water by some elements, and the inadequate environment and facilities (Asyakra *et al.*, 2022).

Peraturan Menteri Kesehatan (2023) concerning Drinking Water Quality Requirements, states that one of the requirements for safe drinking water must meet chemical requirements, such as iron (Fe), manganese (Mn), and arsenic (As) with levels of 2 mg/L, 0.1 mg/L, and 0.01 mg/L (Peraturan Menteri Kesehatan, 2023). Excessive levels of exposure to Fe, Mn, and As metals cause toxicity effects on health, so effective efforts are needed in water treatment (Mursidi, 2015; Sunarsih *et al.*, 2018; Rifqi and Hibatullah, 2022).

During this time, people used alum as a chemical coagulant in water treatment techniques. However, prolonged use of Alum causes problems with requirements, such as Alzheimer's and Parkinson's. The buildup of aluminum in the bloodstream can lead to decreased brain health because blood will flow to the brain. Brain cells wear out more quickly and increase the risk of Alzheimer's disease (Bondy and Campbell, 2018). In addition, the use of alum is not effective in reducing metal contamination instead leaves aluminum residues that endanger health (Andiwijaya, 2017).

To reduce exposure to metals, a new technology is needed in order to treat the raw water source well, using natural coagulants derived from the mucus of the OFI. Mucus can reduce the level of water turbidity and is not toxic, so it is more effective than chemical coagulants (alum) (Vargas-Solano *et al.*, 2022). The processing of OFI mucus is relatively simple with relatively affordable costs, this plant is easy to find and cultivate so there will be no difficulty in finding raw materials for the production of natural coagulants, not only that, this plant has good biodegradability and profitability (Otálora *et al.*, 2022; Vishali and Karthikeyan, 2014).

Based on literature studies that have been conducted, research has previously explored the effectiveness of the use of OFI in reducing turbidity and pH levels of water, but there has been no specific research that discusses the effectiveness of OFI in reducing metal contamination in water treatment. The contents in OFI, namely polysaccharides, hydroxyl, and carboxyl functional groups which are polyelectrolytes could form hydrogen bonds that have the potential to remove metals in water (Otálora *et al.*, 2022). In addition, previous researchers used OFI in the form of mucus, if used directly by the public it would be less efficient because it takes a long time, so the mucus dissolves in water and requires a large amount of mucus in its use. Thus, the novelty of this research is to explore the effectiveness of OFI in reducing metal contamination, especially Fe, Mn, and As in water treatment and converting OFI mucus into powder. Based on the background that has been described, the purpose of this study was to determine the effectiveness and efficiency of *Opuntia-ficus indica* powder in reducing metal contamination Fe, Mn, and As.

## Materials and Methods

### Time and Place of Research

This research was conducted for four months at the University of Andalas. Preparation of tools and materials, sample making, and extraction of coagulants are carried out in the Laboratory of Organic Chemistry of Natural Materials Department of Chemistry, Faculty of Mathematics and Natural Sciences, Universitas Andalas. Metal content test using SSA method and UV-Vis spectrophotometer test was conducted at the West Sumatra Regional Health Laboratory.

### Tools and Materials

The equipment used is an Atomic Absorption Spectroscopy (AAS), UV-Vis Spectrophotometer, ATR-FTIR, analytical balance, desiccator, magnetic stirrer, filter, drying oven, blender, sample bottles and vials. The ingredients for making polluted water samples are distilled water, Fe, Mn, and As metals. The extraction materials are OFI, distilled water, and 96% ethanol.

### Preparation of Water Sample Solution

Water samples were made by adding metals to 10 L of water weighing 0.3 g Fe, 0.5 g Mn, and 0.2 g As. The solution was stirred for one hour using

a magnetic stirrer at 400 rpm to homogenize the solution. The solution was left for 24 h at room temperature so that the solution was completely mixed.

#### ***Opuntia-ficus indica* (OFI) Mucus Extraction**

The extraction process is carried out by rinsing the OFI stems without thorns with water, cutting them on one side and grating them, straining the OFI slime and putting it in a beaker, adding ethanol in a ratio of 1:1, stirring at 200 rpm with a magnetic stirrer for 30 minutes and letting it sit. for 3-4 days until a white supernatant is formed. The mucus solution extract was filtered, and the mucus solution was dried in an oven at 60°C for 24 h. The dry ingredients are blended, then sifted through a sieve until a fine powder is obtained. The powder is placed in a 5 ml vial and stored at room temperature.

#### **Jar Test Method**

Alum coagulant and OFI powder to compare the performance of coagulants with varying doses of 50 mg/L, 100 mg/L, and 300 mg/L. Water samples contaminated with Fe, Mn, and As were prepared in 100 mL each in a baker for each coagulant concentration tested. The coagulant was added to the sample, stirred quickly for 30 sec, and slowly stirred for 30 min using a magnetic stirrer. The coagulation process was stopped and left for 24 h until a precipitate formed. Filter the water with Whatman filter paper no. 40 and store it in a 100 mL sample bottle.

#### **FTIR Test**

Characterization test with ATR-FTIR operated in a frequency range of 4,000-600 cm<sup>-1</sup> and a resolution of 4 cm<sup>-1</sup> to identify functional groups of OFI extract before and after the coagulation process and measurement of Fe, Mn, and As metal concentrations before and after to determine the level of reduction metal contamination (Putri, 2021; Vargas-Solano *et al.*, 2022).

#### **Metal Content Test**

Fe and Mn metal concentrations were analyzed using Atomic Absorption Spectroscopy (AAS). Sample preparation using wet digestion. 50 mL of the clean water treatment sample was pipetted then 5 mL of HNO<sub>3</sub> was added. The solution was heated on a hot plate until dry, then the solution was transferred into a 50 mL beaker, and distilled water was added until it was homogeneous. The solution was filtered using Whatman 42 filter paper (110 mm). The absorbance of the filtrate was measured using AAS. The wavelengths used are 248.3 nm (Fe) and 279.5 nm (Mn) (Nasution and Sihombing, 2017).

#### **Calculation of Effectiveness and Efficiency Values**

Calculation of the effectiveness of adsorption in metal removal using the following equation (Suprihatin and Indrasti, 2010).

$$\% \text{ Allowance} = \frac{Co - Ca}{Ca} \times 100\%$$

Information

Co = initial metal concentration

Ca = final metal concentration

#### **Data Analysis**

The statistical analysis used was an independent t-test for the average difference between giving OFI powder and alum and reducing metal contamination using SPSS software using a confidence interval of 95%.

#### **Interpretation and Collection of Results**

Data interpretation was carried out by comparing the effectiveness of experiments to reduce Fe, Mn, and As metals in water with Peraturan Menteri Kesehatan No. 2 Tahun 2023. If the metal test results meet the maximum metal content requirements or are less than the specified requirements, then OFI is declared effective, and if the costs or costs incurred are cheaper than alum, then OFI is declared efficient.

#### **Results and Discussion**

Based on the metal content test results after carrying out the coagulant process using OFI powder and alum, the results shown in Table 1 are as follows:

Based on Table 1, data was obtained that the Fe content before treatment was at a value of 0.096 mg/L. This Fe content value is above the established quality standard, namely 0.2 mg/L. The results of research on Fe levels carried out after OFI and Alum treatment showed a good reduction at a concentration of 50 mg, namely <0.031 mg/L. This reduction in Fe levels is included in the permitted drinking water quality standards. The research results in Table 1 also show that measurements of Mn levels before treatment were at a value of 15.34 mg/L. This Mn content value is above the established quality standard, namely 0.1 mg/L. The research results of Mn levels given OFI treatment showed a fairly good decrease at a concentration of 50 mg, namely 9.954 mg/L. Meanwhile, Mn given alum treatment was categorized as experiencing a fairly good decrease at a concentration of 100 mg, namely 9.387 mg/L. However, the reduction value in Mn levels treated

**Table 1. Fe, Mn, and As content distribution table using OFI powder and alum coagulants**

| Metal contamination | Before treatment | After Treatment   |        |        |                    |        |        |
|---------------------|------------------|-------------------|--------|--------|--------------------|--------|--------|
|                     |                  | OFI concentration |        |        | Alum Concentration |        |        |
|                     |                  | 50 mg             | 100 mg | 300 mg | 50 mg              | 100 mg | 300 mg |
| Fe                  | 0,096            | <0,031            | 0,043  | 0,224  | <0,031             | 0,116  | 0,362  |
| Mn                  | 15,34            | 9,954             | 11,86  | 10,7   | 16,98              | 9,387  | 13,75  |
| As                  | <0,01            | <0,01             | <0,01  | <0,01  | <0,01              | <0,01  | <0,01  |

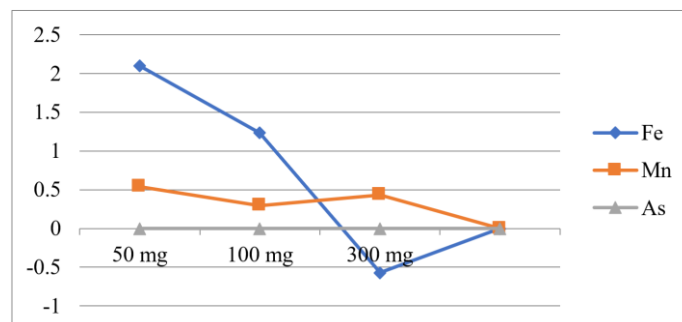
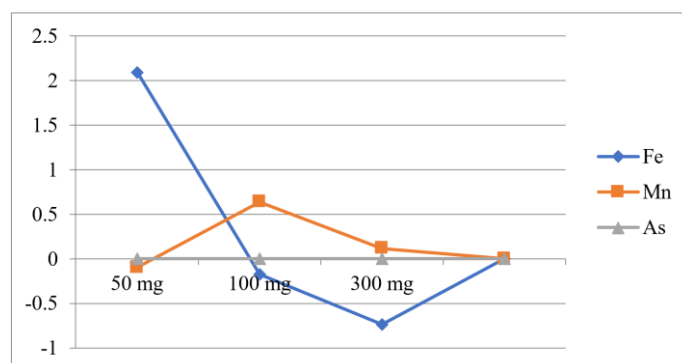
**Table 2. Statistical test results comparing the average values of OFI and Alum**

| Metal contamination | P-Value |
|---------------------|---------|
| Fe                  | 0,68    |
| Mn                  | 0,36    |
| As                  | 1,000   |

with OFI and Mn has not yet entered the permitted drinking water quality standards. Meanwhile, based on Table 1, measurements of As levels before treatment were at <0.01mg/L. This As level value falls within the established quality standard, namely 0.1 mg/L. The results of the research on As levels given OFI and Alum treatment could not be identified because the measurements of As levels before and after treatment were the same and too small than the value of 0.01. Based on Table 1, it is also known that the reduction value of Fe and Mn

metal content in water is greater after treatment with OFI powder coagulant compared to alum in three different treatments so it can be said that OFI powder is more effective in removing Fe and Mn metal contamination in water. To see the difference in the average value of OFI powder and alum treatment in removing Fe, Mn and As contamination in water, a statistical test was carried out with the following results:

Based on Table 2, it shows that there is no significant difference in the average value of statistical test results between the use of OFI powder as a natural coagulant and alum in eliminating Fe, Mn, and As metal contamination in water treatment. However, the effectiveness and efficiency values of OFI powder compared to alum are depicted in Figures 1 and 2 as follows:

**Figure 1. Effectiveness of OFI concentration in reducing metal contamination****Figure 2. Effectiveness of alum concentration in reducing metal contamination**

Based on Figures 1 and 2, shows the percentage effectiveness of OFI powder compared to alum as a coagulant in removing Fe, Mn, and As metal contamination. Based on Figures 1 and 2, which is in line with the results in Table 1, it is known that the percentage effectiveness of OFI powder is greater than that of alum for Fe and Mn metals. A significant difference in the reduction of Fe metal by treating 100 mg of OFI powder and alum is that OFI powder has the ability to remove 1% contamination compared to 0% alum. Meanwhile, for Mn metal, there is a significant difference in the 50 mg and 300 mg treatments where the percentage of effectiveness of OFI powder in removing contamination is also greater than that of alum, namely 0.5% while alum is 0%.

Basically, OFI can be used as a coagulant with an adsorption and fusion mechanism. Adsorption of particles occurs through hydrogen bonds. The natural electrolyte content contained in OFI especially divalent cations, plays an important role in anion polymers which facilitate the adsorption process. The amine functional groups contained in cactus sap, when reacted with metal-contaminated water, will form colloids known as floc (Vinodhini and Das, 2009; El-Mostafa *et al.*, 2014). This is what can make OFI a natural coagulant. Based on the literature on the removal of methylene blue by coagulation-flocculation using bentonite as a coagulant and OFI as a flocculant, the removal rate was 98.99% with an initial concentration of methylene blue of 90 mg/L, in a volume of 1 L. The pH effect was also observed, and it was found that there was no influence on bentonite coagulation capacity and OFI flocculation capacity (Ihaddaden *et al.*, 2022; Satriyani, 2021).

Based on Figures 1 and 2, the efficiency of using OFI powder compared to alum as a coagulant in removing Fe, Mn, and As metal contamination is also better where OFI in particular is a plant that is easy to cultivate by the community or household, so this natural material is also easier to get. When compared with the costs incurred, in Padang City, Indonesia using OFI powder is also cheaper than the cost of purchasing alum. Apart from that, based on the results of its effectiveness, OFI can also help minimize the negative effects of using alum on health because OFI contains natural ingredients compared to alum. It is known that the use of alum has an impact on human health if used for a long period of time, such as disease (Ananda and Ismail, 2016). Abnormal concentrations of alum in tap water may be caused by improper coagulation with aluminum coagulant. It is important to ensure that the amount of residual alum in water intended for human consumption is as low as possible, bearing in

mind that increased concentrations of alum can pose a potential risk to human health, resulting in brain changes that are characteristic of Alzheimer's disease. Alum can also accumulate in the bones, causing brittleness and excessive softening of the bones, resulting in osteomalacia accompanied by osteodystrophy fractures (Krupińska, 2020; Silva *et al.*, 2021).

Coagulant dosage in the water is the most important parameter that must be optimized. Insufficient or excessive doses can reduce OFI performance. At high doses, the active ingredients contained in OFI cannot work optimally. OFI contains pectin, a polysaccharide compound that can dissolve in water and form a thick liquid (jelly) called mucilage (Prasetya and Saptomo, 2018). The main constituent of pectin is usually the polymer D-galacturonic acid, which is linked to  $\alpha$ 1,4 glycosidic. D-galacturonic acid is a carboxyl group that bonds with  $Mg^{2+}$  or  $Ca^{2+}$  ions. D-galacturonic acid contains a negative charge, so it can bind all positive charges in water so that it can purify water and can reduce the level of turbidity in the water (Putra *et al.*, 2019; Nindi *et al.*, 2023).

The coagulant dose will be directly proportional to the quality of the colloid present. The OFI dose concentration in this study was optimal at 50 mg for Fe and Mn.

## Conclusions

### Conclusions

1. The use of OFI powder as a natural coagulant is known to be more effective in removing Fe and Mn metal contamination in water treatment than alum. The optimal concentration of OFI powder in terms of its effectiveness in removing Fe metal contamination is by adding 100 mg/L OFI powder to water contaminated with Fe metal and adding 50 mg/L OFI powder to water polluted with Mn metal. The percentage effectiveness of OFI powder is 1% in removing Fe metal contamination and 0.5% in removing Mn metal contamination compared to alum. However, the effectiveness of OFI powder and alum in removing As metal cannot be identified because the content levels before and after treatment are known to be the same and smaller than the value of 0.01.

2. OFI powder is also more efficient to use compared to alum because it is easy for people to cultivate, easy to obtain, and the cost is also cheaper. Apart from that, OFI powder can also minimize the negative impact of using alum on human health because of the natural ingredients contained in OFI powder.

## Suggestion

Based on the research results, it is hoped that the use of OFI powder as a natural coagulant can be utilized massively by the community. However, in implementing water treatment, it needs to be combined with filtration techniques until the resulting water has a turbidity level that meets the specified quality. It is also hoped that several related agencies can help improve the results of this research in the future so that the benefits of using OFI mucus in water treatment can be felt by the entire community.

## Acknowledgment

We extend our sincere gratitude to the Directorate General of Higher Education Research and Technology for their invaluable financial support, which has been instrumental in facilitating the execution of this research endeavor. Additionally, we express our appreciation to Andalas University for their guidance and training, crucial in ensuring the successful implementation of the PKM activities.

## Author Contributions

Authors one and six conducted research, analyzed research data, and wrote articles. Authors two, three, four, and five assisted in carrying out the research and writing the article.

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