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# Use of Ulluctus Tuberosus and Oxalis Tuberosa as Natural Coagulants in the Treatment of an Environmental Liability, Huancayo - Peru

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**ABSTRACT**

Currently, multiple research efforts have been carried out focusing on the application of biodegradable coagulants as part of environmentally sustainable wastewater treatments, mainly due to their affordability and ease of access. This approach emerges in response to the rise in contamination at sites containing toxic metals that pose risks to both ecosystems and public well-being. For this reason, the objective of this study was to assess the effectiveness of Ullucus tuberosus and Oxalis tuberosa as eco-friendly coagulants in treating an environmental pollution site in Peru. The applied methodology involved a study of an applied nature, incorporating an explanatory level and experimental design, where water samples from various environmental sites were collected and treated using prepared solutions with concentrations of 5 ppm, 10 ppm, 15 ppm, 20 ppm, and 25 ppm of both coagulants. The findings showed that the most effective dose was 15 ppm of Ullucus tuberosus. Furthermore, the solution containing Ullucus tuberosus demonstrated higher efficiency in removing turbidity, chromium, cadmium, and lead contaminants, achieving removal efficiencies of 77.51%, 70.77%, 67.86%, and 69.1%, respectively. In conclusion, the use of these coagulants proved beneficial in reducing pollutants present in aquatic environments derived from environmental contamination in Huancayo.

**Keywords:** Ullucus Tuberosus; Oxalis Tuberosa; Natural Coagulant, Environmental Liability; Heavy Metals.

## INTRODUCTION

The challenge associated with the harm arising from abandoned mining activities is addressed through the principle of “environmental responsibility” or "environmental liability." This principle involves transferring the responsibility for the costs associated with environmental damage back to those who caused it. Heyes [1] analyzes this issue from both legal and economic perspectives. Bergkamp [2] aligns with Faure [3] in examining environmental liabilities, demonstrating that these liabilities have a deterrent effect by influencing the behavior of those responsible. It is observed that countries such as the United States, Canada, and certain European Union nations (e.g., Spain, Ireland, Ukraine, and the United Kingdom) have addressed environmental liabilities solely in relation to the impacts generated by metallic and non-metallic mining—a primary source of hazardous waste affecting human health and ecosystems.

Meanwhile, Earthworks [4], a non-profit organization, asserts that there is no comprehensive global registry of tailings dams. However, China alone accounts for approximately 12,000 of these repositories, suggesting that the global number likely exceeds 18,000. The group also highlights that, although tailings dams are typically resistant to collapse, accidents have been occurring with increasing frequency and severity. Recent incidents have resulted in hundreds of deaths, significant environmental damage, and substantial financial losses due to profit reduction and mitigation costs for mining companies. Therefore, according to Earthworks [4], mining companies should limit the

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inevitable environmental impacts at mining sites, strengthen relationships with communities, establish robust environmental protection measures, and enhance transparency.

Operational mining activities release contaminating substances into the environment from various sources. The negative environmental impacts persist even after mine closure, constituting what is known as environmental liabilities. In the region, the concept of environmental liabilities has been addressed within academic circles and community environmental groups. Both perspectives align in recognizing the environmental degradation caused by foreign companies due to the excessive exploitation of available mineral resources [5]. An incipient compliance with impact mitigation obligations is observed among concessionaire companies in countries such as Peru, Colombia, Chile, Argentina, and Ecuador, where overexploitation of mineral and hydrocarbon reserves has taken place.

The report revealed the presence of 742 tailings deposits in the country, categorized as follows: 2 currently under construction, 104 operational, 463 inactive, and 173 abandoned. From a geographical perspective, 74% of these deposits are concentrated in the Atacama and Coquimbo regions. The issue is becoming increasingly urgent due to the decline in mineral grades, while demand continues to rise to support the energy transition and carbon neutrality goals. This reduction in mineral grades necessitates greater energy and water consumption, posing significant challenges in drought-affected countries such as Chile [4]. In Peru, the Ministry of Energy and Mines (MINEM) has reported a total of 3231 environmental liabilities resulting from hydrocarbon activities, with 152 classified as high risk. According to MINEM, the lack of regulation between 1863 (when the country's first petroleum exploitation occurred) and 1993 is one of the primary causes of the issue affecting communities in the Loreto, Piura, Tumbes, and Puno regions [6].

Labastida et al. [7] carried out a study in Mexico where they demonstrated the effectiveness of chitosan derived from shrimp waste as a coagulant and flocculant in wastewater treatment. Their findings revealed that chitosan achieved a 96% reduction in total suspended solids when applied at a dose of 180 mg/L at pH 4, while at pH 8.2, the removal efficiency dropped to 25%. In Colombia, Choque [8] evaluated three cactus species for wastewater purification, obtaining 99.09% efficiency for the San Pedro cactus, 92.42% for the Ulluquite variety, and 98.98% for the Tuna variety. The optimal doses for each were 0.207%, 0.246%, and 0.754%, respectively. Similarly, Tovar et al. [9] examined plantain starch as a natural coagulant in drinking water treatment. Their research indicated that starch obtained through a wet process was more effective in reducing turbidity than that produced using NaOH, achieving a 94.6% removal efficiency with a 29 mg/L coagulant dose and an agitation speed of 40 rpm. Further, Moein et al. [10] explored the use of Alyssum mucilage in Iran for wastewater treatment, reporting removal rates of 92.30% for COD, 99.92% for TU, and 99% for surfactants when using a 301.8 mg/L coagulant dose at pH 6.53, with a contact time of 23.1 minutes. Cheng et al. [11] conducted a study in Malaysia utilizing guar gum as a natural coagulant for landfill leachate treatment. The best COD removal rate observed was 22.57%, achieved using a 44.39 mg/L guar gum dose at pH 8.56, with an agitation speed of 79.2 rpm, demonstrating additional benefits in pollutant removal. In another study, Kristianto et al. [12] examined the potential of Leucaena seed extract for synthetic wastewater treatment containing Congo red dye. The results indicated that the most effective pH level was 3, as the positively charged Leucaena protein neutralized the negatively charged Congo red molecules, achieving maximum dye removal at a 20 mL/L coagulant dose. Lastly, Moreno et al. [13] investigated the application of Solanum starch in Peru for treating Punrún Lagoon water. The findings showed that the maximum turbidity removal was 93.31%, reducing turbidity levels to 0.55 NTU, while lead concentration was lowered to 0.005 mg/L after treatment with the potato-based coagulant.

Addressing the management of environmental liabilities, particularly those related to mining waste deposits, is crucial. This study aims to assess the effectiveness of a natural coagulant derived from *U. tuberosus* and *O. tuberosa*. These natural coagulants have demonstrated notable coagulation capabilities in clarification processes, providing distinct benefits over conventional coagulants. Some of these advantages include cost efficiency, enhanced coagulation performance, and eco-friendly, non-toxic characteristics [14].

## METHODS AND METHODOLOGY

The research was of an applied nature, with an explanatory focus and an experimental design that included a pre-test and a post-test phase. The study population consisted of samples of contaminated water from the environmental

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liability of the former Yauris Metallurgical Plant. For data collection, documentary analysis and observation techniques were employed, utilizing an observation form as the main instrument.

**Procedures**

During the pre-field stage, all materials and instruments required for data collection were prepared, including personal protective equipment (PPE) such as safety glasses, protective footwear, masks, helmets, and nitrile gloves. Additionally, sample collection materials were gathered, including coolers, scissors, sample preservatives, containers for physicochemical analysis, cooling gel, chain of custody forms for water monitoring, garbage bags, sample labeling tags, a field notebook, a 1 L beaker, pens and markers, adhesive tape, blotting paper, trays, 5 L containers, and sample bags.

During the field stage, authorization from the responsible entity was obtained to schedule a sampling date for tailings collection. In the laboratory stage, the following physicochemical parameters were analyzed: Chemical Oxygen Demand (COD), Suspended Solids (SST), pH, color, turbidity, lead (Pb), cadmium (Cd), and chromium (Cr). For the initial sampling process, a GPS navigation device was used to determine the precise location of the first sampling point. Subsequently, the contamination level of the environmental hazard tailings was assessed. An in-situ sample was collected by filling 1-liter bottles with water for physicochemical parameter analysis using High-Density Polyethylene (HDPE) containers. To sample COD, SST, pH, turbidity, Pb, Cd, and Cr, a container was submerged to a depth of 20 cm. Finally, the containers were labeled with indelible ink markers to record all necessary data for accurate identification [15].

**Preparation of natural coagulant from the oca**

*O. tuberosa*, commonly referred to as oca, was chosen as a natural coagulant due to its accessibility and year-round availability. To replicate the preparation process, 1 kg of oca peels in suboptimal condition was acquired from a local market. The peels were initially washed with potable water, followed by a disinfection step where they were submerged in a 5-liter container of water mixed with five drops of sodium hypochlorite. Next, they were sliced into rectangular pieces measuring approximately 5 cm in length and 1 cm in width. A subsequent washing was performed using distilled water. Afterward, the samples were placed in a laboratory oven set at 100°C and dried for 72 hours. Once dried, they were ground using a grain mill to achieve particle size reduction, followed by sieving with a No. 40 mesh sieve to obtain a fine powder. Finally, the resulting flour was stored in glass jars for preservation.

**Preparation of natural coagulant from the olluco**

The natural coagulant was obtained from *U. tuberosus* due to its extensive availability and common consumption in highland regions. To ensure consistency in the preparation, the peels were gathered, rinsed with potable water, and then immersed in a 5-liter solution containing five drops of sodium hypochlorite for disinfection. A final rinse with distilled water was conducted to eliminate any remaining impurities. The cleaned peels were subsequently dried in a laboratory oven at 100°C for 24 hours. Once dried, the material was ground using a grain mill and passed through a No. 40 mesh sieve to obtain a fine powder. Finally, the processed material was stored in glass jars at room temperature for future use [16].

**Preparation of the stock solution**

The formulation of both stock solutions followed the same methodology. Initially, a stock solution with a concentration of 10,000 ppm was prepared, adopting the approach described by Aquino and Tovar [17] and Salome and Salvatierra [18]. Each natural coagulant, at a concentration of 1%, was obtained by dissolving 3 grams of the powdered raw material in 300 mL of distilled water (3g/300 mL). The mixture underwent homogenization on a magnetic stirrer at a speed of 60 rpm for 30 minutes. Subsequently, it was allowed to settle for 10 minutes, resulting in the stock solution of *U. tuberosus* and *O. tuberosa*. To maintain its coagulation properties, refrigeration was necessary, with an effectiveness period not exceeding one month [19].

**Determination of coagulant doses**

To establish the appropriate coagulant concentrations, doses of 5 ppm, 10 ppm, 15 ppm, 20 ppm, and 25 ppm were prepared from the stock solution. A sample volume of 1000 mL was used for this process. By applying the equation,

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the respective extracted volumes from the stock solution were determined as follows: 0.5 mL, 1 mL, 1.5 mL, 2 mL, and 2.5 mL. Table 1 below provides a summary of these calculated values.

**Table 1**: Determinación de volumen

| Volume found per dose | |
|---|---|
| **Dose– ppm** | **Volume -mL** |
| 5 | 0.5 |
| 10 | 1 |
| 15 | 1.5 |
| 20 | 2 |
| 25 | 2.5 |

**Jar test**

The experiment involved four different treatments using natural coagulants derived from *U. tuberosus* (Olluco) and *O. tuberosa* (Oca) at doses of 5, 10, 15, 20, and 25 ppm. The jar test was performed with a three-paddle system, utilizing 1000 mL beakers labeled according to the coagulant type and corresponding dose. Each coagulant was applied in concentrations of 5, 7, 9, and 11 mL. The coagulation process was conducted at 100 rpm for 10 minutes, followed by a reduction in speed to 40 rpm for 20 minutes to facilitate flocculation. Afterward, the jars remained undisturbed for 10 minutes to allow sedimentation. A 400 mL sample was taken from each beaker for the analysis of physicochemical parameters, including turbidity, pH, total suspended solids, lead, cadmium, and chromium. The procedure was repeated for both coagulants and a control treatment, replicating the processes of coagulation, flocculation, and sedimentation [20] [21].

**Efficiency Determination Equation**

The equation used to determine the percentage removal of contaminants through the use of Oxalis tuberosa and Ullucus tuberosus was as follows [22]:

$$Removal\ efficiency = \frac{Ci - Cf}{Ci} x\ 100\%\% \quad (1)$$

Where: Ci corresponds to the initial concentration and Cf to the final concentration.

## RESULTS

**Descriptive Results**

An analysis was conducted on five parameters of contaminated water from an environmental liability site. Table 2 summarizes the statistical data for pH, turbidity, chromium, cadmium, and lead, with each parameter being measured across 11 observations. The pH values fluctuated between 6.4 and 7.05, with a mean of 6.828 and a standard deviation of 0.1560. Turbidity levels ranged from 141 to 820, averaging 320.64 with a standard deviation of 188.253. Similar patterns were noted for chromium, cadmium, and lead, indicating significant fluctuations in their concentrations. These findings correspond to the control and treatment conditions applied in the study, demonstrating the role of natural coagulants in contaminant removal from water sources affected by environmental liabilities.

**Table 2:** Result descriptions

| | N | Minimum | Maximum | Average | Desv. Desviation |
|---|---|---|---|---|---|
| pH | 11 | 6,4 | 7,0 | 6,828 | ,1560 |
| Turbidity | 11 | 141 | 820 | 320,64 | 188,253 |
| Chromium | 11 | 1,05 | 3,96 | 1,8166 | ,84126 |

| | | | | | |
|---|---|---|---|---|---|
| Cadmium | 11 | 1,51 | 4,83 | 2,3065 | ,97706 |
| Lead | 11 | 1,28 | 4,33 | 2,0745 | ,95922 |
| N Valid Number (Per List) | 11 | | | | |

**Correlation between treatment and reduction of contaminants**

The data in Table 3 presents Pearson correlation coefficients, highlighting significant relationships between the applied treatment and different water quality parameters. A strong positive correlation is identified between treatment and pH levels (r = 0.825, p = 0.002), demonstrating that as treatment intensity increases, pH levels rise accordingly. Conversely, a notable negative correlation exists between treatment and water turbidity (r = -0.810, p = 0.003), suggesting a reduction in turbidity as treatment is applied. Additionally, significant negative correlations were found between treatment and the concentrations of chromium (r = -0.790, p = 0.004), cadmium (r = -0.733, p = 0.010), and lead (r = -0.799, p = 0.003), indicating a decrease in the presence of these metals in treated water. These results establish a clear association between the applied treatment and key water quality parameters in the environmental setting. The findings further suggest that treatment effectively enhances water quality by increasing pH, reducing turbidity, and lowering metal contamination levels. These results reinforce the effectiveness of natural coagulants in removing contaminants and highlight their relevance in addressing and mitigating water pollution in environmentally impacted sites.

**Tabla 3:** Result correlations

| | | **Treatment** | **pH** | **Turbidity** | **Cr** | **Cd** | **Pb** |
|---|---|---|---|---|---|---|---|
| Treatment | Pearson Correlation | **1** | **,825**** | **-,810**** | **-,790**** | **-,733*** | **-,799**** |
| | Sig. (two-tailed) | | ,002 | ,003 | ,004 | ,010 | ,003 |
| pH | Pearson Correlation | ,825** | 1 | -,936** | -,811** | -,771** | -,823** |
| | Sig. (two-tailed) | ,002 | | ,000 | ,002 | ,006 | ,002 |
| Turbidity | Pearson Correlation | -,810** | -,936** | 1 | ,947** | ,898** | ,910** |
| | Sig. (two-tailed) | ,003 | ,000 | | ,000 | ,000 | ,000 |
| Cr | Pearson Correlation | -,790** | -,811** | ,947** | 1 | ,862** | ,857** |
| | Sig. (two-tailed) | ,004 | ,002 | ,000 | | ,001 | ,001 |
| Cd | Pearson Correlation | -,733* | -,771** | ,898** | ,862** | 1 | ,822** |
| | Sig. (two-tailed) | ,010 | ,006 | ,000 | ,001 | | ,002 |
| Pb | Pearson Correlation | -,799** | -,823** | ,910** | ,857** | ,822** | 1 |
| | Sig. (two-tailed) | ,003 | ,002 | ,000 | ,001 | ,002 | |

**Correlation between treatment and reduction of contaminants**

**pH Results**

The initial sampling of contaminated water revealed a pH value of 6.42, surpassing the Environmental Quality Standards (ECA) for water designated for irrigation and animal consumption, as established by the Peruvian Ministry of the Environment. Following the application of coagulants in treating these contaminated waters, a noticeable shift toward acidity was observed. Furthermore, the highest recorded pH value was found in the treatment using *U. tuberosus* (6.98). Both coagulant treatments were found to comply with the ECA standards for water. Notably, the treatment with U. tuberosus produced the highest pH value, highlighting its potential as an effective approach for treating contaminated waters. These findings reinforce the viability of natural coagulants in improving water quality in polluted environments, which is particularly relevant for environmental conservation and public health.

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Additionally, the optimal pH dose was determined to be from the stock solution with *U. tuberosus* at a concentration of 25 ppm (Figure 1).

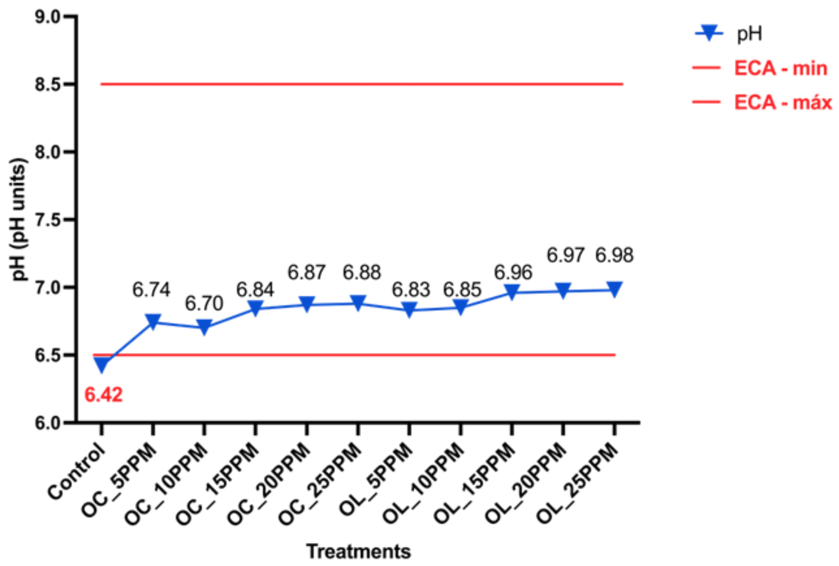


**Figure 1.** pH value before and after the coagulant treatment.

### Turbidity Results

In Figure 2, it can be observed that the initial turbidity value in the untreated contaminated water was 820 mg/L. Subsequently, upon applying treatment with the two coagulants, a significant reduction in turbidity is evident. For instance, in the case of the stock solution of *U. tuberosum* with a concentration of 15 ppm, a removal efficiency of 82.81% was achieved, followed by a concentration of 25 ppm of the same species, which attained a removal efficiency of 76.83%. Regarding the natural coagulant of *O. tuberosa*, a removal efficiency of 65.4% was achieved with a concentration in the mother solution of 5 ppm. It is important to mention that in all treatments with both species, a reduction in the concentration of this contaminant was achieved. Finally, it can be observed that the optimal dose for turbidity removal is reached when using a stock solution of *U. tuberosum* at a concentration of 15 ppm.

The resemblance between the findings of this study and previous research can be attributed to various factors. Firstly, the notable decline in turbidity following the application of natural coagulants *U. tuberosus* and *O. tuberosa* indicates their effectiveness in enhancing the clarity of polluted water. The alignment of these results with prior studies, such as the one conducted by Tavakkoly et al. [22], which documented a turbidity reduction efficiency of 62.4%, reinforces the role of natural coagulants in eliminating suspended solids from water sources. Furthermore, the study by Moreira and Moreira [23], which employed peach seeds (Prunus persica) and Vicia faba as natural coagulants, achieved turbidity removal rates of 89.07% and 93.13%, respectively. This additional evidence further confirms the effectiveness of natural coagulants in improving water clarity. The consistency observed across these studies implies that various types of natural coagulants may exhibit comparable efficiency in purifying contaminated water.

The effectiveness of natural coagulants, such as *U. tuberosus* and *O. tuberosa*, is primarily due to their capacity to aggregate suspended particles and enhance their sedimentation, significantly reducing turbidity. These coagulants function as polyelectrolyte compounds, which can be found in anionic, cationic, or neutral polymeric forms [24]. They are recognized for their safety, cost-effectiveness, and their ability to regulate water pH throughout the treatment process. In contrast to chemical coagulants, natural alternatives do not contribute to increased metal concentrations during the treatment phase and are characterized by producing a smaller volume of sludge, which minimizes disposal costs [25] [26]. Consequently, they offer an environmentally sustainable substitute for conventional chemical coagulants.

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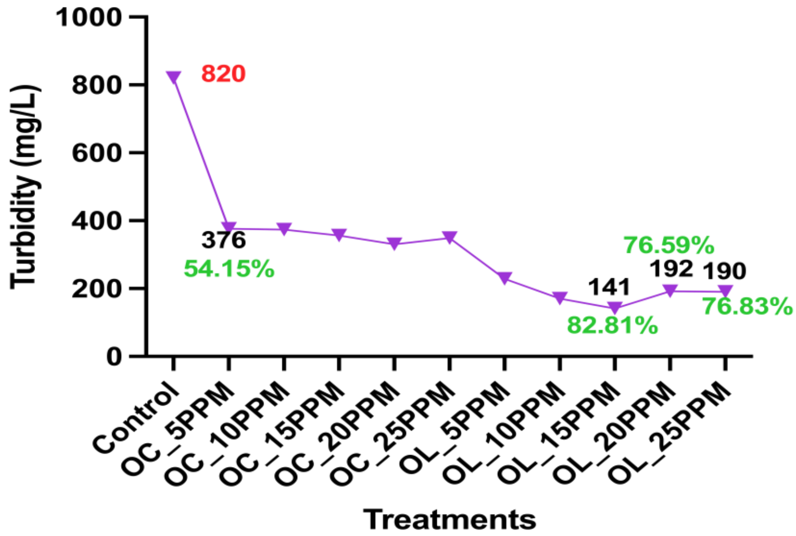


**Figure 2.** Turbidity concentration before and after the treatment.

**Cadmium Results**

In Figure 3, it is observed that the initial value before treatment was 4.83 mg/L of cadmium. Following the application of treatment with the two coagulants, a reduction in the contaminant is evidenced. It is noteworthy that the highest removal efficiency was achieved by adding 25 ppm of the stock solution of *U. tuberosum*, followed by the coagulant with 5 ppm of the same species. Additionally, adding 25 ppm to the stock solution of *O. tuberosa* resulted in a removal efficiency of 45.9%. Finally, adding 5 ppm to the stock solution of *O. tuberosa* resulted in a removal efficiency of 45.7%. However, it is important to mention that the removal of cadmium with the coagulants was not sufficient to meet the Environmental Quality Standards (EQS). Ultimately, the optimal dose for cadmium reduction was observed when applying the stock solution of *U. tuberosum* at a concentration of 25 ppm. The results presented in Figure 3 demonstrate a significant reduction in cadmium concentration after applying treatment with natural coagulants. While an improvement in removal efficiency is observed, it did not reach the levels set by the Environmental Quality Standards. These findings underscore the need to continue researching and developing more effective treatment techniques for the removal of cadmium and other contaminants present in water.

These findings are consistent with the research conducted by Chu et al. [27], who investigated the use of Moringa oleifera as a natural coagulant, achieving a cadmium removal efficiency of 78.1%. Additionally, they align with the study by Elsergany [28], who utilized Moringa peregrina for water treatment, reporting a removal efficiency of 51.8%. The similarity between these studies lies in the fact that, despite using different plant species, both relied on the coagulation and flocculation process to successfully eliminate contaminants from water. This process involves the introduction of a coagulant that promotes the aggregation of small particles into larger flocs, which can then be separated through sedimentation. The effectiveness of this method is closely linked to flocculation, a process that occurs under gentle mixing conditions. In summary, coagulation and flocculation are fundamental mechanisms in treating contaminated water, as they facilitate the formation and subsequent removal of flocs to eliminate impurities [29].

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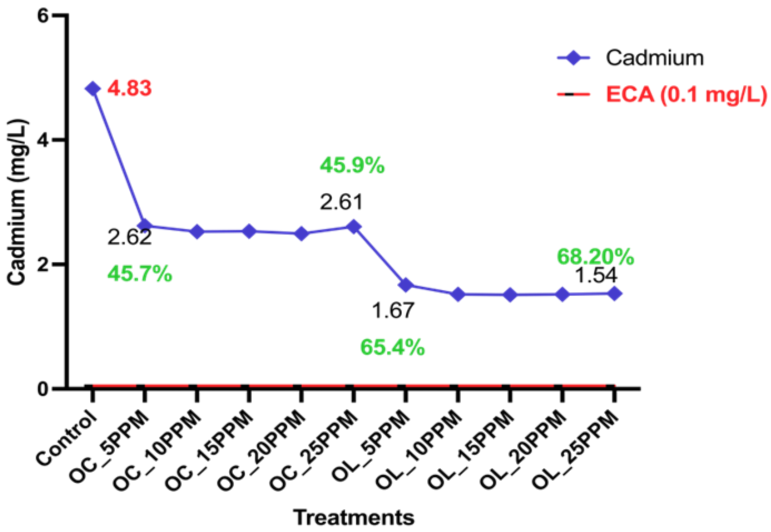


**Figure 3.** Cadmium concentration before and after the treatment.

## Lead Results

In Figure 4, it is evident that the initial concentration of lead was 4.32 mg/L. Following water treatment using the stock solution of the two coagulants, it was observed that the stock solution with 15 ppm of *U. tuberosum* exhibited a removal efficiency of 70.40%. Similarly, the stock solution of the same species with 25 ppm showed an efficiency of 68.51%. Furthermore, it is noted that the stock solution with 25 ppm of *O. tuberosa* demonstrated a removal efficiency of 53.55%, whereas the stock solution with 15 ppm of *O. tuberosa* exhibited a removal efficiency of 25.18%. Additionally, the stock solution of *O. tuberosa* with 5 ppm displayed a removal efficiency of 48.42%. It is important to emphasize that although a reduction in lead concentration was achieved, these results did not meet the Environmental Quality Standards. Ultimately, the optimal dosage for lead removal was observed by adding 15 ppm of *U. tuberosum* to the stock solution. The findings presented in Figure 4 indicate a decrease in lead concentration following treatment with natural coagulants. However, the obtained removal efficiency was insufficient to meet the levels established by the Environmental Quality Standards.

The findings presented in Figure 4 are consistent with the study conducted by Choque et al., [30], who utilized potato peel for heavy metal removal, specifically lead, achieving a removal efficiency of 73.22%. Likewise, they align with the research carried out by Arshad and Imran [31], who employed plant materials as natural coagulants and obtained an average lead removal efficiency of 78.94%. This coherence in results suggests that both potato peel and plant materials hold potential as natural coagulants for lead removal in contaminated water, offering a promising and sustainable alternative for wastewater treatment. It is noteworthy that, although different species were utilized in the mentioned studies, there exists a fundamental similarity among them, as all employed species are of plant origin. This suggests that inherent properties of plants, such as their capacity to adsorb or precipitate heavy metals, may significantly contribute to the effectiveness of natural coagulants in contaminant removal. Despite variations in chemical composition and interaction with contaminants among plant species, consistent results in reducing lead concentration indicate that the utilization of natural coagulants derived from plants is a promising strategy for treating contaminated waters.

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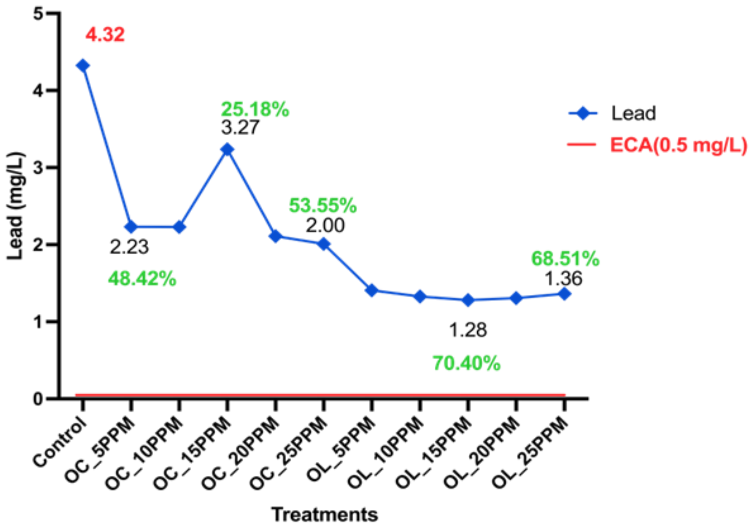


**Figure 4.** Lead concentration before and after the treatment.

**Chromium Results**

In Figure 5, it is evident that the initial concentration of chromium recorded was 3.96 mg/L. Following the treatment of these waters using natural coagulants, higher removal efficiency was achieved by introducing 15 ppm of *U. tuberosum* into the mother solution, with an efficiency of 73.5%, followed by the use of 25 ppm of the same coagulant, yielding a performance of 70.2%. Additionally, it is observed that the inclusion of 25 ppm of *O. tuberosa* in the mother solution resulted in a removal efficiency of 50.1%, while the presence of 5 ppm of *O. tuberosa* in the mother solution produced a removal efficiency of 46.5%. However, despite these improvements, these results failed to meet the levels established by the Environmental Quality Standards. Finally, it can be appreciated that the optimal dose for chromium removal was achieved by adding 15 ppm of *U. tuberosum*. The findings presented in Figure 5 show a reduction in chromium concentration after treatment with natural coagulants. It is observed that both *U. tuberosum* and *O. tuberosa* demonstrated efficacy in chromium removal, with higher removal efficiencies when using higher concentrations of *U. tuberosum* in the mother solution. However, none of the achieved removal efficiencies met the Environmental Quality Standards.

These findings are related to the results obtained by Arshad and Imran [31], who determined an average chromium removal efficiency of 71.2%. Likewise, they agree with the findings of Gaayda et al., [32], who were able to determine the percentage of chromium removal using grape seeds as a natural coagulant. Although the research was conducted in different sociodemographic contexts, the conditions to which they were subjected were similar, which could explain the similarity in the results obtained.

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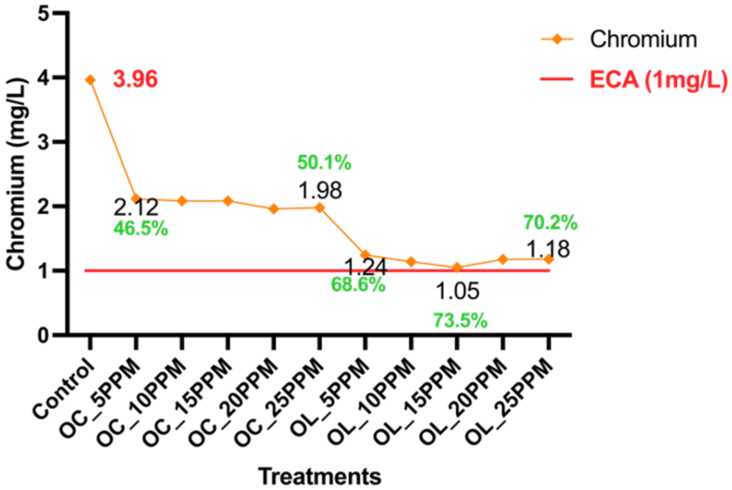


**Figure 5.** Chromium concentration before and after the treatment.

### Correlation between treatment and reduction of contaminants

Figure 6 illustrates that, upon comparing the removal percentages for each of the contaminants, *U. tuberosum* demonstrates higher efficiency in eliminating the analyzed contaminants, achieving percentages of 77.51%, 70.77%, 67.86%, and 69.1% for turbidity, chromium, cadmium, and lead, respectively. In contrast, *O. tuberosa* exhibited efficiencies of 56.46%, 48.4%, 47.02%, and 45.37% for turbidity, chromium, cadmium, and lead, respectively. The results presented in Figure 6 indicate that *U. tuberosum* exhibits greater efficiency in the removal of the analyzed contaminants compared to *O. tuberosa*. These findings suggest that *U. tuberosum* may serve as a more effective natural coagulant in the treatment of contaminated water.

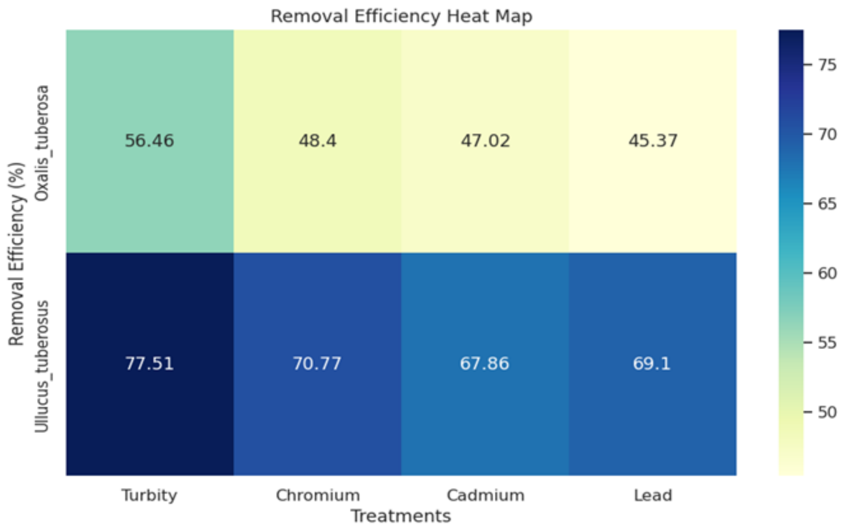


**Figure 6.** Efficiency comparison of the natural coagulants.

## CONCLUSION

This research confirmed the effectiveness of natural coagulants derived from *U. tuberosum* and *O. tuberosa* peels in eliminating contaminants from water. The optimal dosage for removing pollutants varied depending on the type of contaminant, with 15 ppm of *U. tuberosum* proving efficient for turbidity, lead, and chromium, while 25 ppm was required for cadmium removal. Additionally, the study highlighted that the coagulant extracted from *U. tuberosum* peels demonstrated superior efficiency in eliminating all analyzed contaminants. These results emphasize the potential of natural coagulants as a sustainable and efficient alternative for treating contaminated water, offering benefits such as reduced application costs and minimal sludge generation.

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