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Evaluation of using aluminum sulfate and water-soluble *Moringa oleifera* seed lectin to reduce turbidity and toxicity of polluted stream water

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HIGHLIGHTS

- Coagulants were evaluated for reduction of turbidity and toxicity of Cavouco stream water.
- The treatments used aluminum sulfate (AS) and water-soluble *Moringa oleifera* seed lectin (WSMoL) both separated and together.
- Treatment using AS followed by WSMoL was the most effective in reducing turbidity.
- The use of WSMoL after AS treatment decreased the residual aluminum concentration.
- Reduction of ecotoxicity was also detected in water treated with AS and WSMoL.

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ABSTRACT

Aluminum salts are used as coagulants in water treatment; however, the exposure to residual aluminum has been associated with human brain lesions. The water-soluble *Moringa oleifera* lectin (WSMoL), which is extracted with distilled water and isolated by chitin chromatography, has coagulant activity and is able to reduce the concentration of metal ions in aqueous solutions. This study evaluated the potential of using aluminum sulfate and WSMoL to reduce the turbidity and toxicity of water from the Cavouco stream located in Recife, Pernambuco, Brazil. The water sample used (called P1) was collected from the stream source, which was found to be strongly polluted based on physicochemical and water quality analyses, as well as ecotoxicity assays with *Artemia salina* and seeds of *Eruca sativa* and *Lactuca sativa*. The assays combining WSMoL and aluminum sulfate were more efficient than those that used these agents separately. Furthermore, the greatest reduction in turbidity (96.8%) was obtained with the treatment using aluminum sulfate followed by WSMoL, compared to when they were applied simultaneously (91.3%). In addition, aluminum sulfate followed by WSMoL treatment resulted in residual aluminum concentration (0.3 mg/L) that was much lower than that recorded after the treatment using only the salt (35.5 mg/L). The ecotoxicity of P1 was also strongly reduced after the treatments. In summary, the combined use of aluminum sulfate and WSMoL was efficient in promoting a strong reduction of turbidity and ecotoxicity of a polluted water sample, without resulting in a high residual aluminum concentration at the conclusion of the treatment.

1. Introduction

The release of large amounts of waste inadequately treated or with no treatment has multiple environmental impacts on aquatic

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ecosystems (Costa et al., 2008; Frinhani and Carvalho, 2010; Orias and Perrodin, 2013; Yagub et al., 2014). This waste disposal usually results in an increase in the biological oxygen demand of the receiving waters, leading to the exhaustion of dissolved oxygen, death of aerobic bacteria, and disturbance of the entire aquatic ecosystem. Changes in pH, the formation of suspended solids (that can harm fish gills and cause asphyxiation), as well as the adherence of toxic substances (like heavy metals and pesticides) to the suspended particles have also been observed (Schueler, 2000; Burton Jr. and Pitt, 2001; EPA, 2005; Ghaly et al., 2014; Dasgupta et al., 2015).

To date, the environmental monitoring of water bodies has been based on chemical analyses that quantify pollutant concentrations. However, chemical characterization alone is not enough to determine the quality of the water and the degree of danger that it may cause to plants and animals. The contaminants may suffer biotransformations, which result in more or less toxic forms being produced, that can migrate to the sediment and through food webs (Espíndola et al., 2000 ; Zagatto and Bertoletti, 2006; Hwang et al., 2009). Therefore, recent studies have been conducted to assess the toxicity of water bodies. Usually, it is not always possible to identify the acute and chronic toxicity of water from large water bodies, even though these environments may be strongly affected by pollution. Thus, ecotoxicological studies are important to characterize the ability of an environment to accumulate pollutants (Borrely et al., 2002; Hwang et al., 2009).

The Cavouco stream is located in Recife, Pernambuco, Brazil, and its source (8° 2′ 52″ S, 34° 57′ 10″ W) is situated at the campus of the *Universidade Federal de Pernambuco* (UFPE). According to Araújo and Oliveira (2013), the stream receives pollution loads of chemical waste sourced from activities of the research laboratories and health facilities, as well as domestic waste dumped by the surrounding population.

The coagulation-flocculation method is used to remove many types of organic and inorganic materials, such as oils, fats, metals, phosphorus, and matter in suspension. This method is widely used in water treatment techniques and some of the most used coagulants are aluminum or iron salts. The aluminum ion has a strong capability of complexation with organic molecules and neutralization of particle charges, promoting the formation of aggregates (Zouhri et al., 2015). However, the exposure to residual aluminum used in water treatment has been associated with the development of brain lesions in humans (Manivannan et al., 2015; Chen et al., 2016). The Environmental Protection Agency (EPA) has recommended a Secondary Maximum Contaminant Level of 0.05–0.2 mg/L of aluminum in drinking water. The Food and Drug Administration (FDA) has determined a limit for bottled water of 0.2 mg/L of aluminum (ATSDR, 2008). According to Resolution number 357 of the *Conselho Nacional do Meio Ambiente* (CONAMA), the Brazilian Environmental Council, the maximum aluminum concentration should be 0.1–0.2 mg/L for fresh waters (CONAMA, 2005).

Moringa oleifera Lam. is a plant used in various biotechnological fields, and is applied in the pharmaceutical, cosmetic, and food industries (Santos et al., 2015). *M. oleifera* seeds have been commonly used to treat water, including for human consumption use, and studies have confirmed their coagulant property. This property is attributed to the presence of organic polyelectrolyte, cationic proteins, and lectins (carbohydrate-binding proteins) (Gassenschmidt et al., 1995; Ndabigengesere et al., 1995; Okuda et al., 2001; Santos et al., 2009; Ferreira et al., 2011).

A problem associated with the use of crude preparations from *M. oleifera* seeds is the introduction of a considerable amount of organic matter into the system. In addition, it has been reported that the water extract from *M. oleifera* seeds exerts cytotoxic and genotoxic effects on human cells and bacterial strains proper for these studies. However, this toxicity is not linked to the water-soluble fraction but is attributed to the insoluble lipid components that remain in the supernatant after extraction of seed compounds with water (Rolim et al., 2011; Al-Anizi et al., 2014). In this sense, studies that evaluate the action of purified coagulants from *M. oleifera* seeds are welcomed.

The water-soluble *M. oleifera* lectin (WSMoL) is a chitin-binding protein that demonstrates antibacterial and insecticidal activities (Coelho et al., 2009; Santos et al., 2012; Moura et al., 2015). WSMoL was reported to be non-genotoxic and non-mutagenic by DNA plasmid and Kado/Ames assays as well as showed to be non-cytotoxic to human peripheral blood mononuclear cells (Rolim et al., 2011; Araújo et al., 2013). The coagulant property of WSMoL was shown in a turbid water model using kaolin and was linked to the anionic nature of this protein and its ability to promote lowering of electric resistance of the medium (Ferreira et al., 2011; Moura et al., 2016). Another study showed that WSMoL was able to reduce the concentration of several metal ions in aqueous solutions, including aluminum, whose concentration decreased by 49.36% after treatment with this lectin (Freitas et al., 2016). These previous results on the toxicological safety and metal removal property of purified WSMoL influenced us to choose this lectin to perform this work.

In this present research, we investigated the efficacy of using aluminum sulfate and WSMoL for the treatment of a water sample from the Cavouco stream, employing these coagulant agents both separately and together. In addition, we investigated whether the use of WSMoL would be able to reduce the residual aluminum concentration in the treated water.

2. Materials and methods

2.1. Water samples from the Cavouco stream

In order to choose the ideal water sample to be treated, we collected samples at different points along the Cavouco stream and submitted them to screening tests of water quality and ecotoxicological assays. The most affected and toxic sample was used in the assays of water treatment with WSMoL and/or aluminum sulfate as coagulant agents.

Water samples were collected during September 2015 at five points along the Cavouco stream as described by Araújo and Oliveira (2013). All these sampling points were located within the campus of UFPE and were named P1, P2, P3, P4, and P5 (Fig. 1). These points were numerated according to the course of the stream, with P1 corresponding to the stream's source. The samples were taken at an average depth approximately 10 cm from the surface. The collected samples were stored in polyethylene terephthalate bottles (2 L) and immediately sent to the laboratory, where they were stored at 4 °C until analysis.

2.2. Plant material

Seeds of *M. oleifera* were collected at the campus of UFPE, with authorization (No. 36301) from the *Instituto Chico Mendes de Conservação da Biodiversidade* (ICMBio) of the Brazilian Ministry of the Environment. A voucher specimen (73,345) has been deposited at the herbarium *Dárdano de Andrade Lima* of the *Instituto Agronômico de Pernambuco* (Recife, Brazil). The seeds were powdered using a blender and the flour was stored at −20 °C.

2.3. Physicochemical and water quality analyses of samples

Physicochemical parameters (turbidity, conductivity, total