

# Application of Biosorbent Derived from Cactus Peel for Removal of Colorful Manganese ions from Ground Water

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**Abstract:** Access to ground water is a human right, yet more than 80% people of Ethiopia, especially in rural areas, rely on unimproved sources and the need for finding ways of treating water is crucial. Although the use of natural biosorption coagulant agricultural waste product in drinking water treatment has been discussed for a long time, the method is still not in practice, probably due to availability of material and limited knowledge. In this study, Cactus Peel agricultural waste product made from plant materials found in Adigrat city was applied as coagulation biosorption for treatment of heavy metal in ground water. The Natural Biosorption of Cactus peel were applied based on their size particle as it is without addition of any additive chemicals for treatment of water and at room temperature without any extra cost. Based on particle sizes their efficiencies of treatment, 36.02% for  $S_1$ , 17.10% for  $S_2$ , 22.80% for  $S_3$  based on Colorful Mn metal/ion concentration were obtained. High treatment efficiencies were recorded at particle sizes of  $S_1$ (10mm, 0.5gm).

**Keywords:** Biosorbent, Cactus Peel, Coagulation, Manganese

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## 1. Introduction

The increase of accessibility of potable water has been lowest in the least developed countries and amongst the poorest people and there are great disparities between the regions of the world. The situation is worst in sub-Saharan Africa, where 40% still do not have improved water and in this area the population growth exceeds the number of people that have gained access to improved water sources. Water from boreholes is often too hard and although most people in the urban area have access to water treated by the municipality through tap or protected pumps; this water is rarely fit for drinking unless treated first [1].

The target of drinking water treatment is to remove colloidal material and impurity suspended as matter in the bodies of water, to achieve the quality drinking water guidelines [1]. Conventional technique is mostly used for surface water treatment. It typically includes chemical coagulation followed by flocculation, sedimentation, filtration and disinfection. There are many steps in water treatment processes, one of which is water treatment processes which can be applied for removal of suspended particles and colloidal material in raw water cause turbidity, synthetic organic polymers and inorganic coagulants can use

as resource in water treatment or can use natural resource as coagulant. Common artificial coagulants are aluminiumsulphate, polyaluminium chlorides, ferric chloride, and synthetic polymers. All of these coagulants have in common the ability of producing charged ions when liquefied in water, which can contribute to charge neutralization [2]. Aluminiumsulfate (alum) is a common coagulant generally utilized in water treatment. Alum increases concerns when introduced into the environment towards ecotoxicological impact regarding the application of artificial polymers, the occurrence of remaining monomers is unwanted and have many carcinogenic characteristic [2, 3]. When conventional coagulation is used, chemical coagulants such as iron and alum salts are needed but, natural coagulants such as the seeds from many plants can also be used.

Coagulation is an important step in water treatment processes not only for adsorbing the particles but because it is also for removing the microorganisms that are often attached to the particles. That is, by removing turbidity, coagulants also have the possibility to remove pathogens and to significantly improve water quality and, subsequently, human health.

The aim today is how to give other people access to uncontaminated drinking water by cost effective means, particularly the rural people who can't afford any water

treatment chemicals, without affecting the health of their environment. Many countries such as Sudan, Malawi, Zimbabwe and Zambia use plant seeds to cause sedimentation in their own water storage vessels in the home [4].

Water treatment processes exist in many parts of the world to provide safe drinking water and most commonly the municipalities carry out this service through physical and chemical processes.

Currently, the need for better quality water for everyday activities economically, increased the number of treatment units, and the lack of financial investments for the treatment and supply of this product, especially in developing countries, has stimulated research that render the coagulation and flocculation processes more efficient, allowing to increase the production of water without any change in physical body of ETAs and the application of natural polymers as coagulants and coagulant aids primarily or as flocculation [4,5].

In the present work, we described the use of an effective and inexpensive plant waste product of Cactus Peel biosorption material for the removal and treatment of Cadmium, Lead and Manganese species from ground water.

### 1.1. Application of Agricultural Biosorption for Treatment of Water

Coagulation is an essential process in the treatment of industrial or ground contaminated water. Examples of chemical based coagulants that are available commercially include lime, alum, ferric chloride and poly-aluminum chloride. While the effectiveness of these chemicals as coagulants are well noted, there are none the less, disadvantages linked with usage of these coagulants such as comparatively high costs, harmful effects on human health as well as the fact that they appreciably affect the pH of treated waters [1-3]. As such, it is desirable to substitute these chemical coagulants with cost-effective natural coagulants to offset the aforesaid disadvantages. Cactus (Opuntia) exhibited high turbidity removal efficiency [1,4].

Coagulation is a vital process in the treatment of both surface water and industrial wastewater. Its application includes removal of dissolved chemical species and turbidity from the aforesaid water via addition of chemical-based coagulants such as alum ( $\text{AlCl}_3$ ), ferric chloride ( $\text{FeCl}_3$ ) and polyaluminium chloride (PAC). While the effectiveness of these chemicals as coagulants are well noted [6, 7] there are, nonetheless, drawbacks associated with usage of these

coagulants such as relatively high procurement costs, detrimental effects on human health, production of large sludge volumes as well as the fact that they significantly affect the pH of treated water. It is therefore, desirable to replace these chemical coagulants with cost-effective natural coagulants to counteract the aforementioned drawbacks.

Research on natural coagulants have been focused on *Moringa oleifera* [3-7] for the past two decades but more researchers are studying application of other natural coagulants such as long bean extract and cactus opuntia. It was determined, via two separate studies, that standalone long bean extract [8] was ineffective in removing turbidity while cactus opuntia [9] exhibited high turbidity removal efficiency for sewage and seawater treatment. Hence, the positive outcome of the latter study justifies further research on usage of cactus opuntia as a natural macromolecular coagulant to treat other types of highly turbid wastewater such as landfill Leachate.

The previous literature review indicates [9], Coagulation is an important wastewater treatment process used to reduce water turbidity and normally precedes the more complex secondary and tertiary water treatment process. The effectiveness of a natural coagulant derived from a cactus species for turbidity removal from dye industry effluent and their parameters such as pH as well as colour were also studied. The objectives of this study will be to apply and evaluate the effectiveness of biosorption of cactus peel for Cd, Pb and Mn removal from Ground water and determine the effect of dosage and Particle size of cactus powder on heavy metal removal and treatment efficiencies.

### 1.2. Conventional Water Treatment Processes

Water treatment processes exists in many parts of the world to provide safe drinking water and most commonly the municipalities carry out this service through physical and chemical processes. Drinking water treatment involves a number of combined processes based on the quality of the water source such as turbidity, amount of microbial load present in water and the others include cost and availability of chemicals in achieving desired level of treatment.

Generally drinking water treatment protocols consist of two major steps: coagulation/flocculation and disinfection (Figure 1). Commonly alum (aluminum sulfate) is used as a coagulation agent, as it is efficient and relatively cost-effective in developed countries; while, disinfection is achieved by the addition of chemical disinfectants like chlorine-based compounds.

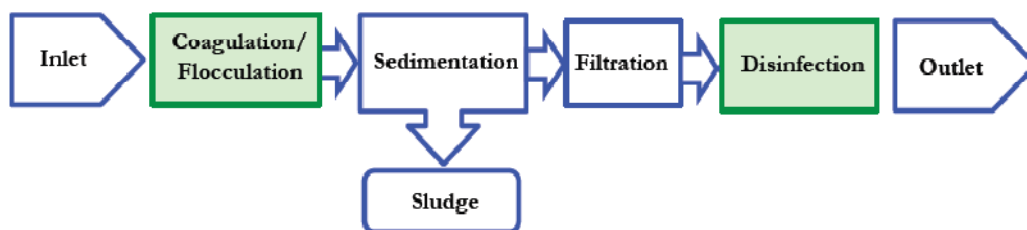


Figure 1. Schematics over conventional water treatment process [9].

### 1.3. Cactus Wastewater Treatment Plant

Biodredging provides cost-effective and environmentally-friendly residuals removals of unwanted material from water source were practiced by the GWI, 2009, American Water Resources management; awards represent what the industry perceives as being the most deserving of merit during the year 2009.

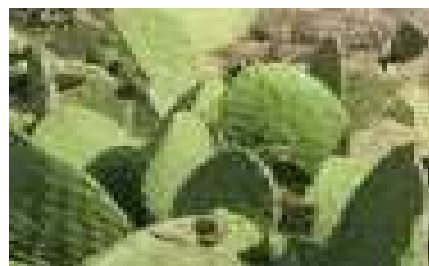


Figure 2. Cactus plant Leaf and Fruit.

### 1.4. Chemical Composition of Cactus *Opuntia* with *Moringa Oleifera*

Elemental analysis (Table 1) was carried out to provide a preliminary comparison between the elemental compositions of the cactus with that of a conventional natural coagulant, *Moringa oleifera* as determined by

Literature, cactus opuntia contained 2.3% nitrogen, 29.4% carbon and 1.7% hydrogen. “*Cactus opuntia* is known to contain 2.3% nitrogen, 29.4% carbon and 1.7% hydrogen (As can be seen in Table 1, the carbon percentage of both the shelled and non-shelled *Moringa* were almost twice the carbon percentage of cactus. This is attributed to the composition of *Moringa* which consisted of more organic matter as compared to cactus.

Table 1. Elemental analysis of natural coagulants.

Content	Cactus opuntia	Shelled seeds	Moringa	Non-shelled Moringa seeds
N%	2.3	6.1		5.0
C%	29.4	54.8		53.3
H%	1.7	8.5		7.7

### 1.5. Effect of Cactus Dosage on Turbidity Removal from Surface Water

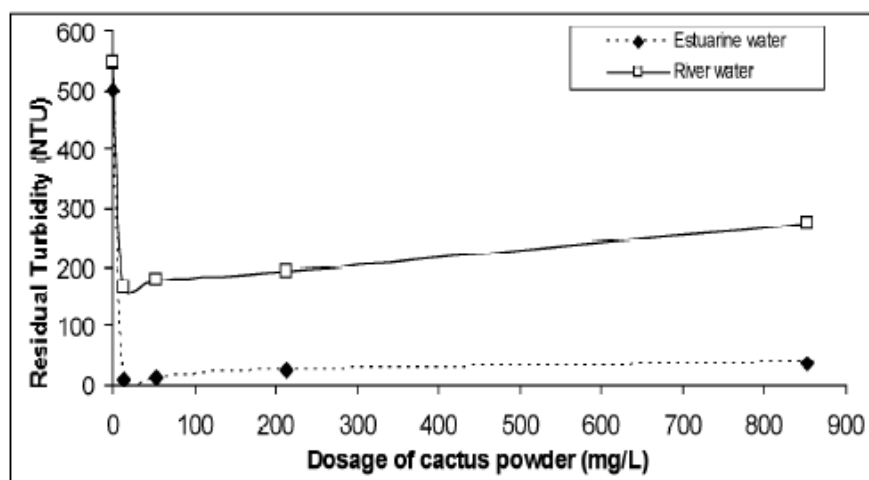


Figure 3. Effect of dosage of cactus powder on turbidity of estuarine and river water.

Literature reviews reveal that the powdered cactus formed large flocs with impurities in the sample which facilitated settling and as a result, clear supernatant was produced. Similar observation was also noted for treated river water. Figure 1 shows the effect of dosage of cactus powder on residual turbidity of surface water.

### **1.6. Chemistry of Heavy Metal and Their Exposure**

By definition, heavy metals are any metallic chemical element that has a relatively high density (superior to 5 g/cm<sup>3</sup>); most of them are toxic or carcinogenic even at low concentrations, such as mercury (Hg), cadmium (Cd), arsenic (As) and chromium (Cr).

Poisoning by exposure to heavy metal is well known to affect central nervous function, damage blood composition, lungs, kidneys, liver and other vital organs. Long-term exposure can cause slower progressing physical, muscular, and neurological degenerative processes. Allergies may also occur and repeated long term contact with some metals, or their compounds may become carcinogenic [10].

### **1.7. Manganese Metals in the Environment**

Mn is present in the solid phase and in solution, as free ions, MnCl<sub>2</sub>, MnSO<sub>4</sub>, or in salt forms, MnO<sub>2</sub>, as a mineral *pyrolusite* or adsorbed to soil colloidal particles. The heavy metal concentration in topsoil is a result of soil-forming processes, as well as agricultural and human activities [10].

Heavy metals are currently of much environmental concern. These metals are dangerous because they tend to bioaccumulate the food chain and they are harmful to humans and animals. Bioaccumulation means an increase in the concentration of a chemical in a biological organism over time, compared to the chemical's concentration in the environment. The threat that heavy metals pose to human and animal health is aggravated by their long-term persistence in the environment [10, 14].

Estimation of the migration ability of any pollutant in the natural environment is considered to be a necessary stage for predicting the ecological situation.

Manganese is a mineral that naturally occurs in rocks and soils and is a normal constituent of the human diet. It exists in well water as a naturally occurring ground water mineral but more also are present due to underground pollution sources. Mn may become noticeable in tap water at concentrations greater than 0.05mg/l by parting the color, odor, or taste of the water. Mn is seldom found alone in water supply; It is frequently found in iron bearing waters but it is more rare than iron. When Mn is present in water; its every bit is as annoying as iron perhaps even more so. In low concentrations it produces extremely objectionable stains on everything with which it comes in contact. Deposits collect in pipe lines and tap water may contain black sediment and turbidity due to precipitated Mn [10-14].

When fabrics are washed in Mn bearing water dark brown or black stains are formed due to the oxidation of the

manganese. The US EPA secondary drinking water regulations recommend a limit of 0.05mg/l Mn because of the staining which may be caused. It is a hard metal and is very brittle. It is hard to melt but easily oxidized. Manganese (Mn) is easily reactive when pure and as a powder it will burn in oxygen. It reacts with water and dissolves in dilute acids.

### **1.8. Health Effect of Mn**

Exposure to high concentration of manganese over the course of years has been associated with toxicity to the nervous system, producing a syndrome that resembles Parkinsonism. This type of effect may be more likely to occur in the elderly. Manganese is unlikely to produce other types of toxicity such as cancer or reproductive damage. Manganese (Mn) is very common compound that can be found everywhere on earth. Manganese (Mn) is one out of three toxic essential trace elements which means that it is not only necessary for human to survive but it is also toxic when too high concentrations are present in a human body [10-14].

## **2. Methodology**

### **2.1. Description of Study Area**

The present study is conducted in Adigrat University, in northern part of Ethiopia. Adigrat is a city of eastern zone Tigray; that found in Tigray regional state of Ethiopia. It is located in the eastern zone around 900 km far from Addis Ababa which is capital city of Ethiopia with longitude 14°16'N 39°27'E coordinates and latitude 14°16'N 39°27'E with an elevation of 2457meters above sea level [15, 16]. Adigrat is gifted with ground water which is their population used for house hold level activity as a source of water. The largest pharmaceutical manufacturing plant in Ethiopia, 'Addis Pharmaceuticals Factory SC, Walwallo Alcohol Factory SC, includes small scale industries are also located in Adigrat.

### **2.2. Cactus and Water Sampling and Analysis**

#### **2.2.1. Samples Collection**

Cactus peel and groundwater samples were collected systematically from the sources during survey times. The cactus samples were collected in plastic bags. The water sample was also collected simultaneously by using plastic bottles from selected site.

#### **2.2.2. Preparation of Samples**

Fresh cactus peel sample were collected from agricultural farm lands surrounding the study areas of Adigrat city, as its availability and transportation is easy. Then the leaves of cactus sample collected were first washed by tap water followed by distilled water, to eliminate air borne pollutants. The peels were allowed to dry in shade for 4-6 days until all the moisture content is lost from it and the color change could be observed from yellow to brownish black. Using the

domestic mixer the peels were incompletely powdered for later usage in sieve analysis unit to obtain different fractions of peels.

### 2.3. Mechanical Shaking of Biosorption with Analyte by Centrifuge Stirrer Test

Centrifuge Stirrer test was used to determine the effectiveness of using cactus powder as coagulant. The test was conducted using centrifuge stirrer apparatus using 20ml to 50ml centrifuge test. Raw effluent sample of 20ml were stirred in the stirrer. Cactus powder of dosages of 0.5 and 0.8 grams were added to the effluent samples. This mixing stage was conducted at 150rpm. After a period of time natural coagulation gets started and the samples were allowed to stand for 30 minutes after each treatment was completed (settling stage). Then the filtrates were digested by 3ml of Conc.  $\text{HNO}_3$  at  $150^\circ\text{C}$  for half hour; clear solution contain blue-black like oil was filtered, diluted to 50ml. Then, Uv-visible Absorption Spectrophotometer was applied based on

the color of the solution which was detectable in the visible region of absorbance related with the original analyzed sample. Since manganese ions are colorfully due to the presence of d-electron, absorbance was done at 400nm-480nm. The result of the absorbance also indicated only the Mn ions which were colorful and easily detectable.

## 3. Results and Discussion

### 3.1. Heavy Metal Concentration in Ground Water before and after Treatment

Figure 4 shows the heavy metal concentration in ground water before and after treatment with Cactus peel biosorption were recorded by Uv-Vis Spectrophotometer at 400- 480nm for Mn metal concentrations. The potential of biosorbent Cactus peel was determined related with the original sample of ground water.

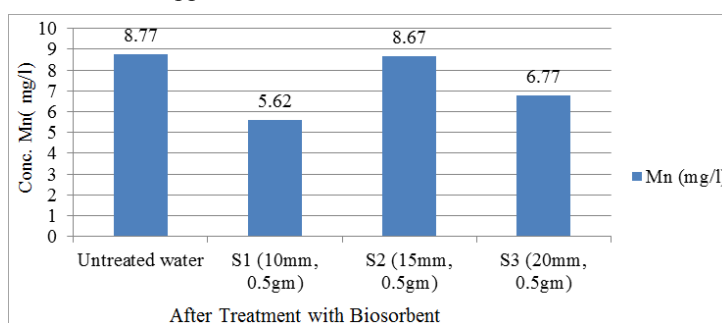


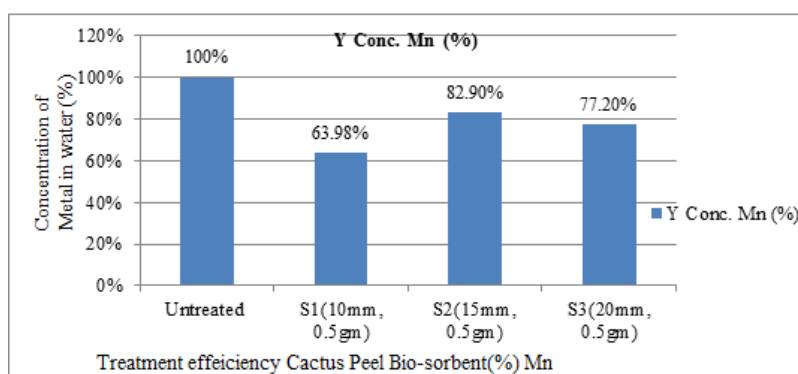
Figure 4. Reduction of Mn concentration by Biosorbent Cactus Peel in Water Samples.

At each different size of biosorption the concentration of metal recorded in each sample were less than the concentrations of metals in original sample. At each size more than 0.1- 3.15mg/l of concentrations Mn were reduced. Biosorption Cactus Peel has high potentials to adsorb Mn ion to it.

### 3.2. Treatment Efficiency of Bio-Sorption Cactus Peel for Removal of Metal Available in Water

The treatment efficiency of biosorption Cactus peel under this investigation was determined relative to the

concentration of metal in original sample and the results were obtained after several treatment stages. The treatment values of Mn metal/ion were analyzed based on different sizes of biosorbent Cactus peel at normal pH value of water or without using additive materials and at room temperature. The removal of Mn concentration in ground water obtained at different particle sizes of biosorption were, 36.02% ( $S_1$ ), 17.10% ( $S_2$ ) and 22.80% ( $S_3$ ). The highest treatment efficiency was determined at  $S_1$  (10mm, 0.5gm), when the lowest obtained at  $S_2$  (15mm, 0.5gm).



\*Key:- 100%Mn = 8.77mg/l,

Figure 5. Treatment efficiency of Biosorbent Cactus peel for removal of Mn metals in water.



Figure 5, recommended that the treatment efficiency determine at  $S_1$  (10mm, 0.5gm) was higher for metal absorption in ground water. Therefore also the lowest treatment efficiency of biosorbent Cactus peel was obtained at larger size of biosorbent for both metal/ion. The results show the reduction of treatment as the size of particle biosorbent increases. Therefore the message observed from Figure 5 showed that the biosorbent derived from the Cactus peel for removal of toxic metal from source water can be easily applicable at house hold level without any cost.

#### 4. Conclusion and Recommendation

In the present investigation it was evident that Biosorbent cactus peel can be used as low cost-effective of plants waste product used as biosorbent for the removal of Mn metal from ground water. The treatments values determined were stimulated the potential value of natural biosorbent cactus peel to be highly size dependent. It was observed that maximum percentage removal for each metal was observed at smaller size. This paper give an evidence on biosorbent derived from cactus peel for removal of metals/ions in water can be easily applied as house hold level; without requiring any additional additive chemicals, but by adjusting only their particle size.

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