ADDIS ABABA UNIVERSITY

COLLEGE OF NATURAL AND COMPUTATIONAL SCIENCES

DEPARTMENT OF CHEMISTRY

The Efficiency of Moringa Seed for the Adsorption of Heavy Metals from Tannery Effluents (Cr, Co, Pb, Cu, Cd)

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The Efficiency of Moringa Seed for the Adsorption of Heavy Metals from Tannery Effluents

A Graduate Project Submitted to the Department of Chemistry in Partial Fulfillment of the Requirements for the Degree of Master of Science in Chemistry

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This is to certify that the project prepared by Hailegiorgis Tsegaye entitled the efficiency of moringa seed for the adsorption of Cr, Co, Pb, Cd and Cu from tannery effluents using Microwave Plasma Atomic Emission spectroscopy (MP-AES) and submitted to the department of chemistry in partial fulfillment of the requirements for the degree of master of science in chemistry complies with the regulation of the university and meets the accepted standards with respect to originality and quality.

Approved by Examining board:

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LIST OF ABBREVIATIONS

M. stenopetala	*Moringa stenopetala*
M olifera	*Moringa olifera*
US EPA	United States Environmental Protection Agency
ED	Electrodialysis
MP-AES	Microwave Plasma- Atomic Emission Spectroscopy

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The Efficiency of Moringa Seed for the Adsorption of Heavy Metals from Tannery Effluents

ABSTRACT

Heavy metals are the most harmful of the chemical pollutants and are of particular concern due to their toxicity to humans. *Moringa stenopetala* seed acts as a natural adsorbent for the removal of heavy metals from waste water. This study dealt with removal of heavy metals from the river water polluted by Dire Leather Tannery effluent located in Winget area. Analysis of the heavy metals cadmium, copper, chromium, cobalt and lead was performed before and after treatment of the water with *Moringa stenopetala* seed powder. The adsorption efficiency of the powdered *Moringa* seed was evaluated as the function of adsorbent dosage and contact time. Microwave Plasma-Atomic Emission Spectrometer (MP-AES) technique was used for the measurement of concentration of the metals before and after adsorption. Only chromium was found in a significant concentration in the sample water before adsorption. The results showed that *Moringa* seeds were capable of adsorbing the heavy metal tested in the water sample. The percentage removal of the adsorbent was 95 percent for chromium at optimum dose of 6g and stirring time of 2.5 hours for 100 ml of the sample water.

1. **Introduction**

Environmental pollution, which arises from the development of modern industrial activities, is one of the most significant problems of the country. Most industrialists try to discharge their waste water effluents inadequately treated or totally untreated, directly to rivers or nearby water bodies, and land without considering the level of damage it may bring to the local community. Water pollution occurs when a body of water is adversely affected by the addition of large amount of waste material to the water body, making it unfit for whatever intended usage. The water pollutants are normally classified into physical, chemical and biological origin depending on the source of the pollutants [1].

Among the category of water pollutants, chemical pollutant particularly heavy metals are the most harmful pollutant and are of particular concern due to their toxicity to human health. They find their way into water bodies as effluent waters from domestic homes, from manufacturing industries and agricultural application of chemicals as well as from heaps of solid refuse dump sites [2, 3]. Different industries such as mining; energy and fuel production; electroplating; atomic energy installation and leather manufacturing, etc discharge their wastes containing different heavy metals into the environment. Heavy metals are generally not removable even after the treatment at treatment plant and thus, long time exposure can cause human health risk of heavy metal contamination/pollution of water, soil and subsequently the transfer of heavy metal into the food chain to affect body organs like spleen. Removal of heavy metals from waste waters has been achieved through chemical precipitation [4, 5], ion exchange [6, 7], ion floatation [8, 9] adsorption [5, 10–12], reverse osmosis [13–17], and membrane filtration [8–10, 18]. Although these conventional methods have higher capacity for the removal of toxic heavy metals, their utilization may require several pretreatments as well as additional treatments, thereby incurring high installation and operating cost [19, 20].

Due to these challenges, there is the need for safer, economical, and effective ways for removal of heavy metals from water. Recently, use of low cost sorbents has focused attention on use of biological materials as a considerable potential solution for removal and recovery of pollutants from industrial effluents [21–27]. These materials have the following advantages: they (i) are readily available, (ii) require little or no processing, (iii) possess good adsorption capacity even for low-level metal concentrations, (iv) have got selective adsorption for heavy metal ions, and

(v) can be easily regenerated [28–30]. Such materials include use of plant parts from indigenous trees like Moringa. These tropical multipurpose trees can be easily cultivated and are adaptable in semiarid climates; hence, they can be beneficial to developing world like Ethiopia. Most parts of these trees are edible and very beneficial to human beings and have a lot of applications.

1.1 Overview of Moringa

The *Moringaceae* or Horseradish tree is the family of trees that consists of 13 different species, of which *Moringa oleifera* is the most widely cultivated. Moringa is native to the sub- Himalayan parts of Northern India, Pakistan, Bangladesh and Afghanistan. Moringa is a multi-purpose food plant, which originated, produced and used in many African countries, South America and New Zealand. However, it has been cultivated in many parts of the world and can now be found in almost all tropical countries. *M. oleifera* typically grows in semi-dry, desert or tropical soils. Almost all parts of this plant: root, bark, gum, leaf, fruit (pods), flowers, seed and seed oil have been used for treating various ailments [31].

Moringaceae have been found to serve many different purposes. They can be used as a food source, as animal fodder and medication as well as for live fencing. The seeds have traditionally also been used as a domestic water purifier agent, as they have been known to decrease the turbidity of water. These properties have later been documented and described in several studies, although the involved mechanisms are only partly known. Recently, studies have shown that Moringa seeds can reduce total coliform and microbial counts [32].

Moringa oleifera tree (drumstick tree) is a rapid growing deciduous shrub or small tree of about 13 m tall and 35 cm in diameter with an umbrella-shaped open cap [29]. *Moringa oleifera* is the most widely distributed species of the *Moringaceae* family throughout the World. It has also been reported that *Moringa oleifera* oil and micronutrients contain antitumor, antiepileptic, antidiuretic, anti-inflammatory and venomous bite characters. *Moringa oleifera* contains specific plant pigments with demonstrated powerful anti-oxidative ability such as vitamins C, E, A, caffe-oylquinic acids, carotenoids-lutein, alpha-carotene and beta carotene, kaempferol, quercetin, rutin [33].

In southern Ethiopia, the species *Moringa Stenopetala* is widely cultivated and is called by the name “Shiferaw”tree [34].

The interest in Moringa as a natural coagulant for water purification has been rising in recent years, as the need for low-cost wastewater treatment methods is growing in developing countries. The use of natural coagulants also provides an alternative to reliance upon chemicals, whose effects on human and environmental health have not always been fully shown. In order to further evaluate the properties of Moringa seeds as a wastewater purification agent, studies conducted to evaluate its ability to reduce metal concentrations showed complete sorption of Cd^{2+}, Zn^{2+} and Cr^{3+} ions above certain pH levels at metal concentration of 4 ppm. The sorption for Cr^{3+} was complete at pH levels 4-6, depending on the Moringa species. The study involved two species from the family *Moringaceae*: *Moringa stenopetala (M.stenopetala)* and *Moringa oleifera (M.oleifera)*. For *M.oleifera*, the maximum removal occurred for pH 6 [35].

Although both species completely removed the metal ions above a certain pH, *M. stenopetala* showed a slightly better sorption capacity at most pH values. The successful outcome for both *M.oleifera* and *M.stenopetala* was partially attributed to the metal cations forming complexes with the Moringa proteins. This was further investigated by researchers, who conducted an in-depth study of the mechanisms of metal remediation using seed powder from the species *M.oleifera*. The results indicated that the oxygen donating carboxylate (-COOH), along with various amino ($-NH_2$) groups in the *M.oleifera* seed extract, form complexes with copper(II) and mercury(II), while chromium(III) undergoes polymeric hydrolysis and forms complexes [35].

The moringa seed pod, the unpeeled seed and the peeled seed are shown in the following figure.

Seedpods Unpeeled seeds Peeled seeds

Figure 1. Peeled, unpeeled and pods of Moringa seed.

The powdered seed act as a natural flocculent, able to clarify even the most turbid water. The seed powder can be used as a quick and simple method for cleaning dirty water. The powder joins with the solids in the water and sinks to the bottom. This treatment also removes 80-90% of bacteria contained in the water. Using Moringa to purify water replaces chemicals such as aluminum sulphate, which are dangerous to people and the environment, and are expensive [28].

1.2 The Pollution of Tanning Industry

Tannery industry is one of the most polluting and hazardous manufacturing sectors due to generation excessive solid, liquid and gaseous pollutants. Treating the tannery effluent contaminated with heavy metal with in the industrial premises before being discharged in to the environment (nearby rivers) is the efficient way to remove heavy metals rather than treating high volumes of wastewater in a general sewage treatment plant.

Heavy metals do not degrade to harmless end products [30,36]. It is well established that the presence of heavy metals in the environment, even in moderate concentrations, is responsible for producing a variety of illnesses of the central nervous system (manganese, mercury, lead, arsenic), the kidneys or liver (mercury, lead, cadmium, copper) and skin, bones, or teeth (nickel, cadmium, copper, chromium) [37].

Due to its properties, water is particularly vulnerable to contamination with heavy metals. Table 1 shows the maximum limits for some metals in drinking water, according to the United States Environmental Protection Agency (US EPA) [38]. The US EPA requires that lead, cadmium and total chromium levels in drinking water do not exceed 0.015, 0.005 and 0.1 mg L^{-1}, respectively. Corresponding values for other metals are presented in Table 1.

Table 1. Maximum acceptable concentrations of metals in drinking water according to the US EPA [38].

Element	US EPA Limit (mg L^{-1})
Antimony	0.006
Arsenic	0.010
Beryllium	0.004
Chromium (total)	0.1
Cadmium	0.005
Cupper	1.3
Lead	0.015
Mercury	0.002
Selenium	0.05
Silver	0.1

Therefore the reduction or removal of the pollutants in tannery industry which are heavy metals discharged to the environment from tannery industry effluent to meet effluent discharges concentration of the government regulation is very important. Adsorbent such as activated carbon is one of the materials used in adsorption process, but it does not remove metals completely. Therefore, researchers had studied to find other natural resources that could be an alternative to activated carbon. Several biomaterials such as tea waste, rice husk, coconut husk and oil palm fiber are low cost agricultural residues and available in large quantities. Moringa seed is available in large quantities in southern Ethiopia. The utilization of natural and agricultural byproducts as adsorbent are not only economically feasible but instead of throwing away wastes, they could be used as heavy metal ions adsorbent to reduce environmental pollution. Therefore, it is necessary to investigate the adsorption capacity of Moringa seed because of its availability and capability of removing heavy metals from tannery wastewater.

1.3. Conventional technologies for heavy metal removal

Heavy metal removal processes are carefully considered as not only toxic heavy metal removal in environmental aspects, but also precious metal recovery in industrial aspects. Chromium contamination is common all over the world. For water resources, the impact of this contamination is severe. Consequently, it is desirable to remove chromium from contaminated waters. Many treatment processes have been developed to remove chromium from wastewater. The most important of these technologies include; chemical precipitation, filtration, ion-exchange, electrolysis, lime coagulation, solvent extraction, reverse osmosis and electrocoagulation. However, all these technologies have their inherent advantages and limitations in application. Most of the methods suffer from some drawbacks such as incomplete metal removal, low selectivity, high reagent and energy requirement, high capital and operational cost and generation of toxic sludge or other waste product that require careful disposal. This makes it imperative for a use of cost effective treatment method.

1.3.1 Chemical Precipitation

Chemical precipitation is the method, in which dissolved and suspended Cr(VI) ions are transformed to the insoluble solid through a chemical reaction. Usually a precipitating agent accelerates this conversion from Cr(VI) ions into insoluble solid. The commonly used precipitation agents are lime and magnesia. This technique has been proven as an effective way to remediate chromium from wastewater. It is a simple, inexpensive, convenient, and safe method. However, this technique requires large amounts of chemicals, and excessive toxic sludge is produced. Sludge filtration and disposal increase the overall cost of the process. Sometimes Cr(VI) precipitation is slow, and aggregation of metal precipitates takes place [39].

1.3.2. Ion exchange

Ion exchange can attract soluble ions from the liquid phase to the solid phase, which is the most widely used method in water treatment industry. However, it requires pretreatment process to reduce suspended solids concentration in solution to prevent fouling or channeling. Ion exchange resins, either synthetic or natural solid resins, has the specific ability to exchange its cation with the metals in the wastewater. The most common cation exchangers are strongly acidic resins with sulfonic groups ($-SO_3H$) and weakly acids resins with carboxylic acid groups (-COOH). Ion exchange resins have also been frequently used for the removal of chromium ions from aqueous solutions [40].

1.3.3. Reverse Osmosis

The reverse osmosis process depends upon a semi-permeable membrane through which pressurized water is forced. Reverse osmosis, simply stated, is the opposite of the natural osmosis process of water. Osmosis is the name for the tendency of water to migrate from a weaker saline solution to a stronger saline solution, gradually equalizing the saline composition of each solution when a semi-permeable membrane separates the two solutions. In reverse osmosis, water is forced to move from a stronger saline solution to a weaker solution, again through a semi-permeable membrane. Because molecules of salt are physically larger than water molecules, the membrane blocks the passage of salt particles [41]. The result is desalinated water on one side of the membrane and a highly concentrated, saline solution of water on the other side. The disadvantage of this method is that it is expensive [42].

1.3.4. Coagulation-flocculation

Coagulation is the destabilization of colloids by neutralizing the forces that keep them apart and reduces the net surface charge of the colloidal particles to stabilize by electrostatic repulsion process. Flocculation process continually increases the particle size to discrete particles through additional collisions and interaction with inorganic polymers formed by organic polymers added. Production of sludge, use of chemicals and transfer of toxic compounds into solid phase are main drawbacks of the process. The objective of the coagulation depends on the source of water and the nature of the suspended, colloidal, and dissolved organic constituents.

1.3.5. Electrodialysis

Electrodialysis (ED) is a membrane separation in which ionized species in the solution are passed through an ion exchange membrane by applying an electric potential. The membranes are thin sheets of plastic materials with either anionic or cationic characteristics. When a solution containing ionic species passes through the cell compartments, the anions migrate toward the anode and the cations toward the cathode, crossing the anion exchange and cation exchange membrane [43]. The disadvantage is the formation of metal hydroxides, which clog the membrane. In the electrodialysis process, ionic components of a solution are separated through the use of semipermeable ion-selective membranes. This process may be operated in either a continuous or a batch mode. Problems associated with the electro- dialysis process for wastewater renovation include chemical precipitation of salts with low solubility on the membrane surface. To reduce the membrane fouling, activated carbon pre-treatment, possibly preceded by chemical precipitation and some form of multimedia filtration may be necessary.

1.3.6. Heavy metal removal using biosorption

The conventional heavy metal removal processes have several disadvantages such as less effective removal of metal ion, high reagent requirement, high costs, the generation of toxic sludges, and the problem of the safe disposal of the materials. Compared with conventional methods for removal of toxic heavy metals, biosorption offers the advantages of low cost, minimization of the volume of chemical and biological sludge to be disposed of, high efficiency in detoxifying very dilute effluents, and high metal selectivity. The advantages of biosorption are cost effective, metal selective, regenerative, minimization of sludge generation, metal recovery, and competitive performance.

1.3.7. Adsorption

Adsorption is now recognized as an effective and economic method for heavy metal removal from wastewater. Adsorption is a surface phenomenon and is defined as the increase in concentration of a particular component at the surface or interface between two phases. Compound (pollutant) that sticks or adheres to the solid surface is called adsorbate and the solid surface is known as an adsorbent. Adsorption is affected by temperature, the nature of adsorbate and adsorbent, the presence of other pollutants and atmospheric and experimental conditions like pH, concentration of pollutants, contact time and particle size of the adsorbent. Biosorption of heavy metals from aqueous solutions is a relatively new process that has been confirmed a very promising process in the removal of heavy metal contaminants. The major advantages of bio sorption are its high effectiveness in reducing the heavy metal ions and the use of inexpensive biosorbents. Biosorption is particularly suitable to treat dilute heavy metal waste water. The presence of suspended particles, oils, and greases reduces the efficiency of the process and, therefore, pre-filtration is sometimes required. When a finely divided solid is shaken with the contaminated or polluted water, the pollutants adhere to the solid surface and a stage of equilibrium is established. At this stage, the concentration of pollutant adsorbed and in the water become constant. The relationship, at a given temperature, between the equilibrium amounts of pollutant adsorbed and in the water is called an adsorption isotherm. Langmuir, Freundlich and other models are well known and can explain the adsorption efficiency of a pollutant systematically and scientifically [44].

1.3.7.1. Adsorption mechanism

The classical mechanism of adsorption is divided into three steps Figure (2) a) diffusion of adsorbate to adsorbent surface, b) migration into pores of adsorbent c) monolayer build-up of adsorbate on the adsorbent. Figure (2) presents the process of adsorbate distribution. In the first step diffusion of adsorbate on the adsorbent surface occur by intermolecular forces between adsorbate and adsorbent. The second step involves migration of adsorbate into pores of adsorbent and distributribution on the surface and filling up the volume of pores. And in the last step, particles of adsorbate are building up the monolayer of reacted molecules, ions and atoms to the active sites of adsorbent [44].

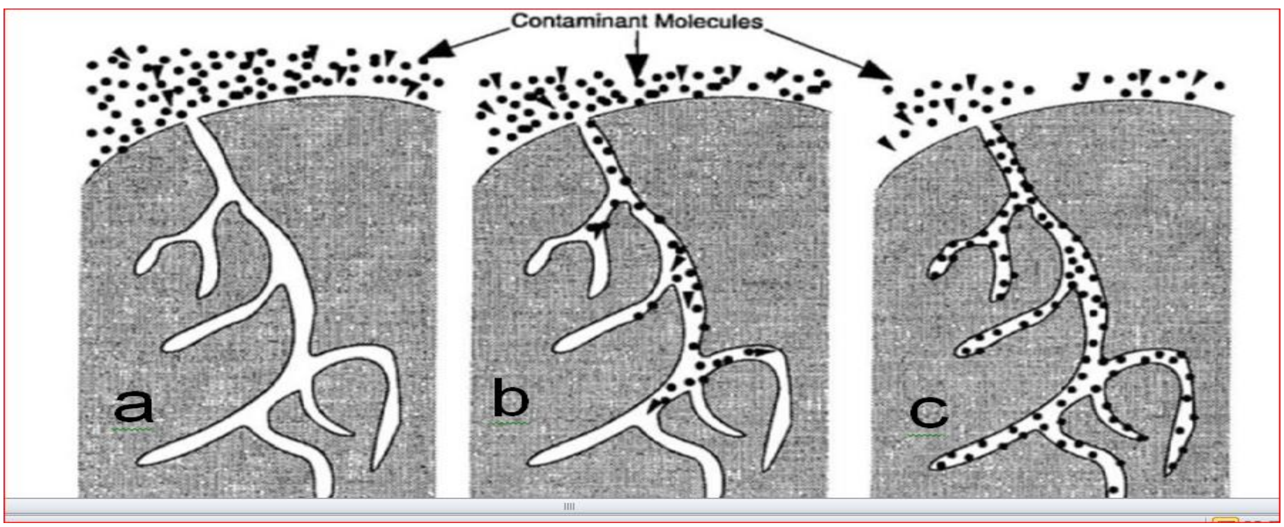

Figure 2. Three steps of adsorption mechanism: a) diffusion of adsorbate to adsorbent surface b) migration into pores of adsorbent c) monolayer build-up of adsorbate on adsorbent.

1.4. Factors affecting adsorption process

1.4.1. pH

The pH value of the metal solution plays an important role in the whole adsorption process and particularly on the adsorption capacity. The pH of the solution would affect both the aqueous chemistry and surface binding sites of the adsorbents. The effect of pH in turn depends on the charge on the adsorbent surface. If the adsorbent surface is negatively charged, at lower pH, the large number of H^+ ions present neutralizes the negatively charged adsorbent surface, thereby reducing hindrance to the diffusion, and a better adsorption is obtained. If the surface charge of the adsorbent is positively charged, the H^+ ions may compete effectively with the cations of the solution causing a decrease in the amount of metal ion adsorbed [45].

1.4.2. Contact time

The amount adsorbed on to the adsorbent is in a state of dynamic equilibrium with the amount desorbed from the adsorbent. The time required to attain this state of equilibrium is termed as the equilibrium time. The amount adsorbed at the equilibrium time reflects the maximum adsorption capacity of the adsorbent under the operating conditions [45].

1.4.3. Adsorbent Dosage

The concentration of both the metal ion and the adsorbent is a significant factor to be considered for effective adsorption process. The adsorbent dosage is an important parameter because this determines the capacity of an adsorbent. It determines the sorbent and sorbate equilibrium of the system. The effect of adsorbent dosage on adsorption was studied by varying the amount of adsorbents and keeping the other parameters constant. Chromium uptake rose with an increase in adsorbent [46]. This appears to be due to increase in the available binding sites, which is the surface area of adsorbent in the biomass for the compellation of chromium. However, the chromium uptake decreased gradually when the adsorbent concentration exceeding more. Accordingly, the chromium(III) ion in solution has been decreased drastically with the increase in the adsorbent dosage.

1.4.4. Concentration

Different initial metal concentrations and a fixed concentration of biomass were used to calculate adsorption capacity. The initial and final concentrations of the solutions were measured by Microwave Plasma-Atomic Emission Spectrometer. These data were used to calculate the adsorption capacity of the adsorbent.

1.4.5. Temperature

An increasing adsorption temperature leads increasing of particle movements at the surface of the adsorbent and this phenomenon facilitates the detachment of metals from adsorbents.

2. Objectives of the study

2.1. General objective

The main objective of this study was to determine the efficiency of powdered moringa seed for the adsorption of chromium and cobalt from tannery effluents

2.2. Specific objectives

The specific objectives were

- to investigate the effect of selected process variables (time and adsorbent dosages) on the adsorption performance of moringa seed powder.
- to determine removal efficiency of the adsorbent

3. Experimental

3.1 Chemicals and Reagents

All reagents were of analytical grade. Nitric acid was used for digesting the waste water sample (HNO_3 69%). HCl and NaOH were used for pH adjustment. Distilled water also was used for dilutions of samples after digestion and washing and rinsing of apparatus. A sample of waste water polluted with tannery effluent was brought from a local river around Winget area (two 2 L plastic bottles). *Moringa stenopetala* seed was brought from Arbaminch – South Ethiopia region.

3.2. Apparatus and Instruments

The equipment used during the adsorption studies were pH meter, Digital balance (Mattler Toledo, AG204 Switzerland) with 0.0001 g precision, graduated cylinder, pipettes, magnetic stirrer, hot plate, Mortar and pestle were used during the tests. The initial concentration and the final concentration of the metal remaining on the waste water sample was determined using Microwave Plasma-Atomic Emission Spectrometer (from Agilent Technologies, USA).

3.3. Procedure

3.3.1. Preparation of Seed Powder

Dry seeds of Moringa were ground in to powder using Mortar and pestle. The final ground sample was dried in open air for three days on clean paper sheets. Then the dried powder was sieved through sieve to obtain appropriate particle size and the fraction between125 to 250 µm was separated for use. Then the sieved powdered seed was stored in bottle for use.

3.3.2. Digestion of Waste Water Sample

Acid digestion using 69 % nitric acid was performed to destroy organic matter and to dissolve larger particles in the sample, thus allowing determination of the total concentration of metals. The acid digestion was performed following the procedure described below. 5 mL of nitric acid was added to 100 mL of raw waste water and heated until the solution started to boil. The heating continued until a volume reduction of about 80 percent had occurred. Once this had occurred the sample was visually inspected and found to be clear, which indicated that all larger particles had been dissolved. A final addition of 1 mL of nitric acid was then made to the sample in order to dissolve any remaining particles. The sample was then filtered through double filter papers into a 100 mL flask and diluted to the original sample volume, i.e. 100 mL. The filtration is made in order to remove particles larger than 0.45 μm. This was done as a precaution in order to ascertain that no blockages would occur in the MP-AES instrument.

The experiments were carried out using the 250 mL conical flask or beaker containing 100mL of digested waste water to analyze removal capabilities of moringa seed powder at room temperature. Adsorption studies was carried out at the original pH value of the sample (which was measured to be 6), the desired contact time and adsorbent dosage. Amount of prepared adsorbent was added to each flask containing polluted waste water and it was agitated intermittently by a magnetic stirrer shaking at speed of 200 rpm for a contact time of from 1.5 hours to 3.5 hours at room temperature. After adsorption, separation of the sorbent and solutions was carried out by filtration using double filter paper and the filtrate was stored in sample cans to determine the metal ion concentrations and removal percentage of the metal ions. The experiment was carried out for different adsorbent of dosage (4 g, 5 g and 6 g), contact time (1.5, 2.5 and 3.5 hours) and constant pH of 6.The pH is not optimized due to limitation of time.

3.3.3. Effect of Contact Time

For the determination of the rate of metal adsorption by the adsorbent from 100 mL sample water in a conical 250 mL flask, the solution was analyzed for residual metal ions at different time intervals (1.5, 2.5 and 3.5 hours). The pH and the adsorbent dosage were kept constant and the process was done under constant shaking speed, 200 rpm, and 25^{o}C.

3.3.4. Effect of Adsorbent Dosage

The effect of adsorbent dosage on the adsorption of the different chromium and cobalt was studied at different dosages (4 g, 5 g and 6 g) with the waste water sample. The contact time and the pH were kept constant, which is varied according to the variation of adsorbent dosage added to waste water pollutant and the adsorption process was done at constant shaking speed 200 rpm and 25^{o}C.

3.3.5. Experimental Design for Adsorption

The study was conducted to show the significance of or influence of the study variables (adsorbent dosage and contact time) at room temperature and pH of the sample on percentage removal of metal ions.

3.3.6. Determination of the Percentage Removal of Chromium and Cobalt

Adsorption studies were carried out at room temperature and constant agitation speed for metal ions in the sample water and initial concentrations were measured. After adsorption, the supernatant liquid was filtered and the concentrations of metal ions left in the filtered waste water were determined.

The concentration levels of Cr, Co and Pb in the water samples before and after treatment were analyzed with MP-AES.

Measurements were carried out and the results are reported as the mean values of 3 measurements.

4. Results and Discussion

The initial concentrations of the metal ions (in ppm) in the sample water before the adsorption process was carried out with the powdered seed of *Moringa stenopetala* are given in Table 2.

Table 2. Initial concentration of the metal ions in the sample water.

Metal ion	Concentration in ppm
Cr	2.7802
Cu	0.1673
Co	0.0102
Cd	0.4898
Pb	ND

The concentrations of the metal ions in the sample after the adsorption process is carried out at different doses (4 g, 5 g and 6 g) and different contact times (1.5, 2.5 and 3.5 hours) are given in Table 3.

Table 3 Concentrations of chromium and cobalt ions after adsorption.

Adsorbent Dose(g)		4	4	4	5	5	5	6	6	6
Time (h)		1.5	2.5	3.5	1.5	2.5	3.5	1.5	2.5	3.5
Concentration left	Cr	0.2003	0.1717	0.1472	0.2202	0.1417	0.2199	0.8562	0.1384	0.2258
	Cu	0.1252	0.1960	0.2899	0.1632	0.1432	0.3205	0.6176	0.1664	0.2325
	Co	0.0053	0.0062	0.0036	0.0034	ND	0.0073	0.0023	ND	ND
	Cd	0.6908	0.8889	1.0120	0.8453	0.9112	1.0512	0.8889	0.9522	0.9180
	Pb	ND	ND	ND	ND	ND	ND	ND	ND	ND

The percentage removal of metal ions (efficiency) of the powdered seed of *Moringa stenopetala* adsorbent is determined by the formula

$$\% \text{ Removal} = \frac{C_i - C_f}{C_i} \times 100\%$$

where C_i is the initial concentration of the metal ion.

C_f is the concentration of the metal ion after adsorption.

Only chromium was detected in a significant concentration in the sample water. The percentage removal of this metal by the adsorbent was studied further.

The initial concentration of lead in the sample was below the detection limit of the instrument hence the analysis was not included.

The initial concentration of cobalt was very small and hence the analysis was not included.

Though the initial concentrations of copper and cadmium were significant, their analysis were not included due to increase in their concentration that comes from the moringa itself.

The percentage removal of chromium at different doses of adsorbent (4 g, 5 g and 6 g) and different contact times (1.5, 2.5 and3.5 hours) is given in Table 4.

Table 4. Percentage removal of chromium

Dose(g)	4	4	4	5	5	5	6	6	6
Time(h)	1.50	2.50	3.50	1.50	2.50	3.50	1.50	2.50	3.50
%removal	92.8	93.8	94.7	92.1	94.9	92.1	69.2	95.0	91.9

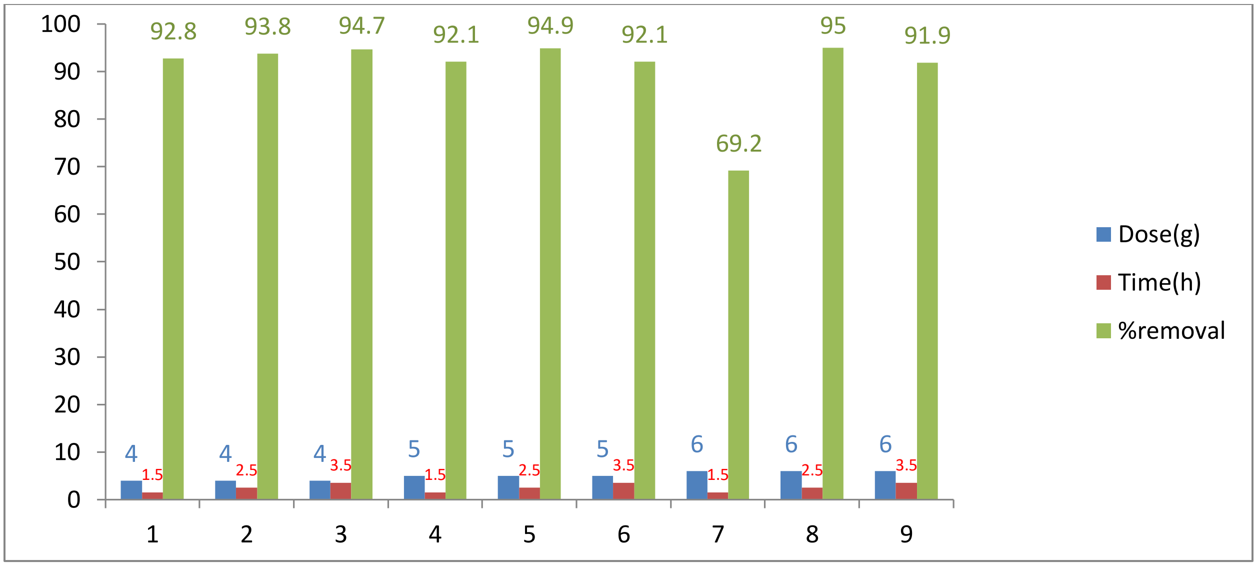

Figure 3. The Percentage removal of chromium at a given dose and time

1 to 3. Shows the percentage removal of 4 g dosage at the different contact times.

4 to 6. Shows the percentage removal of 5 g dosage at the different contact times.

7 to 9. Shows the percentage removal of 6 g dosage at the different contact times.

The contact times are 1.5, 2.5 and 3.5 hours for each dose.

As it is shown in the chart the maximum removal of chromium by the adsorbent (95%) is at a dosage of 6g for a contact time of 2.5 h followed by 5 g dosage for a contact time of 2.5 h.

5. Conclusion

Moringa stenopetala is a species of Moringa found in southern Ethiopia. The root, the seed and the leaf are used as food, for medicine and waste water treatment as it removes turbidity of water. The powdered seed can be used as newly alternative adsorbent for removal of heavy metals from waste water.

The experiment was conducted at various adsorbent dosage and contact time, and at the pH of the sample water at room temperature. The result indicates that the efficiency of chromium removal is 95% at adsorbent dosage of 6 g and contact time of 2.5 h.

It is an environmentally friendly natural coagulant most suitable for the treatment of water containing heavy metals. It is economically advantageous and locally available for the developing countries like Ethiopia.

6. Recommendation

This study aimed to show the ability of Moringa seed to remove heavy metals from waste water polluted by tannery effluent.

Only the effects of adsorbent dosage and contact time are investigated in this study. However, other factors like pH and initial concentrations of metals are not included. Therefore further study is needed to increase the efficiency of removal of the heavy metals.

Tannery industries have treatment plants for the effluents. However, there is a significant concentration of chromium in the effluent discharged to a river.

It is recommended to use Moringa seed rather than chemicals in their treatment plants.

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