Removal Of Chromium (VI) In Solution By The *Mentha piperita* Biomass

María José Gonzalez Padilla
Facultad de Ciencias Químicas
Universidad Autónoma de San Luis Potosí
San Luis Potosí, México
Majopadilla1410@gmail.com

Claudia M. Martínez Rodríguez
Facultad de Ciencias Químicas
Universidad Autónoma de San Luis Potosí
San Luis Potosí, México
Claudiam.martinezr@gmail.com

Dalila Contreras Briones
Facultad de Ciencias Químicas
Universidad Autónoma de San Luis Potosí
San Luis Potosí, México
dalila.contreras@uaslp.mx

José F. Navarro Castillo
Facultad de Ciencias Químicas
Universidad Autónoma de San Luis Potosí
San Luis Potosí, México
josef@uaslp.mx

Ismael Acosta Rodríguez
Facultad de Ciencias Químicas
Universidad Autónoma de San Luis Potosí
San Luis Potosí, México
iacosta@uaslp.mx

***Abstract*—The wild plant *Mentha piperita*, belonging to the Lamiaceae family, is a variable perennial plant with a mint scent. It grows widely in regions with a Mediterranean climate, both in Europe and in Asia Minor, Australia and North Africa. Its habitat corresponds to semi-shaded places in humid soils. In addition to its culinary uses, the different species of the genus *Mentha,* they are also used in traditional medicine, mainly used to cure gastrointestinal disorders, but the spectrum of medical activities is broadening, and different parts of the plant are used as the leaves, the flower, the stem or the seeds. Depending on the country, *M. piperita* is used traditionally for various medicinal purposes.**

Too, the potential use of their biomass for accumulate heavy metals has been analyzed. So, the objective of this work was analyzing the Cr (VI) removal capacity in aqueous solution by the *M. piperita* biomass by a colorimetric method.

Biosorption at different pH was evaluated for 3 hours. We too studied the effect of temperature in the range of 28 to 60°C, the removal at different initial concentrations of Cr (VI), biomass, and in contaminated niches. Therefore, the highest biosorption of the metal (100 mg/L) occurs within 3 hours, at pH of 1.0, 1.0 g of analyzed biomass, and 28°C. With respect to the incubation temperature, the most efficient removal, was between 40°C, 50°C, and 60°C, since 100% of it is eliminated after 75 and 90 minutes, and the heavy metal concentration removal, is most efficient at 60°C. If the biomass concentration increases, too increase the removal of the metal in solution. Finally, this natural biomass removal efficiently the metal *in situ* (79 % and 94 % in soil and water contaminated, after 15 of incubation), with 5 g of biomass and 28°C. So, it can be used to eliminate it from industrial wastewater.

Keywords—Mint, Chromium (VI), Removal, Elimination

I. Introduction

Mentha piperita is an aromatic plant that belongs to the Lamiaceae family, known as mint, peppermint, brandy mint, candy mint, plant minty, bubblegum mint. This species is a hybrid of the peppermint plant (*Mentha spicata* obtained from *M. longifolia* and *M. rotundifolia*) and water mint (*M. aquatica*). Mint is one of the most used plants by the Mexico country's population in all types of disorders digestive, as an antiparasitic and to combat headaches. The leaves and flowering tops have stimulant, stomachic, carminative properties and antiseptics. It can be taken fresh or dried, alone or in mixtures with other species; with it they prepare syrups, alcoholates, tinctures and elixirs; very employed in liquor stores and in the preparation of aromatic vinegars. An essential oil is obtained from mint leaves. used in the food, pharmaceutical and cosmetics as a flavoring and flavoring agent due to its high menthol content, which is mainly responsible of the pleasant aroma and therapeutic activity of this plant [1]. In traditional medicine it is used as a remedy homemade for the treatment of gastrointestinal problems, respiratory, inflammation, nausea, menstrual cramps, liver, gallbladder and controls blood sugar levels blood, and diabetes [1]. Being considered a plant generally recognized as safe, is mainly used in the food industry (beverages, flavorings), cosmetics and pharmaceutical. Essential oil is used topically for headaches, muscle pain and of joints, toothache and as a repellent. By inhalation, used to relieve cold symptoms. The essential oil is obtained mainly by distillation using vapor carryover being menthol (35-55%) and menthone main components, and menthofuran, isomenthone, eucalyptol and menthol esters as components minorities [2]. Too, organic compounds were identified, such as caffeic acid, medioresinol, caffeoylquinic acids, rosmarinic acid and luteolin, demonstrating that the hybrid ultrasound-microwave technology is a viable alternative to extract compounds of interest with excellent returns [3]. Too, was evaluate the antifungal activity of alcoholic extracts and essential oil from the leaves of *M. piperita* against the fungus *Malassezia furfur*, showed bigger aura inhibitors against this fungus, which is the main cause of diseases such as seborrheic dermatitis, in comparison with the alcoholic extracts [4], bactericidal activity against strains of *Staphylococcus aureus* and *Pseudomonas aeruginosa* isolated from skin lesions [5], the effect of the essence of *Mentha piperita* on the in vitro and in vivo growth of *Vibrio* spp. in the shrimp *Litopenaeus vannamei*, by three essences prepared with dried mint leaves [6], and the essential oil, as well as its fractions, show antimicrobial activity against some bacteria, like: *Staphylococcus aureus, Enterococcus faecalis, Bacillus cereus, Micrococcus luteus, Escherichia coli* 25922, Escherichia coli O157H, *Salmonella* sp., and *Pseudomona aeruginosa* [7].

On the other hand, the great industrial growth has produced a progressive increase in wastewater discharges from the same and, heavy metals are the main contaminants of aquifers due to its high toxicity, persistence, and mobility. Not being biodegradable, can become toxic to vertebrates and invertebrates, and they are directly related to the risks to the health of living beings, soil contamination, plant toxicity, and negative effects on the quality of natural resources and the environment. These risks are related to the specific toxicity of each metal, bioaccumulation, persistence and non-biodegradability, the greatest danger being its accumulation in plants and its transfer to humans and animals [8]. Their distribution in the different environments is highly complex and involves different factors, among which are: redox potential, pH, organic matter content, cation exchange capacity, groundwater level and its fluctuations, among others [9], and there are different investigations for carry out to determine the contamination of heavy metals in the environment, such as: cobalt, lead, mercury, chromium (VI), cadmium, and others, like: heavy metals potentially dangerous for human and environmental health, contamination of water sources. Others contaminants are of organic origin, such as hydrocarbons and pesticides, but, all are their importance and potential danger [10]. Some metals that are of great toxicological and ecotoxicological importance are: mercury, chromium, lead, cadmium, nickel and zinc, which, once released into the environment, accumulate and concentrate in the soil and sediments, where they can remain for hundreds of years affecting ecosystems. Therefore, it is more feasible to control the problem from the source and source of emission before they reach the environment [9]. In Mexico, agribusiness is one of the most important activities due to its growth in recent years, and it is the one that generates the most by-products that are not used [11], among which are: coffee bagasse, agave, maguey, sugar cane, straws from different crops, organic residues of fruits and vegetables [12]. In this regard, the use of different plant products with the ability to accumulate and/or bioadsorb heavy metals has been reported, which include mint biomass (*M. piperita*), for example: the removal of nitrates and phosphates by *M. piperita* and *Chamaemelum nobile* [13], the hydroponic phytoremediation of iron, copper and potassium with *M. piperita* [14], the phytoremediation of wastewater by hydroponics [15], and the accumulation of cadmium by seeds of different plants [16]. Therefore, the objective of this work was to analyze the removal capacity of chromium (VI) in solution, by the biomass of *Mentha piperita*,

II. EXPERIMENTAL

A. *Biosorbent used*

The *M. piperita* biomass, was obtained from the marketplace Republic, in the months of July of 2023, of the capital city of San Luis Potosí, S.L.P. México. To obtain the biomass, the sheets was washed with EDTA 10% (p/v) for 24 hours, and after with trideionized water during 7 days at constant stirring, with water changes every 12 hours. Subsequently, it was boiling 1 hour to removal traces of the color and dust and were dry at 80°C for 72 hours in an oven, ground in blender and stored in amber vials until use.

B. Biosorption studies and determination of hexavalent chromium.

For these studies, was used 1 g of dried biomass mixed with 100 mL of trideionized water containing 100 mg/L of the metal, in an Erlenmeyer flask at the desired temperature and pH. The flasks were agitated on a shaking bath Yamato BT-25 model. Samples of 5 mL were taken at different times, and centrifuged at 3000 rpm for 5 min. The supernatant liquid was separated and analyzed for chromium ions. Hexavalent chromium was quantifying by a Spectrophotometric method with Diphenylcarbazide [17]. The information shown in the results section are the mean from three experiments carried out by triplicate.

III. RESULTS AND DISCUSSION

A. Effect of incubation time and pH

The optimum time and pH for Cr (VI) removal by mint biomass was 3 hours and pH 1.0, with 1 g/100 mL of biosorbent, and 1000 mg/L of the heavy metal, at 28°C (Figure 1). These results are very similar to what was reported 150 minutes with *Eucalyptus* leaf extract and for different natural biomasses [18, 19], 120 minutes for *Moringa stenopetala* seed powder [20], 24 hours for the biomass of palm leaf-derived biochar [21], 30 minutes for in natura and magnetic nanomodified hydroponic lettuce roots [22]. Changes in the cell permeability of unknown origin, could partly explain the differences founded in the incubation time, providing greater or lesser exposure of the functional groups of the cell wall of the biomass analyzed [8]. Adsorption efficiency of Cr (VI) was observe a maximum at pH 1.0 and 180 minutes with the biomass analyzed. The results showed with respect to the increase in pH resulted in decrease in the removal of the metal. It was reported an optimum pH 1.5 for adsorbents from agricultural waste material [19], a pH of 1.0 for in natura and magnetic nanomodified hydroponic lettuce roots [22]. Although other authors report an optimum pH 3.0 for adsorbents from agricultural waste material [20], pH of 2.0 for dry raw biomasses of *Dioscorea rotundata, Elaeis guineensis, Manihot esculenta, Theobroma cacao* and *Zea mays* [19], a pH value of 2.0 and 4.0, for the removal of chromium(VI) from wastewater using *M. stenopetala* seed powder and banana peel powder [20], too, a pH value of 2.0 using palm leaf-derived biochar, tea stalk biochar, and waste of *Musa acuminata* residue [23, 24]. This was due to the dominant species (CrO_4^{2-} and $Cr_2O_7^{2-}$) of Cr ions in solution, which were expected to interact more strongly with the ligands carrying positive charges [25].

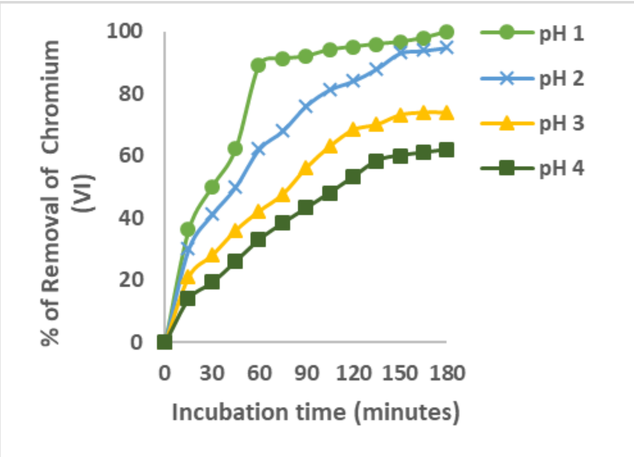

Figure 1. Effect of incubation time and pH on Chromium (VI) removal by mint biomass. 100 mg/L Cr (VI), 100 rpm, 28°C. 1.0 g of biomass.

B. *Effect of the temperature*

On the other hand, the incubation temperature does not influence the removal of the metal, since at temperatures of 40°C, 50°C and 60°C, the removal is complete after 75 minutes, while at 28°C 100% of this contaminant is eliminated at 180 minutes (Figure 2). To maintain constant the temperature in all experiments, we use a shaking bath Yamato BT-25 model. These results are coincident for the biomass of palm leaf-derived biochar, with the same temperature of removal [23], by a reusable chitosan-modified multi-walled carbon nanotube composite [26], by dried twigs of *Melaleuca diosmifolia* [27], for the removal of Cr (VI). But, they are different for removal of chromium (VI) from wastewater using *M. stenopeta* seed powder and banana peel powder, if increase this parameter, decrease the removal capacity of this biomasses [22], and for different natural biomasses, which exhibit higher adsorption efficiency at intermediate and low temperature values [21]. The increase in temperature increases the rate of removal of Cr (VI) and decrease the contact time required for complete removal of the metal, to increase the redox reaction rate [28].

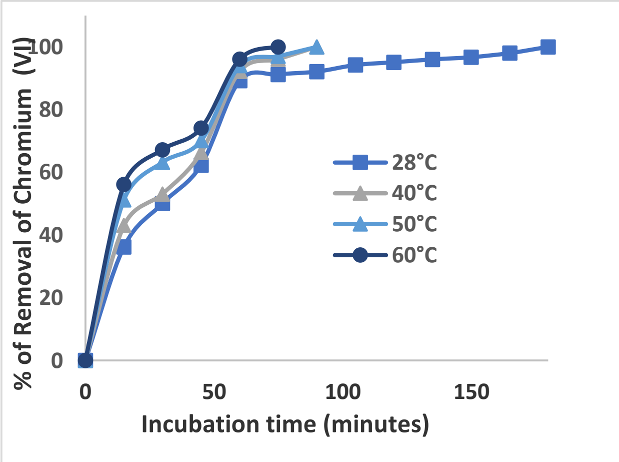

Figure 2. Effect of the temperature on Chromium (VI) removal by mint biomass. 100 mg/L Cr (VI), pH 1.0, 100 rpm. 1.0 g of biomass.

C. *Effect of initial metal concentration*

We observe that the removal of metal was 100% at 14 and 24 hours, at 28°C, for 200 and 1000 mg/L, respectively (Figure 3), while at 60°C, the removal is total between 5 and 9 hours of incubation, at the chromium (VI) concentrations analyzed (Figure 4). These results are coincident for the removal of Cr (VI) by *Cucumis sativus* biomasses [31], but are different for the chromium removal using using *M. stenopetala* seed powder and banana peel powder, in which if increase the heavy metal concentration decrease the efficiency of removal and palm leaf-derived biochar [22, 23]. The increase in initial concentration of Cr (VI), results in the increased uptake capacity and decreased in the percentage of removal of the metal. This was due to the increase in the number of ions competing for the available functional groups on the surface of biomass [25, 26].

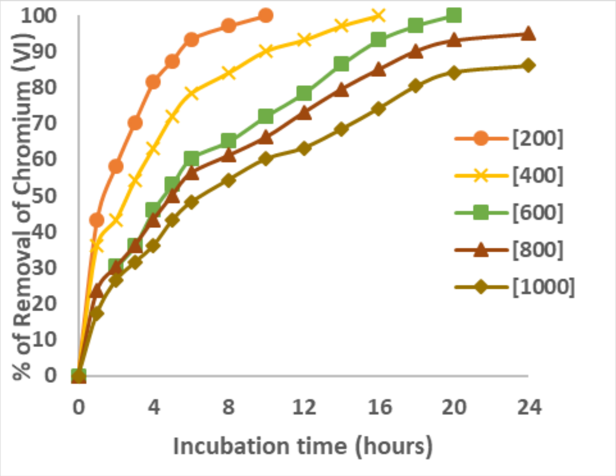

Figure 3.- Effect of initial metal concentration on Chromium (VI) removal by 1 g of mint biomass. pH 1.0, 28°C. 100 rpm.

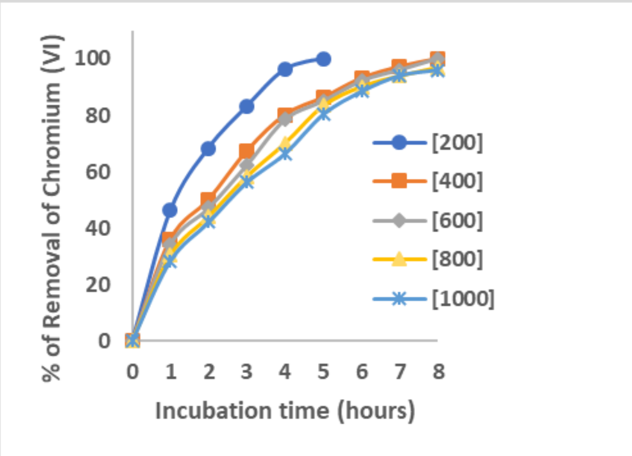

Figure 4. Effect of initial metal concentration on Chromium (VI) removal by 1.0 g of biomass. pH 1.0, 100 rpm, 60°C.

D. Effect of biosorbent dose

The influence of biomass concentration on the removal capacity of Cr (VI) is depict in Figure 5. If we increase the amount of biomass, the removal of the metal in solution decreased significantly, because with 1 g of the analyzed biomass, 100% of the metal is removed after 180 minutes, while with 4 and 5 g, the removal is total after 75 minutes, although it has been reported what with more biosorption sites of the same, because the amount of added biosorbent determines the number of binding sites available for metal biosorption [34]. These results are similar for the removal of chromium (VI) from wastewater using *M. stenopetala* seed powder and banana peel powder, if increase the biomass concentration of 5 to 20 g/L [22], too for palm leaf-derived biochar [23], for the removal of chromium (VI) by *B. Cucumis sativus* biomasses [29]. Too, was reported a efficient removal of the metal if the biomass concentration was increased using modified Russian knapweed flower powder to initial concentrations of the heavy metal of 2, 10 and 15 mg/L with pH 2.0 [30].

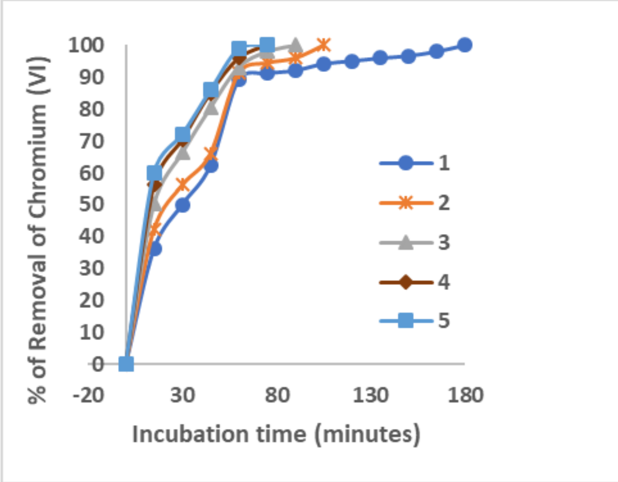

Figure 5. Effect of biomass concentration of mint biomass, on the removal of 100 mg/L Cr (VI), 28°C, pH 1.0, 100 rpm.

E. Removal of Cr (VI) in industrial wastes with B. vulgaris biomass.

We adapted a water-phase bioremediation assay to explore possible usefulness of this biomass for eliminating Cr (VI) from industrial wastes. The biomass (5 g), was incubate with 5 g of non-sterilized contaminated earth with 200 mg/g, and wastewater containing 200 mg/L of Cr (VI) (adjusted), suspended in trideionized water to a final volume of 100 mL. It was observing that in 15 days of incubation, the Cr (VI) concentration of earth and water samples decrease 79% and 94% in both samples (Figure 6), and the decrease level occurred without change significant in total chromium content during the experiments (date not shown). In the experiment carried out without biomass, the Cr (VI) concentration of the earth samples decreased by about of 18% (date not shown); this might be caused by indigenous microflora and (or) reducing components present in the soil [32]. These results coincide with the literature reports for another natural biomass, such as for different natural biomasses [21, 33], for *Ginkgo biloba* leaves can effectively remove soil Chromium (VI) and reduce Chromium (VI) to Chromium (III) via quercetin in soil (36), removal of Chromium (VI) from wastewater using *M. stenopetala* seed powder and banana peel powder [22], for the biomass of palm leaf-derived biochar [21], the removal of chromium was found 95% from dilute tannery wastewater and 72% of chromium was extracted directly from raw tannery effluents by using different quantities of water hyacinth (37), for the phytoremediation of chromium-polluted waters in cold region [36], for waste of *M. acuminata* residue [24], and is more efficient that *Avena sativa* L. biomass, in which a lower uptake of chromium from soil in the Cr(VI)-contaminated, was observed [38].

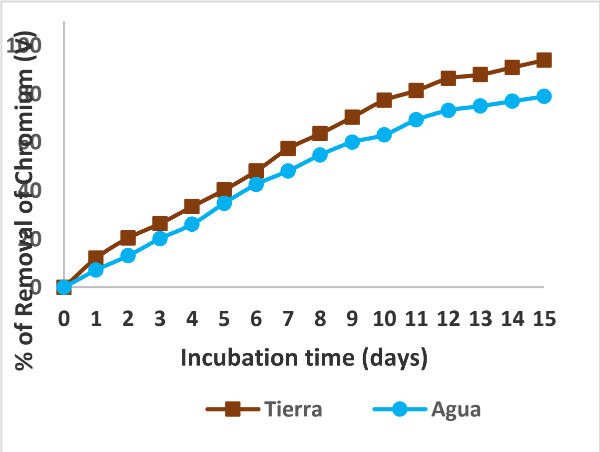

Figure 6. Removal of Cr (VI) in industrial wastes incubated with 5 g of mint biomass. 28°C, 100 rpm, 5 g of contaminated earth with 200 mg/g and 100 mL of contaminated water with 200 mg/L.

F. Conclusions

The biomass analyzed, showed complete capacity of biosorption of 50 mg/L of Cr (VI) in solution at different time of incubation, at 28°C, 100 rpm with 1 g of natural biomass, besides this removal the metal *in situ* (7 days of incubation, with 5 g of biomass), in earth and water contaminated, respectively. These results suggest their potential applicability for the remediation of this metal from polluted soils in the fields.

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