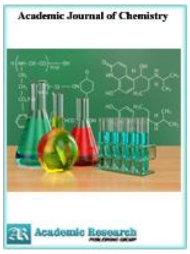

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Trace Metals Uptake by Algae Species in Contaminated Water in Some Industrial Areas in Omdurman City, Sudan

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Abstract: This research aimed to estimate the uptake trace metals (TMs) by the algae species which grow inside contaminated water in streams originating from some industrial areas in Omudrman city in Sudan. It also aimed to verify the possibility of making use of this phenomenon in bioremediation of environmental pollution. The flame atomic absorption spectrophotometry was used to evaluate the concentration of the selectedt metals in waste water and algal biomass of the phyla Chlorophyta, Cyanophyta, Euglnophyta and Bacillariophyta. The TMs studied in waste water and algal biomass were Fe, Zn, Cd, Pb, Cu, Ni, and Cr. The physical parameters studied were pH and electrical conductivity (EC) of waste water. The study covered during dry and rainy seasons 5 sites in Omdurman industrial area. Samples were collected, and digested in conc. acids mixture of 3:1 of HNO_3 and $HClO_4$ and analyzed for trace metals concentrations. The algal biomass was found to be more efficient for TMs uptake and accumulation. The phytoremediation by the mentioned algal biomass is a promising technique for the removing the TMs considered in the present study.

Keywords: Trace metals; AAS; Phytoremediation; Algae species; Omdurman city.

1. Introduction

The bio-accumulation of wastes of domestic and industrial processes in the nearby water bodies results in water contamination. The contaminated water pollutants discharged into the water bodies are dangerous to environment and cause various health problems in human beings [1]. The phytoremediation of metals by algae and other living organisms has been of interest for a number of reasons, including concern over potentially toxic trace metal accumulation in the food, metal recovery techniques from different industrial processes and contaminated water treatment methods [2]. Although, a lot of research has been focused on the use of living microorganisms and their efficiency to degrade organic compounds, the potential use of these microorganisms, as well as higher organisms, for metal uptake and bioremediation of trace metal-containing waste streams and sludge has only recently received attention. A great deal of studies indicated that fungi and bacteria are capable to absorb trace metal ions. The utility of particular plant species, whether it is considered for use in environmental areas, is determined by screening for metal uptake efficiency. The screening can involve evaluating the uptake efficiency for single metal or the ability to selectively adsorb a metal from a mixture of several ions or metal ion species [3]. Bioremediation is an effective process for the removal and recovery of heavy metal ions from aqueous solutions. The red algae *Porphyra leucosticta* was investigated to eliminated Cd(II) and Pb(II) ions from wastewater through biological enrichment and biological precipitation [4]. Either living or nonliving microorganisms, such as yeast, fungi, bacteria, and algae have ability to accumulate metals from aqueous solutions by different chemical and biological mechanism [5]. Algae of different species have ability to absorb Arsenic and Boron pollutant from water [6]. Metals concentration are monitred by algae in lakes and oceans [7]. Micro and macroalgae species were used to absorb and accumulate organic pollutants and heavy metals in contaminated aquatic sites [8]. Removal of heavy metal and hardness from ground water was investigated by micro algae *Synechocystis salina* [9]. The phytoremediation of some heavy metals in water by calcifying macro algae (charophytes) was observed to be 0.06% Cr by dry weight and for Cd it was 0.02% [10]. The *Dunaliella salina* (belong to Chlorophyta) was revealed ability to accumulate zinc, cupper, cobalt and cadmium [11]. Biological remediation processes (microbial remediation and phytoremediation) are indicated to be very effective in the treatment of trace metal pollutants in wastewater. Microbial remediation is the restoration of the environmental quality utilized microorganisms, such as bacteria, fungi, protozoan and algae while phytoremediation is the use of plants todegrade or accumulate toxic metals, thereby leading to a reduction in the bioavailability of the contaminant in the soil or water [12]. A unicellular alga, *Chlorella sorokiniana* displaying a high growth rate under heterotrophic growth conditions was were capable of taking up the heavy metal ions Cd^{2+}, Zn^{2+} and Cu^{2+} at 43.0, 42.0 and 46.4 µg/mg dry weight, respectively [13]. In KSA, heavy metals were removed biologically from wastewater at concentration (about 85 mg/L) by Dunaliella algae [14]. This work examines the

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trace metal uptake by algal biomass from contaminated water in some industrial area in Omdurman city in Sudan for two seasons (dry and rainy) with respect to the variations in the physicochemical parameters during these seasons.

2. Materials and Methods

2.1. Samples Area and Preparations

The contaminated water in streams and the algae species studied originate from the industrial area located in Omdurman city in Sudan. The contaminated water stream run through the densely populated city and drains into the River Nile and its branch, White Nile. The contaminated streams collect large amount of waste products. The contaminated streams are the sink for contaminated water from many workshops, iron industries, plastic industries, as well as discharges of diesel and other automobile waste liquids. The side streams also empty their waste load in the main streams. Description of sampling locations in Omdurman city as shown in (Table 1).

Table-1. Description of Sampling Locations in Omdurman Industrial Area

Location Site	Description of Site
Site (1)	Stream of contaminated water close to workshops for car repairs, car paints, and shops for spare parts sales.
Site (2)	Stream of contaminated water close to a factory for iron industries and iron doors industries, and shops for spare parts sales.
Site (3)	Stream of contaminated water close to factory for iron industries, and a factory for plastic industries.
Site (4)	Stream of contaminated water close to a factory for manufacturing spongy foam, and plastic factory.
Site (5)	Stream of contaminated water close to a factory for chairs industry, a factory for wires, and soft drinks industries.

2.2. Collection of Samples

The most common plant species drown in contaminated water found close to the industrial compounds in Omdurman city are algae biomass which are mixed of several species but mainly of four divisions: (i) Chlorophyta (the green algae) e.g. *mougeotia sp*. , *uronema sp*. , *scenedesmus sp*., *ulothrix sp*. , *cosmarium sp*., and *oedogonium sp*. (ii) Cyanophyta (the blue green algae) e.g. *oscillatoria spp*. (iii) Euglnophyta (euglenoid algae) e.g. *euglena sp*., *trachelomonas sp*., and *phacus sp*. (iv) Bacillariophyta (diatoms) e.g. *synedra sp*., *gomphonema sp*., and *rhopalodia sp*. All these samples were collected in precleaned polyethylene bags, and the contaminated water samples from the these sites were collected in cleaned polyethylene sample containers. These containers were brought to the sampe sites and filled with contaminated water samples completely to prevent the bubbles formation. The contaminated water in polyethylene bottles were acidified with drops of nitric acid to prevent adhering of metals on the container wall. Algae biomasses were washed three times with distilled deionized water. The algae samples were distributed on cleaned plastic bags and covered for air drying. The dried samples were ground in a porcelain mortar to fine powder and stored in a polyethylene bags to avoid spoiling, degradation or other decomposition as contamination. All samples were collected during the dry season, and compared with rainy season in order to compare and study the seasonal variations on the efficiency trace metals uptake. Five separate sets of samples from industrial areas were collected for each algae biomass and contaminated water.

2.3. Chemicals and Reagents

Analytical grade of chemicals and reagents were used in this work.

2.4. AAS- Measurements for Trace Metals in Samples

2.4.1. Standard Solutions and Optical Parameters for AAS

The trace metals concentrations in samples were measured by using Atomic absorption spectroscopy (model AAS-6800, Shimadzu, Japan). Concentration of 1000 mg/L stock solutions of Fe, Zn, Cd, Pb, Cu, Ni, and Cr were prepared.

2.4.2. Optical Parameters and Preparation of Standard Curves

Series of standard solutions of trace metals were prepared by appropriate dilutions. The instrument was setting for each the selected element. A calibration curve for the elements under study was constructed by graphing the absorbance versus the concentration of standard solutions. The curve used to determined the concentration of selected elements.

2.5. Preparation of Contaminated Water Samples for Analysis

A 20.0 mL of contaminated water sample were put in beaker. Then followed by addition of 5.0 mL of conc. HNO_3. The mixture was then swirled slowly and then put into a 25.0 mL volumetric flask and completed to the mark by water sample.

2.6. AAS- Measurements of Contaminated Water Sample

A blank solution was also prepared by the same procedure using deionized water. Then the trace metal concentrations were measured by AAS.

2.7. Preparation of Plant Samples for Analysis

2.7.1. Preparation of sample Extracts

In order to bring the dried powder samples into solution, wet digestion method was used.

2.7.2. Wet Digestion

A 1.0 g of the dried plant powder samples were weighed accurately in a small beaker, and then covered with a watch glass. 30.0 mL of conc. HNO_3 were added and the mixture was permitted for a while at room temperature until initial reaction is minimized, and then heated on a sand bath until the production of brown NO_2 fumes ceased. The solution was then cooled and 10.0 mL of conc.$HClO_4$ were added and heating continued till the volume reduced to half. The solution was set a side to cool, a pale yellow or colourless solution was obtained, and diluted. The watch glass washed with distilled deionized water three times in a beaker as well as the beaker side. This solution was filtered in 25.0 mL volumetric flask and completed to the mark with distilled deionized water, and transferred to a polyethylene container. This was carried out according to the method of AOAC International [15].

2.8. AAS- Measurements of Algae Samples

A blank solution for samples was also prepared in the same way as the sample solution . The net absorbance of the analyte in the sample solution was obtained by subtracting the absorbance of the analyte in blank solution from that of the analyte in the sample solution. The metal ion (Fe , Cu , Zn , Pb , Ni, Cr , and Cd) concentrations of algae samples were read on AAS.

2.9. Statistical Analysis

Each treatment was carried in three replicates and each sample was analyzed three times and the results are expressed as mean (n = 3), by using one-tail analysis of variance. And the results expressed as (Mean standard deviation SD).

3. Results and Discussion

Contaminated water is one of the greatest human problems in last decades. Trace meatals are constantly released into the environment, so there is an urgent need to find out low-cost, effective, and sustainable methods for their removal. Plants used for phytoremediation, are relatively inexpensive since they are performed *in situ*. In this study, we discussed the trace metals (iron (Fe), zinc (Zn), cadmium (Cd), lead (Pb), copper (Cu), nickel (Ni), and chromium (Cr)) uptake by algae species which grow in contaminated water which were released from some industrial compounds in Omdurman city, and to find out their ability to uptake and accumulate trace metals, and hence help in remediation through preconcentration of these metals in the plant tissues and consequently reducing their concentrations in the contaminated water. Results of algal biomass studies showed existing of four mainly divisions: (i) Chlorophyta (the green algae) e.g. *mougeotia sp*. , *uronema sp*. , *scenedesmus sp*., *ulothrix sp*. , *cosmarium sp*., and *oedogonium sp*. (ii) Cyanophyta (the blue green algae) e.g. *oscillatoria spp*. (iii) Euglnophyta (euglenoid algae) e.g. *euglena sp*., *trachelomonas sp*., and *phacus sp*. (iv) Bacillariophyta (diatoms) e.g. *synedra sp*., *gomphonema sp*., and *rhopalodia sp*. in all of the five sample sites of contaminated water for two seasons (dry and rainy). The results of measurements of trace metals (Fe , Cu , Zn , Pb , Ni, Cr , and Cd) concentrations in samples of contaminated water and algae species from industrial sites of Omdurman for the dry season were summarized in (Table 2), whereas Table 3 gives the comparisons of trace metals concentrations of samples of algae species of different sites in industrial areas for the rainy season. The resuls of comparisons of trace metals concentrations in contaminated water and that uptake by algae species of different sites in Omdurman industrial areas for the two seasons were summarized in (Figure 1). Tables 2 and 3 show the comparisons of trace metals in contaminated water and that uptake by algae species of different sites of industrial areas for the two seasons.

Table-2. Concentration Of Trace Metals of Contaminated Water Samples Collected from Omdurman Industrial Area for The Dry Season and Its uptake by Algae species

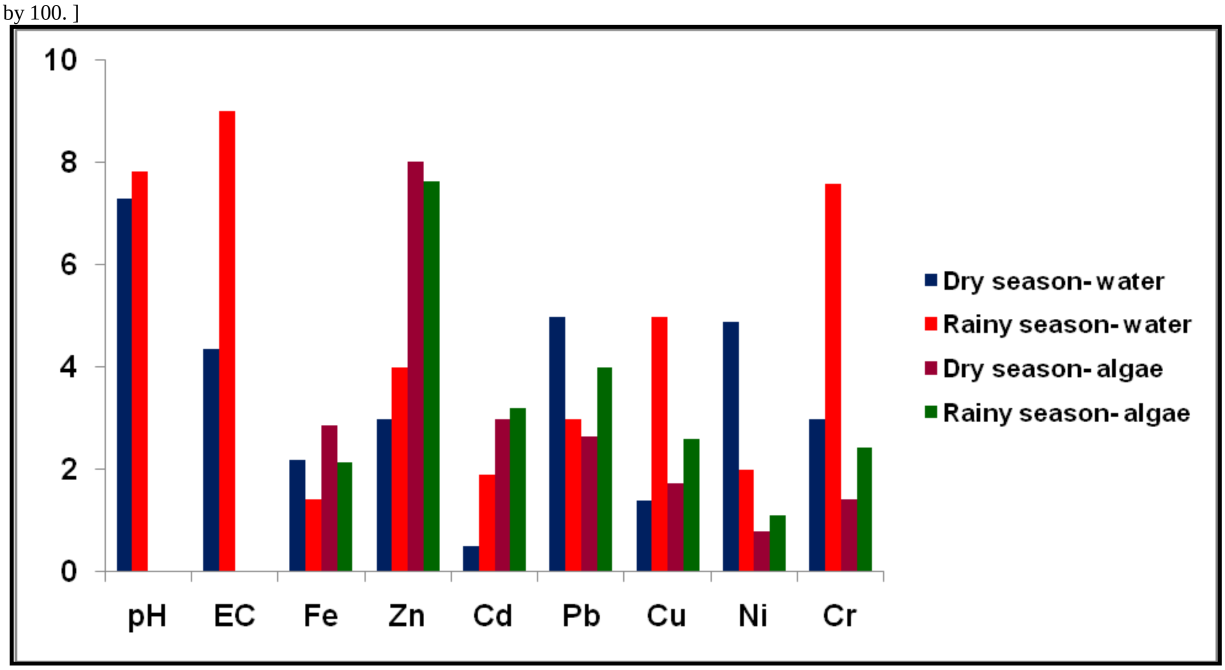
Sample	Parameter	Location sites					
		Site 1	Site 2	Site 3	Site 4	Site 5	Mean ±SD
Cont.H_2O	pH	6.67	6.97	7.67	7.10	8.14	7.31 ± 0.59
Cont.H_2O	EC (mS/cm)	6.69	3.76	4.03	3.86	3.44	4.36 ± 1.32
Cont.H_2O	Fe (mg/L)	4.57	1.55	1.59	1.64	1.64	2.20 ± 1.33
Algae	Fe (mg/kg)	2212	2330	4100	3060	2690	2860 ± 780
Cont.H_2O	Zn (mg/L)	0.13	0.05	0.02	0.03	0.03	0.03 ± 0.01
Algae	Zn (mg/kg)	9.58	9.07	10.50	4.85	6.12	8.02 ± 2.42
Cont.H_2O	Cd (mg/L)	0.005	0.004	0.007	0.004	0.007	0.005 ± 0.002
Algae	Cd (mg/kg)	0.027	0.037	0.025	0.043	0.021	0.030 ± 0.009
Cont.H_2O	Pb (mg/L)	0.05	0.05	0.03	0.03	0.09	0.05 ± 0.002
Algae	Pb (mg/kg)	4.47	2.14	2.17	2.42	2.06	2.65 ± 1.03
Cont.H_2O	Cu (mg/L)	0.016	0.013	0.015	0.012	0.013	0.014 ± 0.001
Algae	Cu (mg/kg)	2.48	1.40	2.01	1.58	1.25	1.74 ± 0.50
Cont.H_2O	Ni (mg/L)	0.48	0.40	0.10	0.56	0.93	0.49 ± 0.30
Algae	Ni (mg/kg)	0.71	0.64	1.04	0.69	0.84	0.79 ± 0.16
Cont.H_2O	Cr (mg/L)	0.03	0.03	0.02	0.03	0.02	0.03 ± 0.01
Algae	Cr (mg/kg)	1.38	1.28	1.45	1.64	1.34	1.42 ± 0.14

(*Cont.* H_2O *is abbreviation for contaminated water*).

Table-3. Concentration Of Trace Metals of Contaminated Water Samples Collected from Omdurman Industrial Area for The rainy Season and Its uptake by Algae species

Sample	Parameter	Location sites					
		Site 1	Site 2	Site 3	Site 4	Site 5	Mean ± SD
Cont.H_2O	pH	7.49	7.33	8.27	8.38	7.61	7.82 ± 0.48
Cont.H_2O	EC (mS/cm)	8.08	8.80	10.33	9.50	8.32	9.01 ± 0.92
Cont.H_2O	Fe (mg/L)	3.92	0.19	0.56	0.43	1.95	1.41 ± 0.80
Algae	Fe (mg/kg)	2620	1510	2250	1960	2330	2140 ± 420
Cont.H_2O	Zn (mg/L)	0.06	0.02	0.04	0.02	0.06	0.04 ± 0.02
Algae	Zn (mg/kg)	10.87	8.13	6.38	5.42	7.37	7.64 ± 2.08
Cont.H_2O	Cd (mg/L)	0.016	0.003	0.022	0.013	0.040	0.019 ± 0.010
Algae	Cd (mg/kg)	0.023	0.059	0.021	0.016	0.041	0.032 ± 0.020
Cont.H_2O	Pb (mg/L)	0.07	0.03	0.01	0.01	0.02	0.03 ± 0.02
Algae	Pb (mg/kg)	6.83	3.86	1.89	5.56	1.86	4.00 ± 2.21
Cont.H_2O	Cu (mg/L)	0.08	0.03	0.07	0.06	0.04	0.05 ± 0.02
Algae	Cu (mg/kg)	5.64	1.55	1.89	2.53	1.42	2.61 ±1.75
Cont.H_2O	Ni (mg/L)	0.02	0.02	0.03	0.02	0.01	0.02 ± 0.01
Algae	Ni (mg/kg)	1.04	0.85	1.32	0.98	1.29	1.10 ± 0.21
Cont.H_2O	Cr (mg/L)	0.32	1.19	0.84	0.37	1.06	0.76 ± 0.40
Algae	Cr (mg/kg)	2.33	2.04	2.64	2.32	2.85	2.44 ± 0.32

Figure-1. Comparison of Concentration Of Trace Metals of Contaminated Water Samples Collected from Omdurman Industrial Area and Its uptake by Algae species for Two season (Dry and Rainy). [Note: The columns for Fe in algae are divided by 1000, For all water samples the columns are multiply 100 (except For Cr in rainy season and Ni in dry season multiply by 10) and Cd for all water and algae samples are multiply by 100.]



Trace metals were evaluated for two seasons (dry and rainy) in order to study the effects of seasonal variations on the TMs uptake and accumulation by the plants under study and hence their efficiencies for clean up, bioaccumulation, and phytoremediation of trace metals in the contaminated water in the industrial areas under study. Algae species can be used in controlling and monitoring of trace metal pollution in water streams since it can be used in determination of contaminants. Concentrations of trace metals in algal biomass reflect metal load in the stream water. Algae can therefore be used in the phytoremediation process of trace metals in contaminated water stream. Our findings revealed that the algae species under study uptake and accumulate trace metals and distribute them between tissues proportionally to its level in the contaminated water, although, this pattern varied moderately between different trace metals. Seasonal variations of trace metals in contaminated water, might be related to the variations of water pH, river flow, and water temperature. Rainfall plays an important role in bioavailability of trace metals. In the present study, the pH and EC of contaminated water were considered to be important factors influencing the bioavailability of TMs and their uptake by the plant species. The pH of the contaminated water showed seasonal variations in Omdurman Industrial Areas, the values pH and EC changed were showed an increase for dry to rainy season. It could be clearly observed that the total TMs concentration in the contaminated water were the main controls on their uptake by the algal biomass, considering that the pH and EC of the contaminated water are also important factors. It is obvious from the above tables that phytoremediation by algal biomass was a promising technique for Fe, Zn, and Pb, and also, though to a lesser extent for Cu and Cr compared to the rest of the metals considered in the present study.

4. Conclusions

We can conclude that the trace metals uptake and accumulation by these algae species is very significant to increase the trace metals removing efficiency by phytoremediation used in practice over the course of the two seasons (dry and rainy). Also this research provides the foundation for which further research can expand upon. There are many directions that can be explored. As this research was conducted to investigate how algae species could be used to remove or uptake trace metals in contaminated water, additionally, research could be conducted on the use of the selected plant species for bioremediation of trace metals other than the selected TMs. Recommendations that could be drawn from this investigation are that further studies and screening should be carried out on other plant species capable of trace metals uptake and accumulation is very necessary for cleaning up the environment. Further research could also be conducted to find out best method of bioremediation for contaminated soil and air.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this article.

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