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# Research Article
# Chromium Removal from Water Using *Spirodela polyrhiza*

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## Abstract

**Background and Objective:** Waste water containing highly toxic chromium hexavalent (Cr VI) causes threat to human, plants and aquatic life, eventually disrupts all components of the environment by its noxious nature. Traditional methods of treatment comprising high capital and operational cost to treat heavy metals from water that do not give environment-friendly solution. The current study focused on evaluating the performance of *Spirodela polyrhiza* for treatment of Cr (VI) contaminated water. **Materials and Methods:** Series of batch experiments were performed placing fixed quantity of *Spirodela polyrhiza* in varying initial Cr (VI) contaminated water. The effect of various experimental parameters such as initial ion concentration, contact time and temperature were also investigated to identify their impact on achieving maximum removal efficiency. Analysis of variance, one-way ANOVA was carried out to classify and test the significance of the results statistically. **Results:** The result shows that within 7 days of treatment period *Spirodela polyrhiza* can extract 92-97% of contaminants from water and removal efficiency decreases with the increase of temperature. Bio-concentration factor found to be very high in the plant which signifies appropriateness of the plant for phytoremediation purpose. **Conclusion:** The obtained results revealed that *Spirodela polyrhiza* is very effective in extracting Cr (VI) from aqueous solution and can be used as excellent metal extractor.

Key words: Wastewater, bio-concentration factor, chromium uptake, *Spirodela polyrhiza*, phytoremediation

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

## INTRODUCTION

Chromium (Cr), particularly hexavalent chromium Cr (VI) is one of most dangerous hazardous metal that exposes in the environment by means of numerous industrial activity. Though Cr (VI) exploits in plating operation, aluminum anodizing, paint, dye operation, welding on stainless steel, tanning and leather processing industry[1,2], it may also occur in the natural environment. World Health Organization (WHO) recommended value for chromium in drinking water 0.05 mg $L^{-1}$ [3]. When excessive amounts of chromium exposed in the body, it leads to severe diseases such as liver problems, low blood platelets, kidney damage, breakdown of red blood cells, chest pain, gastrointestinal disorders, erythema, headache, dizziness and agitation[4].

Several techniques based on the principle of precipitation, ion exchange, electrolysis, solvent extraction, reverse osmosis and bio-sorption process have been established to remove chromium from water[5-7]. But these processes are not comprehensive as leaching from the treatment plant or effluent in fresh water after treatment possess danger of aquatic life. Hence, using plants to treat Cr (VI) contaminated water can provide very effective, environment pleasant and less costly practice.

Diverse variety of plants can be used for extracting contaminant from water, but the fact is that plant remediates contaminate via several processes such as phytodegredation, phytostabilization, phytoextraction, phytovolatization, rhizosphere degradation, rhyzofiltration[2,8] hold risk of producing hazardous plant waste or releasing metals in the food chain. Hence, the potentiality of removing contaminants from wastewater by proper plant has established much concern.

In the present study, one of the most common aquatic plants, *Spirodela polyrhiza* was investigated Laboratory of Civil and Environmental Engineering department at Shahjalal University of Science and Technology (SUST), under ample supervision to check plant's potentiality as Cr (VI) extractor from wastewater. Selecting this species was due to its great aesthetic view in water surface in addition to its wide spread availability in the world and ability to grow in a broad diversity of water bodies. Some studies have been implemented to determine *Spriodela polyrhiza* as an extractor and an accumulator of As, Ni and Cd, revealed that the tissue of the *Spirodela polyrhiza* can accumulate high concentrations of metal[9,10]. The main objective of the study was to investigate performance of *Spriodela polyrhiza*, for extracting Cr (VI) from wastewater and finding out metal accumulation mechanism, effect of temperature and concentration during investigation period.

## MATERIALS AND METHODS

**Aquatic plant:** *Spirodela polyrhiza* was collected from the lake of SUST and rinsed in supply water 2 times to wash any impurity and kept in the room for 24 h to adjust to room temperature. Chromium concentration in the lake water and hereafter collected plants were also checked by 1, 5-Diphenylcarbodrazide method to ensure that there is no initial chromium contents in the plants.

**Chemicals:** The stock solution of chromium (50 mg $L^{-1}$) was prepared by dissolving potassium dichromate ($K_2Cr_2O_7$) salt in distilled water (pH 6.8-7.2). The solution was further diluted for preparing required chromium concentration before use.

**Phytoremediation experiment:** Batch experiments were conducted putting fixed amount of *Spirodela polyrhiza* (Fig. 1) in 1 L Cr ion solution with desired concentration (4.5, 3.7, 2.8, 2, 1 and 0.5 mg $L^{-1}$) in a number of identical plastic container (diameter 9" and depth 4") at Environmental and Pollution Control Engineering Lab of Department of Civil and Environmental Engineering, SUST. Each container was open to air for growing plants in the natural state. Six additional unplanted treatments were also carried out for each concentration to find out if any adsorption occurred in the container. The whole experiment was conducted ensuring adequate air and sunlight in the central laboratory room. The observation of temperature effects were done by conducting the experiment in the year of 2014 and 2015 during the month of the monsoon and winter so that the variation of temperature perfectly fit with real field scale weather condition. Undisturbed samples were also prepared to fit sorption model. On the 1st day, water was collected from the container following the interval of 1, 2, 4 and 7 h. From the following day, water was collected once a day, which means

Fig. 1: *Spirodela polyrhiza* in water before treatment

after 1, 2, 3, 4, 5, 6 and 7 day from each container. The sample plants (Fig. 1) were collected randomly and then air dried for 2-3 days and oven dried for 7 h at 110°C for 1 day. The dried samples of the plant were powdered and stored in polyethene bags. The powdered samples were subjected to acid digestion. One gram of powdered plant material was separated in digestion flask and digested with $HNO_3$ and HCl in the ratio of 1:3 for 1 day. Solutions were evaporated at 105°C until a minimum saturation condition exists, then the samples were cooled, filtered and the filtrate diluted to 500 mL with distilled water prior to analyzing.

**Equipment's used for testing:** The digital pH meter was used to measure pH of the solution. Chromium concentration in water and plants was measured by spectrophotometer following 1,5-Diphenylcarbodrazide method. Balance machine and other subsidiary equipment were used to perform the research work. Standard analytical procedures were followed all the way throughout the experimental work.

**Statistical analysis:** Analysis of variance one-way ANOVA was used to classify and test the significance ($p<0.05$, least-significance difference, LSD). In this analysis, the difference between 3 replicate means is tested for significance. The data obtained in three replications was statistically analyzed for analysis of variance (ANOVA) test using MS Excel 2007 with statistical significance $p<0.05$. All the data presented in graph and table are the mean of three replicates. Since the p-values are found as zero (<0.05) in the statistical analysis of remaining amount of different concentration of chromium (VI) and exposure time (Table 1), the results of the study is statistically significant at 95% confidence level.

## RESULTS

**Effect of contact time on chromium removal:** The depletion of Cr concentration in water during first several hours deduce that after putting plants in the container concentration of metal decrease drastically but almost static condition for least concentration. In the following hours abatement continued and within 7 h concentration of chromium in water decreases drastically achieving average removal efficiency of more than 50% (Fig. 2). The concentration of chromium gradually decreased up to 5 days in all water samples at varying degrees, but a constant static condition maintained in the following days. However, for 2.8 mg $L^{-1}$ initial concentration of Cr after 3 days of experimental period graph suddenly shows a trend of increase giving exceptional behavior from

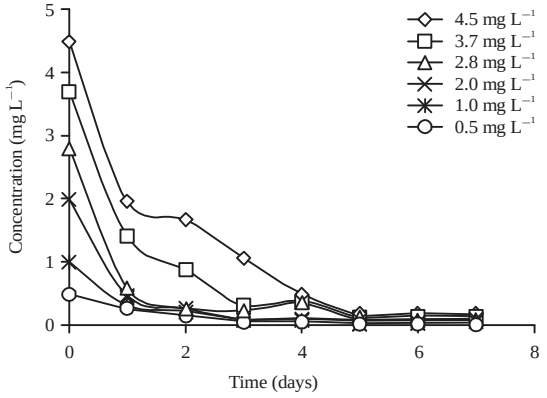


Fig. 2: Depletion of Cr in water during experimental period

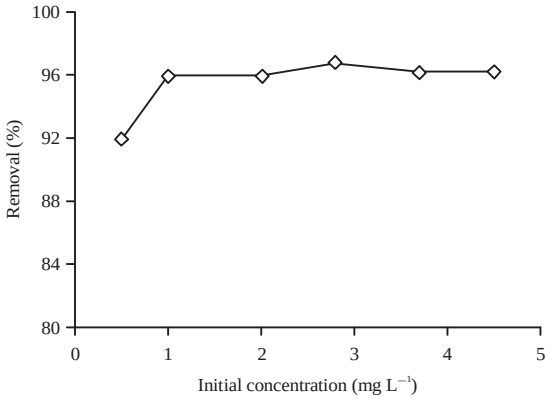


Fig. 3: Percent removal Cr against initial concentration in water (pH = 6.8)

other samples because of abrupt dissolution of metal ion from plants. It is revealed from the study that metal uptake is very high in the initial state of the treatment period, though gradually up taking capacity decreases with the days progressed. Since percent removal of metal increases with the increase in the initial concentration of metal ion (Fig 3), *Spirodela polyrhiza* has enormous potential as high metal concentration extractor from water which is significant finding of the study.

**Effect of temperature:** The sorption of metal ion (Cr) different temperatures were studied to find out whether removal efficiency influenced by temperature. Temperature effect was tested for highest initial concentration and the results are shown in Fig. 4 concludes that temperature has a negative effect on sorption efficiency. The graph also shows a constant condition in the temperature range of 302-304 K but for value higher than 304 K removal efficiency decreases, therefore, this temperature is the boundary point for achieving removal efficiency more than 95% as the temperature higher than

the value has a trend of decreasing removal efficiency significantly. To achieve desirable removal efficiency temperature should be maintained properly if Cr removal by plant is done in laboratory scale and in natural environment removal efficiency will vary depending on the temperature.

**Effect of bioconcentration factor:** The bioconcentration factors in an equilibrium situation for different initial concentrations of chromium are presented in Table 1. The average bioconcentration factor is 4558 obtained only in 7 days.

## DISCUSSION

*Spirodela polyrhiza* is proper aquatic plant for phytoremediation purpose because of its fast growth, widely distributed, ability of doubling biomass in 24 h under supreme condition[11]. Tissue of the plant can accumulate high concentration of manganese ((17.062 mg $g^{-1}$ DM) therefore, it has potential for use in phytoremediation[12]. *Spirodela polyrhiza* has been used to improve the quality of polluted wet land where percentage reduction of heavy metals such as lead, copper, zinc, chromium, mercury, cobalt and manganese after 8 days treatment period were 95, 79, 66, 53, 45, 26, 20 and 7%, respectively[13]. Removal of fluoride and chromium in industrial waste water using other aquatic plant such as Ipomoea aquatica found to be 37 and 87%, respectively[14]. Since achieved removal efficiency of 96% which is significantly higher *Spirodela polyrhiza* can play a vital role for phytoremediation purposes. The results of chromium accumulation by *Spirodela polyrhiza* at different concentrations and exposure times presented in Table 2 demonstrate that increase of chromium accumulation in plants with increase of chromium concentration and exposure time. Plants treated with 4.5 mg Cr accumulated highest chromium (855.56 mg $kg^{-1}$). The lower value of BCF is found in the case of low concentrations as the *Spirodela polyrhiza* doesn't die completely, but for higher concentrations the plants have completely died in 7 days and equilibrium situation reached. Previous studies demonstrated that high concentrations of metals in water can lead to decreasing BCF values[15,16]. The BCF values over 1000 generally indicate the appropriateness of plant for phytoremediation[17]. Since the average BCF is 4558 after 7 days and so *Spirodela polyrhiza* is a useful plant for phytoremediation of chromium (Table 1).

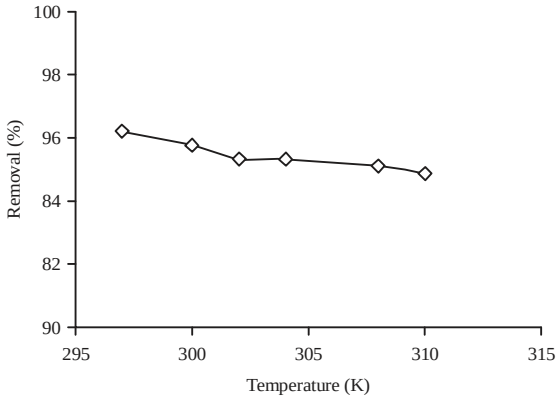


Fig. 4: Effect of temperature on metal removal (pH = 6.8)

Table 1: Bioconcentration factor of aquatic plants corresponding to different initial chromium concentration in the water sample

| Concentration (mg $L^{-1}$) | BCF |
|---|---|
| 4.5 | 5029.41 |
| 3.7 | 5718.92 |
| 2.8 | 6072.77 |
| 2 | 4934.21 |
| 1 | 3399.26 |
| 0.5 | 2195.00 |

**Bioconcentration factor (BCF):** Bioconcentration factor (BCF) is the ratio of the metal concentration in the plant to the concentration of metal in the wastewater, at the end of the experiment[18-20]. It presents the appropriateness of a plant for phytoremediation potential and greater values of BCF found in the present study proves the effectiveness of *Spirodela polyrhiza* in effective phytoremediation of chromium.

Table 2: Accumulation of chromium (VI) in *Spirodela polyrhiza* at different initial chromium concentration and exposure times

| | Cr accumulation in plant (mg $kg^{-1}$) with standard deviation | | |
|---|---|---|---|
| | Exposure time (days) | | |
| Initial Cr concentration in water (mg $L^{-1}$) | 3 | 5 | 7 |
| 4.5 | 605.16±12 | 851.22±15 | 855.56±10 |
| 3.7 | 593.75±8 | 678.51±11 | 686.27±7 |
| 2.8 | 470.86±12 | 565.34±5 | 570.84±8 |
| 2 | 325.39±5 | 359.28±9 | 375.00±6 |
| 1 | 165.87±7 | 175.40±10 | 183.56±4 |
| 0.5 | 75.38±8 | 80.72±5 | 83.41±7 |

**Translocation of Cr (VI) and accumulation mechanism:** Chromium (VI) cross the cell membrane, whereas, the phosphate-sulphate carrier transports the chromite anions and accumulated inside the plant and translocated through the symplast at high concentrations in a manner that does not disrupt cytoplasmic function[21]. There exists possibility of mechanism responsible for detoxifying heavy metals stored in the plant that ease burden of metal accumulation.

## CONCLUSION

The findings presented in the study demonstrate that *Spirodela polyrhiza* is very promising plant for removing Cr (VI) from water as the concentration of chromium in the water reduced significantly with removal efficiency as high as 96% at the end of the testing period. For higher initial concentration of Cr (VI) removal efficiency is very high. However, the temperature increment has a negative impact on the chromium removal as with the increase of temperature plants tend to uptake less metal. The bio-concentration factor analysis reveals that greater BCF value proved appropriateness of a plant for extracting metal from water and so the project provides a successful outcome. Still, more studies are required to find out the real BCF and pilot tests and small scale real field applications are also recommended to conduct before the application of phytoremediation by *Spirodela polyrhiza* in the real field.

## SIGNIFICANCE STATEMENTS

This study discovers the potentiality of *Spirodela polyrhiza* for extracting Cr (VI) from water. This study will help the researcher to disclose the potentiality of aquatic plants for extracting other heavy metals form water. Thus, this pant can contribute in environment friendly remediation process of polluted water.

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