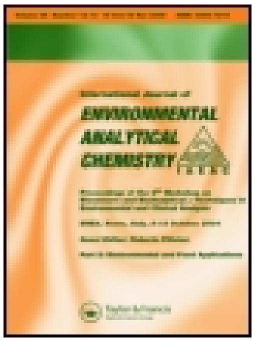

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Phytoremediation potential of water hyacinth in heavy metal removal in chromium and lead contaminated water

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ARTICLE

Phytoremediation potential of water hyacinth in heavy metal removal in chromium and lead contaminated water

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ABSTRACT

The presence of heavy metal in river water due to the disposal of industrial waste in that water, this causes the environmental effects and leads to the health issues. Various modern equipment and natural methods are available to remove the heavy metals in polluted water, the methods available to remove heavy metals are such as chemical precipitation, ion exchange, reverse osmosis, membrane filtration, bio absorption and phytoremediation. The objective of the study is to evaluate the phytoremediation capability of water hyacinth (*Eichhornia Crassipes*). The people from the study area faces water shortage due to poor water quality issues for their daily needs. Therefore, attempts were made to treat the water present in the Amaravati River near by dye industry, Under the 7 days of operation period, water hyacinth showed the maximum removal efficiency in the pH, BOD, COD, TDS, Chromium and Lead. The novelty of the present study is to use water hyacinth (*Eichhornia Crassipes*) for treating the industrial effluent (heavy metals accumulated) with the variation in combination of phytoremediation such as 10% and 20% were used for treatment and found that optimum percentage is 20% of water hyacinth. The research findings reveal that the use of *Eichhornia Crassipes* technique in treatment of Dye waste water is an economical way.

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Heavy metals; phytoremediation; eichhornia crassipes; removal efficiency

1. Introduction

Water plays a vital role in all living organisms in the earth surface. Due to increase in urbanisation and rapid growth of populations are the major threats to contamination of surface and sub surface water. All living organisms require water in every stroll of life on one side; on other side polluted water may be deadly for present lifestyles [1–3]. The shape of environmental contamination appears when pollution is suddenly or circuitously transfers into waterbodies without adequate treatment to get rid of dangerous materials. Various treatment techniques were hired to clean up polluted sites. At present a wide range adopts many techniques [4,5]. Different physical and chemical methods used for this cause suffer from serious boundaries like high cost, extensive labour, alteration of soil houses and disturbance of soil native micro flora. This topic has been a high-quality deal of studies over the last ten years [6–9]. Excessive concentration of heavy metals is the major threat to ecosystem and that can cause the water and soil contamination, such as weakening of soil

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structure, ruin of ecosystem and decline in biodiversity [10–14]. Some of the heavy metals in polluted water are Mercury (Hg), Cadmium (Cd), Arsenic (As), chromium (Cr), Lead (Pd). Cobalt, copper is widely involved to treat many methods such as membranes filtration, reverse osmosis, ion exchange, chemical precipitation, electrochemical treatment (IS 9806:2001). The main contamination of waterbodies leads to damage due to the unwanted mixing of household wastewater and other industrial wastewater such as dye waste, chemical waste, hospital waste [15–18].The heavy metals are having non degradable waste case sever damage to living things which consume the contaminated water. The heavy metals contaminated water can also affect the nearby water source and underground water [19,20]. Ali et al. (2013) [21] stated that the assembly of heavy metals by man through extraction from minerals and handling for various applications has prompted the arrival of these components into nature. Since substantial metals are non-biodegradable, they accumulate in the earth and consequently contaminate the natural pecking order. This pollution represents a hazard to natural and human well-being.

Islam Samuel et al. 2010 [22] said that a coordinated methodology of contamination assessment indices, principal component analysis (PCA) and cluster analysis (CA) was utilised to assess the power and sources of contamination in water system and drinking water frameworks of north western Bangladesh. Changes to the current HPI and Cd plans show practically identical outcomes with HEI, and demonstrate that about 55% of the mine waste/water system waters and half of the groundwater's are respectably to profoundly debase. Joan Savitha et al. (2018) reported that the drawback of conventional technologies for wastewater treatment has prompted genuine intuition on interchange, minimal effort, regular and energy saving technologies on water and wastewater treatment. Methods like phytoremediation which employs floating plants, constructed wetlands etc. Thus, water hyacinth is found to be an effective biological organism in removing pollutants in waste water [23].

Water hyacinth is a free-floating plant and highly available in south and northern part of the India. The water hyacinth reproduction systems are classified as sexual and asexual reproduction system [24]. In sexual and asexual reproduction of water hyacinth is by producing seeds through flowers and by budding through vegetative reproduction systems. The optimum growth of water hyacinth was found in the temperature of 28°C to 30°C with a pH of 6.5 to 8.5, concentration of salt less than 2%, maximum permissible level of 20 ppm of nitrogen, 3 ppm of phosphorus and 53 ppm of potassium [25]. The water hyacinth causes negative impact on ecosystem and it alter the system of lake hydrology by increasing the evapotranspiration process. In view of wastewater treatment process, water hyacinth is an effective way of phytoremediation process. It is capable to treat heavy metal pollutants like lead, chromium, high COD, BOD and chlorine. The root system of water hyacinth absorbs toxic compounds present in the wastewater [26].

Mary et al. (2010) [27] reported water hyacinth is one of the aquatic plant species effectively utilised for wastewater treatment. It is productive in expelling toxins like suspended solids, BOD, natural issue, heavy metals and pathogens. The investigation led in such manner uncovered how effectively wastewater could be treated with utilising the plant 'Water hyacinth'. The effectiveness of waste water treatment stated the variety in pH, biochemical Oxygen Demand (BOD), complete Dissolved Solids (TDS) and heavy metals during treatment.

The major source of chromium (Cr) and lead (Pb) are electroplating industry, sludge, solid waste, tanneries and mining of ores, buring of leaded gasoline, industrial waste and municipal sewagerespectively. Abolanle et al. (2012) [28] evaluated the utilising water hyacinth as a contamination screen for the simultaneous removal of heavy metals, for example, copper (Cu), cadmium (Cd), iron (Fe), zinc (Zn), lead (Pb), chromium (Cr) and aluminium (Al). The cleaning test indicated that water hyacinth has the ability to clean up the effluents of their heavy metals content by removed around 70% to 90% of their initial concentration inside four to six days of the trial set-up. Akinbil et al. (2010) [29] explored water hyacinth and water lettuce (Pistiastratiotes) to decide their viability in aquaculture wastewater treatment in Malaysia. Wastewater from fish farm in Semanggol Perak, Malaysia was examined and the parameters determined included, the pH, turbidity, dissolved oxygen (DO), biochemical oxygen demand (BOD), nitrite, phosphate, nitrate ($NO3-$), nitrite, Ammonia ($NH3$), and Total kjedahl nitrogen (TKN). The research gap identified in the previous study is removal of heavy metal in wastewater with use of water hyacinth phytoremediation method. The several plants have been identified and tested for their characteristics and behaviour in the uptake and accumulation of specific heavy metals such as lead and chromium. The main objective of the present study is to remove the heavy metal accumulation using water hyacinth followed by phytoremediation techniques.

2. Methodology and experimental setup

This study shows that removal of dye waste in river water using phytoremediation treatment. Through the literature survey, it was found that water hyacinth plays a vital role in treating the wastewater [30–32]. So, water hyacinth had been selected for this treatment method. The wastewater is taken from the Amaravati river in which the dye waste is mix in this river, the river water is taken the 30 L plastic bottle, totally four samples were taken in that river in different locations with equal interval of 2 km and the latitude and longitude of the sample stations are 10º91′ N and 78º00′ E, 10º92′ N and 78º01′ E, 10º92′ N and 78º02′ E, 10º93′ N and 78º02′ E then collected water is undergoes initial treatment method which contains pH, TDS, DO, Hardness, sodium, potassium, BOD and COD. During sample collection, pH and TDS were measured by using handy pH and TDS metre (Hanna, HI-98,129). Hardness was determined followed by complexometric titration method using 0.05 $molL^{-1}$ ethylene diamine tetra acetic acid (EDTA) solution. Sodium and potassium were determined by flame photometer (Model S-931). BOD and COD were estimated followed by standard titration method followed by IS 3025: Part 44 and 58, respectively, [33,34]. Before the phytoremediation process acclimatisation process follows, in that 500 gm of water hyacinth was taken. The plants were then transferred and spread uniformly into a plastic trough having capacity of 30 litres containing waste water with dilution of 10% and 20%. The experimental setup was placed near window so that the plant receives enough sunlight. The acclimatisation process carried for 2 days after that the major treatment method that is phytoremediation process follows for 7 days in that period it removes the major wastes in that water. After 7 days the waste water was taken for heavy metal analysis. The experimental setup follows as 10% of wastewater and 90% of Tap water and another form 20% of wastewater 80% of Tap water. Figure 1 represents the methodology followed in the present research work. The removal

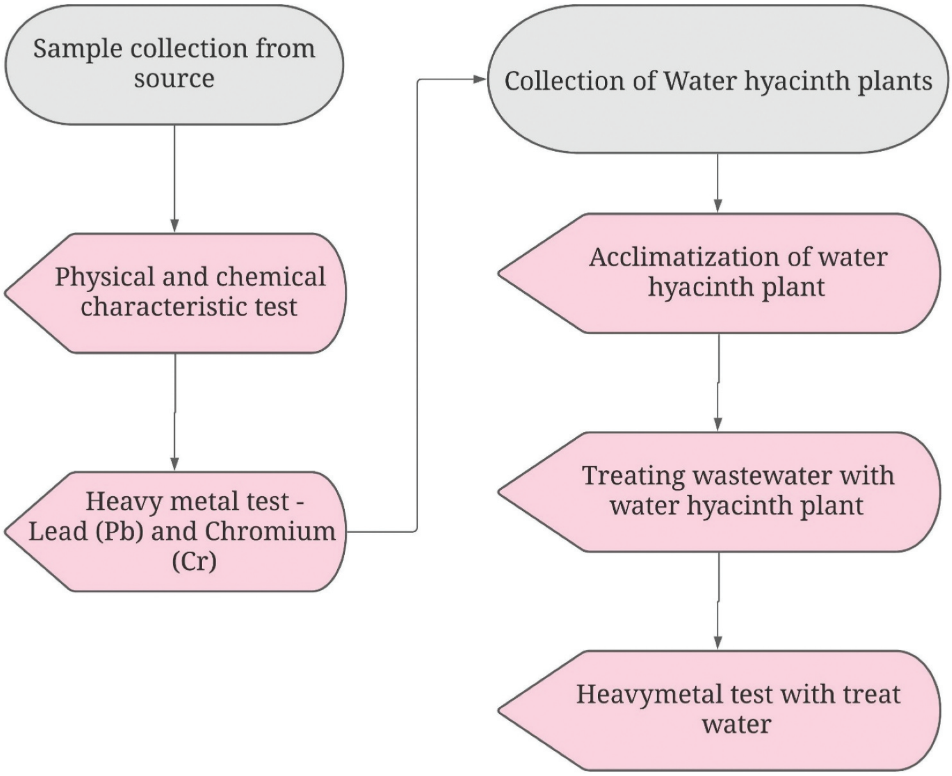

Figure 1. Methodology for phytoremediation.

efficiency (RE) and relative growth rate (RGR) [35] of the water hyacinth was calculated using equation 1 and 2.

$$RE = \frac{Inlet\ concentration - Outlet\ concentration}{Inlet\ concentration} \times 100 \tag{1}$$

$$RGR = \frac{In(Final\ biomass\ of\ treatment) - In(Initial\ biomass\ of\ treatment)}{Days\ of\ growth} \tag{2}$$

3. Results and discussion

Contaminated wastewater was analysed using Atomic absorption spectroscopy for heavy metals viz. Aluminium, Barium, Cadmium, Chromium, Copper, Phosphorous, Manganese, Nickel, Lead, Selenium, Zinc. It was found that the concentration of Barium, Cadmium, Copper, Phosphorous, Nickel, Selenium and Aluminium are in lower level. Hence, Chromium and lead are found that high concentration and it has been considered for the study.

4. Relative growth of water hyacinth

The relative growth of water hyacinth has been studied in detail and it indicate that different concentration of chromium and lead affects the growth of water hyacinth. The concentration of chromium ranged from 0.5 to 2 mg/L has increased the growth and high concentration of chromium about 5 mg/L has decreases the growth of water hyacinth.

5. Effect of chemical characteristics on phytoremediation process

pH

pH is an important parameter to evaluate the quality of water for domestic uses. The variation in concentration of hydrogen ion in water is indicated by the value of pH. The value ranges from 0 to 7 is acidic, 7 is neutral and 7–14 is alkaline in nature (Piyush Gupta, 2019). The pH value plays a significant role in the concentrations of heavy metals of a given biological system [36–38]. The removal efficiency for different location by using phytoremediation is shown in figure 2. In the present study, all four samples are in alkaline nature, in 10% and 20% of phyto remediation treatment, 26.37% of pH value reduce in all samples. There is no effective reduction of pH in 10% to 20% of phyto remediation treatment. The peak removal efficiency is observed at both treatments with 26.37% using Water Hyacinth Plant.

6. Total hardness

TH is arisen in water due to natural and man-made sources. The disposal of waste from the residents, sewage intrusion, and industrial effluents are the major reason for elevated concentration of hardness in water [39–43]. Hard water is high in disintegrated minerals, both calcium and magnesium.The hard water can cause indigestion problem and possibilities of forming calcium oxalate crystals in urinary tracks. In this study all four samples are examined for total hardness in which There is no effective reduction of Total Hardness in 10% to 20% of phyto remediation treatment. The peak removal efficiency is observed at both treatments with 30%-50% using Water Hyacinth Plant is shown in figure 3.

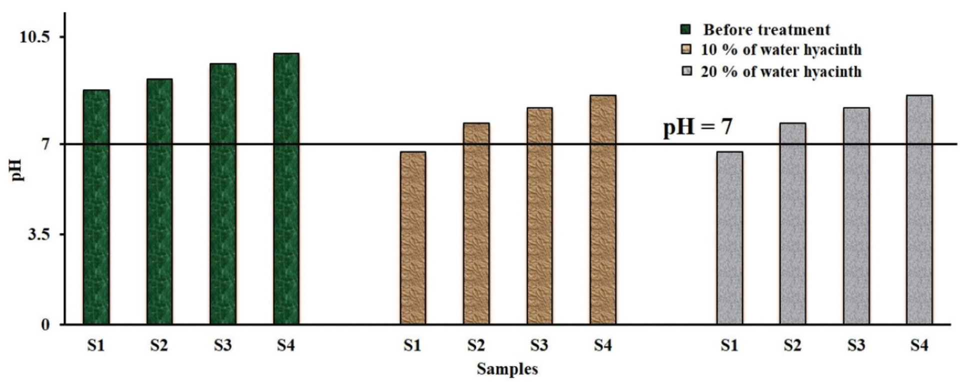

Figure 2. Removal Efficiency of pH at different locations

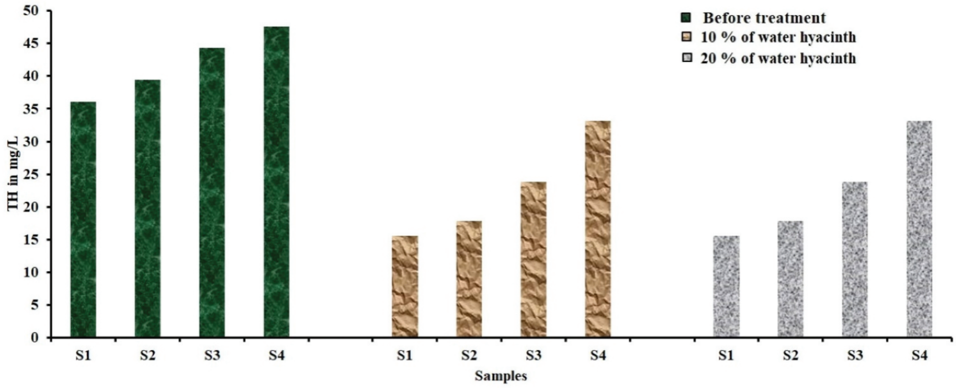

Figure 3. Removal Efficiency of Total Hardness at different locations.

7. TDS

TDS in water contains inorganic salts such as carbonates, bicarbonates, major anions such as calcium, sodium, major cations such as chlorides, sulphates, phosphates and nitrate [44]. The immediacy of high TDS will ordinarily influence all the treatment procedure and removal of TDS is tedious under biological treatment system (Table 1). The highest removal efficiency of TDS is obtained at Sample 4 at 10% and 20% Phytoremediation is shown in figure 4. High TDS was recorded in all locations. As per drinking water standard (BIS, 1991), permissible limit of TDS is 500 mg/l. It was

observed that water hyacinth can bring the TDS level within the norms. It was found that at the end of 7 days, the removal efficiencies varied from 35% to 50%, after that plants started dying.

8. Sodium

Metal contamination in textile effluents occurs due to the presence of dyes and additives used (e.g. caustic soda, sodium carbonate and salts) during the textile manufacturing steps. The dye effluents contained dying ingredients, sodium sulphate anhydride and

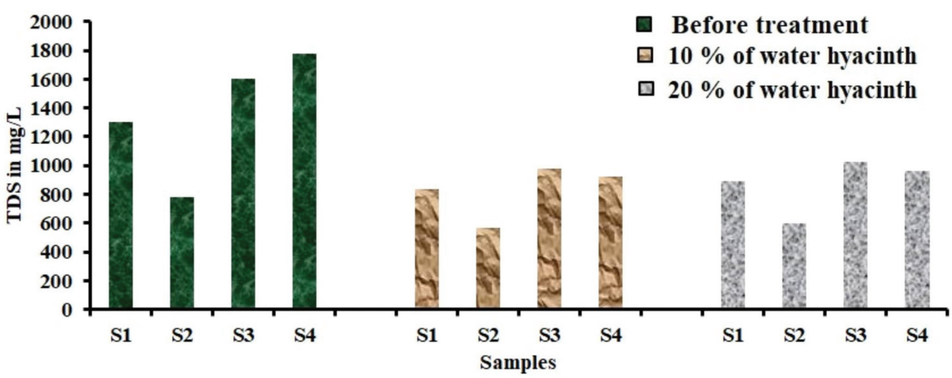

Figure 4. Removal efficiency of TDS at different locations.

Table 1. Physical characteristic of water before and after treatment of 10% and 20% of phytoremediation.

		S1			S2			S3			S4		
S. No	Physical parameters	Raw water	10% of Water hyacinth	20% of Water hyacinth	Raw water	10% of Water hyacinth	20% of Water hyacinth	Raw water	10% of Water hyacinth	20% of Water hyacinth	Raw water	10% of Water hyacinth	20% of Water hyacinth
1	Appearance	Not Clear	Partially clear	Partially clear	Not Clear	Partially clear	Partially clear	Not Clear	Partially clear	Partially clear	Not Clear	Partially clear	Partially clear
2	Colour (Pt. Co – scale)	Brownish	Light green	Light green	Green	Light green	Light green	Dark Brown	light green	Light green	Dark Brown	Light green	Light green
3	Odour	Bad Smell	Greenish smell	Greenish smell	Bad smell	Greenish smell	Greenish smell	Acetic Smell	Greenish smell	Greenish smell	Acetic smell	Greenish smell	Greenish smell
4	TDS (mg/L)	1300	839	888	784	567	600	1600	976	1025	1780	926	960

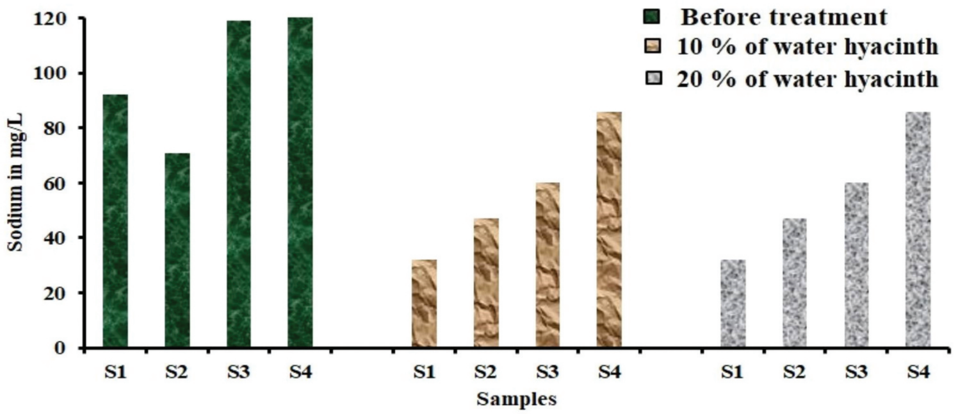

Figure 5. Removal efficiency of sodium at different locations.

polyvinyl alcohol. Dye waste water containing organic material and a high concentration of inorganic ions such as sulphates, phosphate and sodium that may have affected the adsorption efficiency [45–47]. High level of sodium was recorded in all samples. As per drinking water standard (BIS, 1991) [48], permissible limit of Sodium is 40 mg/l. It was found that at the end of 7 days, the peak removal efficiencies varied from 30% to 65%, after that plants started dying (figure 5).

9. Potassium

Potassium might be expelled from water by methods for Reverse Osmosis. Potassium is applied in water decontamination [49]. For instance, potassium permanganate is material for oxidation of waterborne compounds, for example, for iron or manganese removal, and disinfection. Potassium removal efficiency is insufficient in both the treatment using water Hyacinth Plant. Potassium should be zero in drinking water. The peak removal efficiency of potassium is obtained in each treatment is 40% to 28% is shown in figure 6.

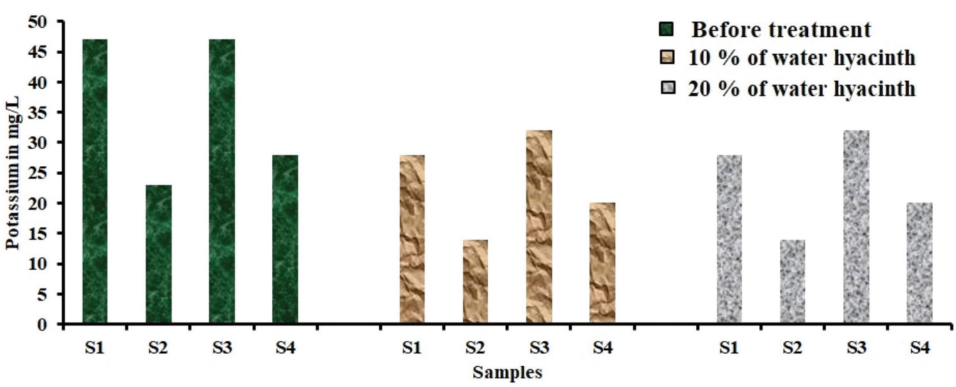

Figure 6. Removal efficiency of potassium at different locations.

10. Effect of oxygen concentration on phytoremediation

DO

DO is another important parameter to assess the quality of water for domestic usage in day-to-day life. It refers the concentration of vaporous oxygen that blended with water. The minimum range DO in waterbodies should not be less than 4 mg/L for aquatic and 9 mg/L for human being [50]. The degree of DO in any water shows condition of contamination level. The water hyacinth expanded the DO level in all water tests at various areas is shown in figure 7. In this study all four samples are under 4 ppm of DO, which is not suitable for living organisms. After treatment with 10% and 20% of phytoremediation, the DO is increased more than 4 mg/l. Now the water is suitable for living organisms and aquatic plants.

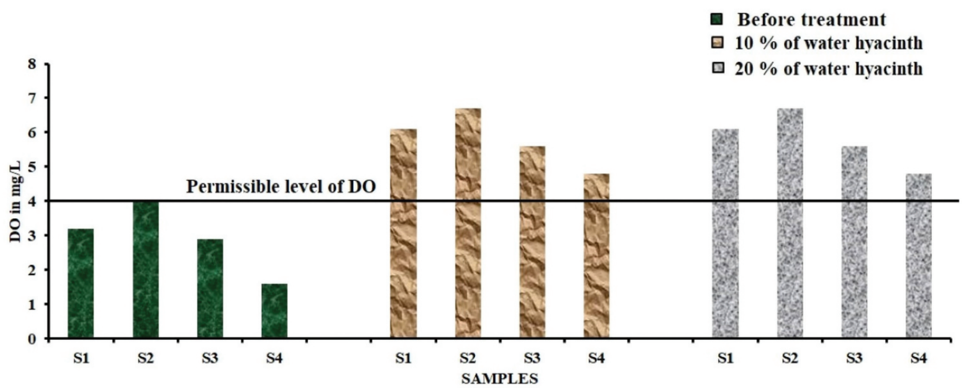

Figure 7. Removal efficiency of DO at different locations.

11. BOD

BOD is the amount of dissolved oxygen required by aerobic biological organisms to separate natural material present in a given water test at certain temperature over a particular timeframe [51]. Water supply with a BOD level of 3–5 ppm is considered moderately clean. In this study all the four samples are within the range in both 10% and 20% of Phytoremediation. The Peak removal efficiency of BOD is obtained at both the treatments with 40% to 55% using water Hyacinth Plant is shown in figure 8.

12. COD

Chemical Oxygen Demand (COD) is an indicative measure of the amount of oxygen that can be consumed by reactions in a measured solution [52–54]. This high reduction in COD is attributed to the reduction in pH which in turn favours microbial action to degrade COD. In this study all four samples are examined for total COD in which there is an effective reduction of COD from 10% to 20% of phyto remediation treatment (Table 2).

Table 2. Chemical characteristic of water before and after treatment of 10% and 20% of phytoremediation.

S. No	Chemical parameters	S1 Raw water	S1 10% of Water hyacinth	S1 20% of Water hyacinth	S2 Raw water	S2 10% of Water hyacinth	S2 20% of Water hyacinth	S3 Raw water	S3 10% of Water hyacinth	S3 20% of Water hyacinth	S4 Raw water	S4 10% of Water hyacinth	S4 20% of Water hyacinth
1	pH	9.10	6.70	6.70	9.50	7.80	7.80	10.10	8.40	8.40	10.50	8.90	8.90
2	Total hardness	36.10	15.60	15.60	39.40	17.80	17.80	44.30	23.80	23.80	47.60	33.20	33.20
3	Sodium (mg/L)	92.00	32.00	32.00	71.00	47.00	47.00	119.00	60.00	60.00	123.00	86.00	86.00
4	Potassium (mg/L)	47.00	28.00	28.00	23.00	14.00	14.00	47.00	32.00	32.00	28.00	20.00	20.00
5	DO (mg/L)	3.20	6.10	6.10	4.00	6.70	6.70	2.90	5.60	5.60	1.60	4.80	4.80
6	COD (mg/L)	1740	837	900	1900	894	1200	2130	1487	1500	2560	1890	2000
7	BOD (mg/L)	5.65	2.57	2.57	7.11	3.19	3.19	6.28	3.23	3.23	8.04	4.86	4.86

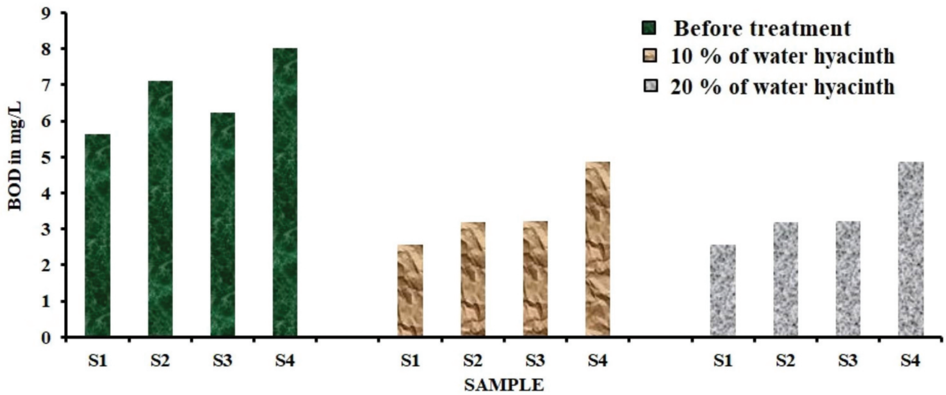

Figure 8. Removal efficiency of BOD at different locations.

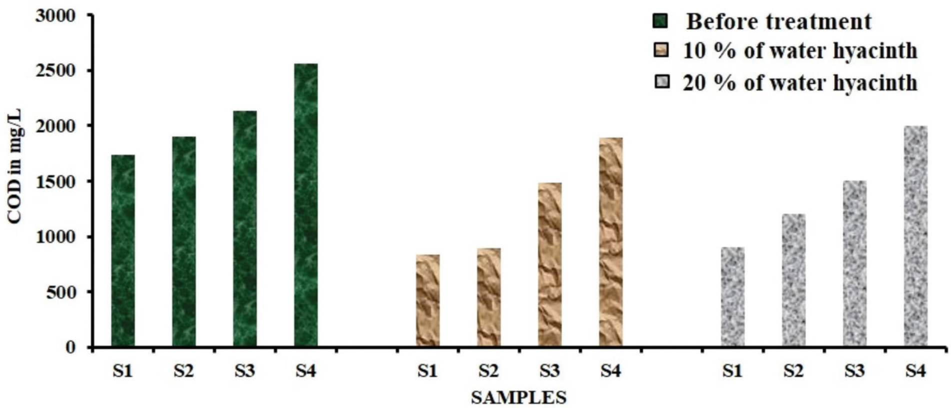

Figure 9. Removal efficiency of COD at different locations.

The peak removal efficiency is observed at both treatments with 50–65% using Water Hyacinth plant is shown in figure 9.

13. Effect of heavy metals on phytoremediation process

13.1. Chromium

Chromium is used in textile manufacturing as a catalyst in the dyeing process and as a dye for wool [55]. Chromium often accumulates in aquatic life, adding to the danger of eating fish that may have been exposed to high levels of chromium (Table 3). In the present study showed that the chromium was slightly decreased. The Peak removal efficiency of chromium is at 20% to 46% in both 10% and 20% of Phytoremediation is shown in figure 10

Table 3. Concentration of heavy metals in water before and after treatment of 10% and 20% of phytoremediation.

S. No	Chemical parameters	S1			S2			S3			S4		
		Raw water	10% of Water hyacinth	20% of Water hyacinth	Raw water	10% of Water hyacinth	20% of Water hyacinth	Raw water	10% of Water hyacinth	20% of Water hyacinth	Raw water	10% of Water hyacinth	20% of Water hyacinth
1	Cr (mg/L)	1.07	0.86	0.96	2.38	1.76	1.96	0.81	0.56	0.8	0.45	0.24	0.34
2	Pb (mg/L)	0.037	0.021`	0.025`	0.183	0.112	0.15	0.053	0.034	0.054	0.031	0.019	0.022

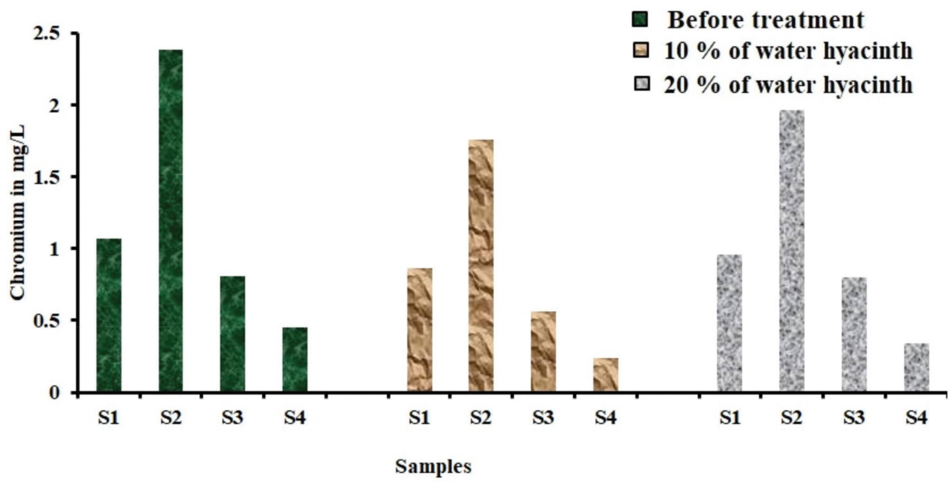

Figure 10. Removal efficiency of chromium at different locations.

14. Lead

Excessive concentration of lead is a most significant contamination in water. A continuous consumption of lead contaminated water leads to servere effects on human health such as brain diseases, cognitive and reproductivity problems, carcinogenic effects, cancer, kidney and bones diseases. The International Agency for Research on Cancer has classified it as a human carcinogen; exposure to antimony can cause reproductive disorders and chromosome damage [35,56].In this study lead level was initially high, after the treatment lead content was reduced upto 38%to 43% in 10% and 20% of Phytoremediation is shown in figure 11.

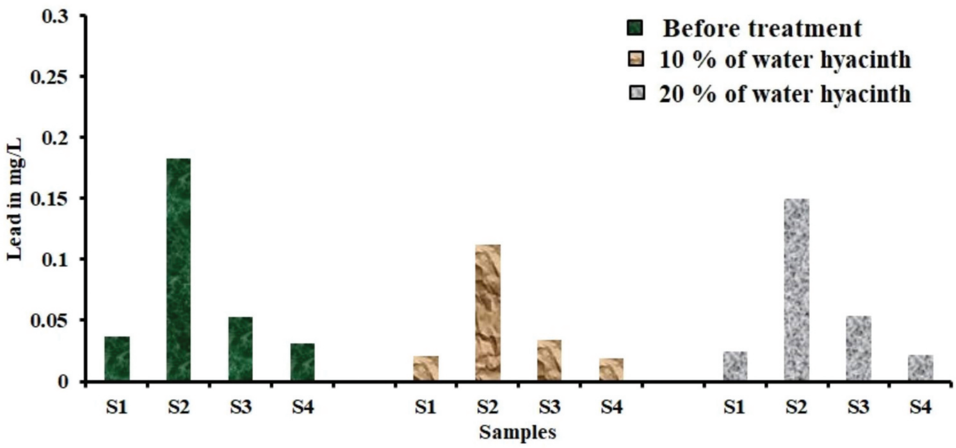

Figure 11. Removal efficiency of lead at different locations.

15. Conclusion

Water is an indispensable element for domestic and other uses in all over the world. The developing countries like India and China are still struggling to safe and maintain the nature source of surface water for human betterment. In present study helps to treat the contaminated water using phytoremediation is a cost effectively and more efficient way for treatment. Higher values of certain parameters of river water nearby dye industry indicate the unfitness of water for drinking purpose.

The present study concluded that, the excess concentration of hydrogen ion in water was removed by 26.37%, dissolved oxygen concentration was increased by 15% during the treatment process.

The effective removal of BOD and COD was recorded during the 10 and 20% of phytoremediation process up to 40 −50% efficiency.

The concentration of heavy metals such as chromium and lead were effectively removed by 46% and 43% in 20% of phytoremediation respectively.

TDS and TH were removed by 30 to 50% during the 20% of phytoremediation process. The concentration of sodium and potassium effectively removed up to 28 to 40% by high phytoremediation process.

The above treatment process revealed that 20% of the phytoremediation process effectively removed the high concentration of chemical and heavy metals present in the contaminated water. Results suggest that the water hyacinth (*Eichhornia Crassipes*) can be effectively used for the removal of heavy metals and other water quality parameters. The study concluded that use of water hyacinth as an adsorbent is a most economical and very effective way of removing a high concentration of lead and chromium in industrial effluents before it disposed to the natural water system. This study helps to researcher and scientists works in the field of using low-cost materials for wastewater treatment process.

Disclosure statement

We declare that all authors have no any potential conflict of interest including financial and personal or other relationships with other people or organizations.

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