Assessment of pollution load in sewage water and treatability potential of aquatic plants

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Abstract

In present study, pollution load particularly organic material was assessed in the sewage water with its treatment by using efficient aquatic plants in the controlled laboratory condition. Sewage samples were collected from the urban area of the Jaipur city, India and analyzed for wastewater quality parameters. Various wastewater quality parameters recorded *viz.* pH, 7.52; Electrical Conductivity (EC), 7.6 µS/cm; Phosphate, 2.85 mg/L; NO_3-N, 3.21 mg/L; NH_3-N, 6.06 mg/L; TSS, 165.7 mg/L; TDS, 521.424 mg/L; VSS, 121.9 mg/L; BOD = 152 mg/L, COD, 575 mg/L; Cl, 2336.27 mg/L including metal content as Cu, 0.1657 mg/L; Cd, 0.0736 mg/L; Cr, 0.1454 mg/L and Pb, 1.0842 mg/L in the raw sewage. Locally growing aquatic plants *viz Phragmites karka*, *Eichhornia crassipes*, *and Spinacia oleracea* in the sewage contaminated area were selected for sewage treatment for different duration. Improvement in wastewater quality parameters were observed during the sewage treatment by growing selected aquatic plants in the raw sewage. Results indicate the plant *Eichhornia crassipes*, *Phragmites karka*, and *Spinacia oleracea* were found to reduce BOD level by 68 to 73% and COD by 62 to 70% in the sewage water. The plant, *Eichhornia crassipes* emerged as more efficient plant to reduce BOD level, however, *Phragmites karka* found more effective in removing metal (Cr) and *Spinacia oleracea* removed NO_3-N more efficiently. Present study concludes that using efficient aquatic plants in combination for sewage treatment could be a low cost and sustainable technology for wastewater management and environmental safety.

Keywords**:** Sewage, Eutrophication, Macrophyte, BOD, Metals, Water Pollution

1. Introduction

Water pollution is not a new environmental issue, it has long been associated with urbanization and modernization, as well as the rapid rise of the world's population [1]. Sewage water produced from household activities which includes water from the washbasin, bathroom, toilet, washing machine and dishwasher. Mousavi and Khodadoost [2] reported that detergents, sanitizers, chemicals from boilers, and residential wastes are most common causes of water contamination. Wastewater has several adverse effects on the ecosystem, including eutrophication and a decline in the water quality of natural water due to the presence of nitrogen and phosphorus [3]. Hanafiah et al. [4] reported that wastewater containing compounds will have serious adverse effects on environment and human health. Environmental problems such as eutrophication, toxicity in aquatic plants and animals and changes in aquatic organisms' behaviors are caused by the excessive pollutant discharge into the aquatic environment, which also results in elevated levels of organic substances, and other toxic contaminants [5]. The main causes of the massive amounts of wastewater that are released into the environment are population growth and industrialization, which mainly consist of organic substances and metals [6]. A sustainable technique is therefore required to treat wastewater before it is discharged into aquatic bodies [7]. A global concern is the restoration of potentially harmful metals and metalloids contaminated water. It has been well-established, when compared to chemical treatments, biological methods for removing contaminants from the environment are less expensive [8]. Developing effective, affordable, and eco-friendly options for the remediation of trace elements and other contaminants in wastewater has become more challenging in recent years due to increasing wastewater discharges. Physical and chemical processes, such as the denitrification method by Mook et al. [9] and chemical precipitation by Kiran et al. [10], have been used to treat wastewater. These techniques are becoming less environmentally friendly due to the possibility of creating toxic sludge as a byproduct [11]. Phytoremediation is a new approach that uses green plants to remove different types of toxins from wastewater safely and economically [12, 13]. It is suitable for application in wastewater treatment because of its high pollution tolerance, large biomass production rate, and capacity to absorb metals and nutrients from wastewater [14, 15]. Cost-effective phytoremediation technology has attracted a lot of research interest recently for the environmentally and socially responsible growth of society [16, 17]. *Eichhornia crassipes* [18], water lettuce [19], duckweed [20], and vetiver grass [21] have been reported to treat wastewater, however, limited data are available to utilize aquatic plants for treating raw sewage. The pollutant removal technique comprises an interplay between bacterial metabolism, plant absorption, and plant accumulation potential [22]. Objective of present study was to assess the potential of naturally growing plant *Eichhornia crassipes*, *Phragmites karka*, and *Spinacia oleracea* in removing pollutants from swage water for possible wastewater management and pollution control.

2. Materials & Methods

2.1 Sewage sampling and experimental set up

The urban area, Sanganer situated between 26° 49° and 26° 51° N and 75° 46° and 75° 51° E of in the Jaipur district of Rajasthan, India was selected for present study. Polyethylene plastic bottles with a one-liter capacity were used to collect the sewage samples, stored in container at pH 2 and 4^0 C, with 65% nitric acid (HNO_3) and brought to laboratory for analysis of water quality parameters including metals (Cd, Cr, Pb, and Cu) using AAS technique. Collected sewage samples were systematically labeled as S1 to S5 for different sites and evaluated for physio-chemical and water quality parameters in the laboratory following standard procedure [23]. The data analyzed as the average value of all the sets in triplicates [24]. For treatability potential study, three naturally growing plants in the sewage contaminated area i.e., *Eichhornia crassipes*, *Phragmites karka*, and *Spinacia oleracea* were selected based on their survival and fast-growing ability in the raw sewage. Collected aquatic plants were properly washed and acclimatized in the laboratory condition for before the experiment and grown in three separate plastic tubs (38cm X 25cm X 15cm) containing raw sewage along with a set of control (tap water) for 15 days of treatment duration.

2.2 Determination of physicochemical and water quality parameters

Initial parameter analyzed on the spot measurements (pH, conductivity), however, TSS, COD, NH_3-N, and BOD were performed in the laboratory following standard methods. The hydrogen ion concentration (pH) in the collected sewage water samples was determined using a pH meter [25]. The electrical conductivity meter measures electrical conductivity (EC) using a calibrated EC probe [26]. The amount of chloride in a water sample was determined using an argentometric titration [27]. COD content was calculated by the reflux titrimetric method [28]. The Nessler method was used to calculate the NH_3-N level. [29]. TSS was determined using the gravimetric method. Titration method was used to determine total alkalinity. Winkler titration method was used to determine biological oxygen demand [30].

2.3 Metal estimation

Metal concentration of the collected sewage water samples was evaluated using an atomic adsorption spectrophotometer (AAS) (Shimadzu, acetylene flame) using a specific hollow cathode lamp and a certain wavelength after acid digestion of samples [31].

3. Result and Discussion

3.1 Wastewater quality of Sewage water

Analysis of sewage water collected from different sampling from the selected area of Jaipur city, Rajasthan, India indicates high level of organic load including metals. Average values of wastewater quality parameters in collected sewage recorded as pH,7.5; Electrical Conductivity (EC),7.6 µS/cm; Phosphate, 2.85 mg/L; NO_3-N, 3.21 mg/L; NH_3-N, 6.06 mg/L; TSS, 165.7 mg/L; TDS, 521.42 mg/L; VSS, 121.9 mg/L; BOD = 152 mg/L, COD, 575 mg/L; Cl, 2336.27 mg/L and Metal as Cu, 0.16 mg/L; Cd, 0.073 mg/L; Cr, 0.14 mg/L; Pb, 1.08 mg/L as depicted in the table 1.

Table 1. Physicochemical and wastewater quality parameter of sewage water samples collected from different sites of Sanganer and Jaipur regions, Rajasthan, India.

Parameter	S1	S2	S3	S4	S5	SD
pH	7.4	7.3	7.5	7.1	7.5	0.074
EC	2.4	7.6	7.6	1.9	0.9	0.002
PO_4-P	2.85	2.03	1.92	1.72	2.06	0.207
NO_3-N	0.36	0.46	1.02	2.72	3.21	0.165
NH_3-N	1.60	1.10	1.24	3.30	6.06	0.178
TSS	165.7	75.5	56.69	43.58	26.64	0.629
TDS	1.37	4.36	3.99	521.42	119.93	0.311
VSS	121.9	66.1	50.33	43.58	26.64	0.274
BOD	152.5	22.5	78.3	62.32	70.91	0.784
COD	575	178	177	176	161	0.137
Chloride	444.86	2336.27	2262.29	332.89	186.94	0.267
Cd	0.061	0.041	0.041	0.045	0.073	0.0004

Cr	0.088	0.099	0.278	0.145	0.105	0.0001
Pb	0.913	0.945	1.084	0.860	0.977	0.0007
Cu	ND	ND	ND	0.165	ND	0.0001

Values are means (mg/L) ± SD (n=3).

pH of collected sewage water showed in slightly alkaline in nature may be mixing soap, urine, and detergent in the sewage by household activities. Maximum TSS values 165.7 mg/L was observed in the sewage. Presence of algae as well as soil particles in the water body influenced the TSS value due to rains, soil particles from the surrounding area enters the water bodies leads to increase suspended solids in water. Total suspended particles (TSS) in water usually may be larger than two microns which includes algae, bacteria, and inorganic components. Organic particles produce from the degradation of the raw materials may also be responsible for an increasing suspended solid. TSS is an essential component for assessing the wastewater quality parameters. As the value of suspended solids increases, the quality of water depleted [32]. Maximum value of COD recorded as 575 mg/L in the sewage sample (S1). High COD level in wastewater indicate high organic and pollution load which lead to depletion of dissolved oxygen (DO). Basically, COD is a measurement of how much oxygen is needed in water to oxidize dissolved organic matter [33]. It is an important aspect of water quality since it provides a score that indicates whether sewage discharge will have an adverse effect on the aquatic ecosystem. Similarly, high BOD level (152 mg/L) recorded in the sewage water which measures amount of dissolved oxygen needed by microorganisms for decomposition of organic compounds. The level of organic and pollution load in the aquatic environments estimated using BOD as an indicator [34]. Water quality consider to be good when the BOD value found low, however, high BOD value indicates poor quality of wastewater. Maximum value of NH_3-N (6.06 mg/L) in the sewage recorded in the sample S6. A significant amount of ammonia produces during the sewage treatment because of the decomposition of organic matter [35]. Sewage wastewater with a high ammonia nitrogen content can prevent nitrification naturally occurring, impair the capacity of water purification, and harm the aquatic environment. An increase in algae growth and eutrophication, which lower the amount of oxygen in the water, can be caused by discharging untreated sewage into water bodies.

3.2 Treatability potential of Aquatic plants for sewage treatment

Treatability potential of aquatic plants for sewage assessed by growing *Spinacia oleracea*, *Phragmites karka,* and *Eichhornia crassipes* in raw sewage (sample S1) with high pollution load as phosphate, NO_3-N, NH_3-N, TSS, TDS, VSS, BOD, COD, Chloride, Cd, Cr, and Pb were 2.85 mg/L, 0.368 mg/L, 1.6 mg/L, 165.7 mg/L, 1.372 mg/L, 121.9 mg/L, 152 mg/L, 575 mg/L, 444.86 mg/L, 0.0618 mg/L, 0.0884 mg/L, and 0.9136 mg/L. However, the pollution load observed maximum reduction after the treatment by *Spinacia oleracea* and recorded as 1.17 mg/L, 0.016 mg/L, 0.987 mg/L, 97.54 mg/L, 1.057 mg/L, 102.14 mg/L, 41 mg/L, 184 mg/L, 213.46 mg/L, 0.0214 mg/l, 0.0195 mg/L, 0.233 mg/L for phosphate, NO_3-N, NH_3-N, TSS, TDS, VSS, BOD, COD, Chloride, Cd, Cr, and Pb, respectively, with efficiency of 58.94%, 95.68%, 38.31%, 41.13%, 22.95%, 16.21%, 73.02%, 68%, 52.01%, 65.37%, 77.94% and 74.49% (Table 2).

Table 2. Wastewater quality of sewage during treatment by using *Spinacia oleracea* at different duration (days).

Parameter	Raw sewage (S1)	7 days	15 days	Removal efficiency (%)
Phosphate	2.85±0.25	1.48±0.12	1.17±0.10	58.94
NO_3-N	0.368±0.03	0.197±0.017	0.016±0.001	95.65
NH_3-N	1.6±0.14	1.2±0.10	0.987±0.088	38.31
TSS	165.7±14.85	127.95±11.51	97.54±8.77	41.13
TDS	1.372±0.12	1.139±0.10	1.057±0.09	22.95
VSS	121.9±10.97	111.8±10.06	102.14±9.19	16.21
BOD	152±13.68	87±7.83	41±3.69	73.02
COD	575±51.75	298±26.82	184±16.56	68.24
Chloride	444.86±40.03	276.24±24.86	213.46±19.21	52.01
Cd	0.0618±0.005	0.0358±0.003	0.0214±0.001	65.37
Cr	0.0884±0.007	0.0574±0.005	0.0195±0.001	77.94
Pb	0.9136±0.08	0.438±0.039	0.233±0.02	74.49

Values are means (mg/L) ± SD (n=3).

On the final day of sewage treatment by using *phragmites karka*, the phosphate, NO_3-N, NH_3-N, TSS, TDS, VSS, BOD, COD, Chloride, Cd, Cr, and Pb value were decreased to 1.08 mg/L, 0.148 mg/L, 1.05 mg/L, 83.56 mg/L, 1.058 mg/L, 86.54 mg/L, 48 mg/L, 168 mg/L, 168.51 mg/L, 0.0279 mg/l, 0.0247 mg/L, 0.316 mg/L respectively. Maximum removal efficiency by using *phragmites karka* after phytoremediation of metal ion for Cr observed 72.05% and minimum 29% for VSS (Table 3).

Table 3. Wastewater quality of sewage during treatment by using *Phragmites karka* at different duration (days).

Parameter	Raw sewage (S1)	7 days	15 days	Removal efficiency (%)
Phosphate	2.85±0.25	1.96±0.17	1.08±0.09	62.10
NO_3-N	0.368±0.03	0.237±0.021	0.148±0.013	59.78
NH_3-N	1.6±0.14	1.36±0.12	1.05±0.094	34.37
TSS	165.7±14.85	116.89±10.52	83.56±7.52	49.57
TDS	1.372±0.12	1.278±0.11	1.058±0.095	22.88
VSS	121.9±10.97	109.33±9.83	86.54±7.78	29.24
BOD	152±13.68	110±9.9	48±4.32	68.42

COD	575±51.75	289±26.01	168±15.12	70.78
Chloride	444.86±40.03	247.82±22.30	168.51±15.16	62.12
Cd	0.0618±0.005	0.0378±0.003	0.0279±0.002	54.85
Cr	0.0884±0.007	0.0531±0.004	0.0247±0.002	72.05
Pb	0.9136±0.08	0.679±0.061	0.316±0.028	65.41

Values are means (mg/L) ± SD (n=3).

However, on the final day of sewage treatment by using *Eichhornia crassipes*, the phosphate, NO_3-N, NH_3-N, TSS, TDS, VSS, BOD, COD, Chloride, Cd, Cr, and Pb value were decreased to 1.84 mg/L, 0.214 mg/L, 1.13 mg/L, 107.65 mg/L, 1.107 mg/L, 117.7 mg/L, 48 mg/L, 216 mg/L, 289.71 mg/L, 0.0248 mg/l, 0.0375 mg/L, 0.4917 mg/L respectively. Maximum removal efficiency of BOD found by using *Eichhornia crassipes* by 68.42 % and the minimum by 3.44 % of VSS (Table 4).

Table 4. Wastewater quality of sewage during treatment by using *Eichhornia crassipes* (Water hyacinth) at different duration (days).

Parameter	Raw sewage (S1)	7 days	15 days	Removal efficiency (%)
Phosphate	2.85±0.25	2.26±0.20	1.84±0.16	35.43
NO_3-N	0.368±0.03	0.287±0.025	0.214±0.019	41.84
NH_3-N	1.6±0.14	1.29±0.11	1.13±0.10	29.37
TSS	165.7±14.85	132±11.88	107.65±9.68	34.91
TDS	1.372±0.12	1.297±0.11	1.107±0.099	19.31
VSS	121.9±10.97	119.6±10.76	117.7±10.59	3.44
BOD	152±13.68	118±10.62	48±4.32	68.42
COD	575±51.75	387±34.83	216±19.44	62.43
Chloride	444.86±40.03	366.58±32.99	289.71±26.07	34.87
Cd	0.0618±0.005	0.0438±0.003	0.0248±0.002	59.87
Cr	0.0884±0.007	0.0568±0.005	0.0375±0.003	57.57
Pb	0.9136±0.08	0.7694±0.069	0.4917±0.04	46.17

Values are means (mg/L) ± SD (n=3).

Aquatic plants with developed root zone system often have ability to remove more TSS [36]. A greater amount of suspended particles can be filtered because the root capacity grows as the plant grows. A decrease in water flow was also associated with an increase in suspended solids and solids filtration by plant's roots. Plants take up nitrate as nutrients for growth and development lead to reduction of NH_3-N in the treated sewage. Selection of aquatic plants to reduce NH_3-N levels in wastewater is important due to their high tolerance for ammonia levels in wastewater and effective treatment of sewage through phytoremediation techniques [37]. High concentration of NH_3-N in wastewater may be due organic matter decomposition processes [38]. Photosynthetic activities of aquatic plants during sewage treatment add more oxygen into the wastewater and improve dissolved oxygen in the water, resulted in increasing bacterial activity in wastewater lead to lowering BOD and COD levels [39]. Aquatic plants used as a phytoremediation agent in present study found to reduce the levels of TSS, NH_3-N, NO_3-N, BOD, TDS, COD, and metals in sewage wastewater samples with varied potential. Similarly, *Lemna minor* reported to reduce TSS and organic pollutants levels in a wastewater sample [40, 41]. Nizam et al. [42] reported *Centella asiatica* remove the 98% of NH_3-N from wastewater followed by *Centella asiatica* treat sewage wastewater by reducing contaminants including TSS, NH_3-N, and COD [43].

4. Conclusion

Present study was attempted to assess the potential and possibility of using aquatic plants in reducing organic and inorganic pollution load from sewage to be employed in phytoremediation technology for wastewater management and pollution control. Potential of the *Spinacia oleracea*, *Phragmites karka*, and *Eichhornia crassipes* for removal of phosphate, NO_3-N, NH_3-N, TSS, TDS, VSS, BOD, COD, Chloride, Cd, Cr, and Pb from sewage water evaluates. Plants showed luxuriant growth in sewage water with potential of uptake of nutrients and metals contaminants and emerged as potential phytoremediation agent for sewage treatment. Results showed significant removal of BOD, 68.42% by *Eichhornia crassipes*, Cr, 72.05% by *Phragmites karka*, and NH_3-N 95.68% by *Spinacia oleracea* after 15 days of treatment. Study concludes that applying potential of efficient aquatic plants for sewage treatment could be a sustainable Phyto-technique over convention methods for wastewater management and environmental conservation.

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