RESEARCH ARTICLE

Potential uses of aquatic plants for wastewater treatment

Said M. Badr El-Din, Reda A. Abdel-Aziz

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ABSTRACT

The potential uses of growing aquatic plants for wastewater purification were examined on laboratory scale in batch experiments. These aquatic plants, duckweed, water hyacinth and green algae (*Chlorella vulgaris*), enhances the removal of pollutants by absorbing in the form of plant nutrients. Plants are capable of decreasing all tested indicator of water quality to level that permit the use of the purified water for irrigation. Chemical oxygen demand (COD) and biological oxygen demand (BOD5) reduced in wastewater to (43% and 42%) by duckweeds, (28% and 33%) by water hyacinth, and (33% and 38%) by green algae for 21 days. Duckweeds have much higher pollutants removal efficiencies, especially, N, P, K and other heavy metals than water hyacinth and green algae. So, duckweed was promise to use in wastewater treatments than water hyacinth and green algae.

Key Words: *Wastewater treatment; Aquatic macrophytes; Duckweed; Water hyacinth; Green algae*

INTRODUCTION

Raw sewage contains complex organic and inorganic materials, including proteins, urea, amines, cellulose, fats, carbohydrates and soap. In biological treatment facilities bacteria, fungi, zooplankton and algae degrade and use these complex materials, resulting in an effluent rich in nitrogen, potassium, phosphorus and other elements. The treated waste has usually been discharged into the nearest lake or river with little thought of the consequence, today, however, the growing world population and increasing demand for an improved environment make better disposal mandatory.

Some aquatic weeds, such as duckweed and water hyacinth, were found to possess the ability of purifying the organic pollutants and taking up inorganic nutrient salts such as nitrogen and phosphorus compounds. Research over the past few decades has proved that some floating plants, such as water hyacinth (*E. crassipes*), water lettuce (*Pistia stratiotes*), pennywort (*Hydrocotyle umbellata*), duckweed

(*Lemna minor*), water peanut (*Alternanthera philoxeroides*) and lidded cleistocalyx (*Cleistocalyx operculatus*), have the greatest effects on purifying eutrophic water (1-5). Thus, the macrophyte pond can be used as wastewater treatment facilities with such merits as low capital and operating/maintenance costs, energy saving, wide spectrum pollutants removal and the recovery of the aquatic plants as foodstuffs for animal or preparation of green manure and the reuse of wastewater as resources.

In this study a laboratory trial was made to assess the pollutant removal from wastewater in macrophyte pond of El-Nazlah wastewater treatment plant at El-Fayum Governorate, Egypt using duckweeds, water hyacinth and green algae as guide for application of macrophyte pond.

EXPERIMENTAL PROCEDURE

Glass tanks 0.25 m^2 in area and 60 cm height were filled with wastewater (v/v 1:1) from El-Nazlah sewage treatment plant after primary and secondary treatment, at El-Fayum Governorate, Egypt. The tanks were cultivated using a dose of 5 g for duckweed (*Limna* spp.), 2 g for strain of green algae (*Chlorella vulgaris*), 25 g for water hyacinth (*Eichhornia crassipes*) for each tank and a tank was left without cultivation as control. Each treatment was replicated 4 times. All treatments were left at room temperature (18-22^{o}C) for 21 days. At the end of experiment, macrophytes were harvested and its dry weights were determined. Macrophytes and wastewaters were chemically analyzed initially and at the end of experiment. Wastewater samples were analyzed for NH_4-N and NO_3-N using semi-micro Kjeldahl distillation procedure, and available P by Olsen method by the methods described by Jackson (6). Chemical oxygen demand (COD) and biological oxygen demand (BOD_5) were measured according to American Public Health Association (7). Dried plant and wastewater samples were digested with an H_2SO_4-$HClO_4$ acid mixture. Total-N and Total P in the digest were determined by Kjeldahl and colorimetric methods, respectively (6). Heavy metals (Fe, Zn, Mn, Cu, Co, Cr) were also assayed in the digest on a Perkin-Elmer 5000 atomic absorption spectrophotometer.

RESULTS AND DISCUSSION

Data in Table 1 show that all of aquatic tested plants have a potential and actual use for purifying wastewater. Duckweeds have high removal of COD and BOD5 (43% and 42) than water hyacinth (28% and 33%) and green algae (33% and 38%) for 21 days. DeBusk and Reddy (8) and Clough et al. (9) demonstrated that pennywort provides higher rate removal of BOD5 and suspended solids removal than water hyacinth and duck weeds. Similarly, Jianbo et al. (5) shows that the constructed wetland by water hyacinth removed as much as 64.44% of chemical oxygen demand. Sahah et al. (10) found that the average reduction by using water hyacinth in the treatment of wastewater were 50.61% for BOD5 and 46.38% for COD, by using duckweed were 33.43 % for BOD5 and 26.37% for COD, and by using water lettuce were 33.43% for BOD5 and 26.37% for COD. The explanation for lower COD in wastewater that plants transport oxygen to the root surface, thereby increasing the removal of organic matter by micro-organisms in sediments or on the surfaces of the plant rootstocks (1,11-13). Duckweeds have much higher pollutants removal efficiencies, especially, N, P, K and other heavy metals than water hyacinth and green algae (Table 1). The percentages of element recovery from wastewater were 46% N, 46% P, 43% K, 18% Fe, 14% Zn, 12% Mn, and 5.0% Cr for growing duckweed for 21 days, 30% N, 27% P, 21 % K, 9% Fe, 9% Zn, 8% Mn, and 5.0% Cr for growing water hyacinth for 21 days and 35% N, 36% P, 29% K, 14% Fe, 14% Zn, 10% Mn, and 0.0% Cr for growing green algae for 21 days. Jianbo et al. (5) shows that water hyacinth in the treatment of wastewater from a duck farm removed 21.78% of total nitrogen (TN) and 23.02% of total phosphorus (TP). Sahah et al. (10) found that the average reduction by using water hyacinth in the treatment of wastewater were 40.34% for nitrogen and 18.76% for phosphorus, using duckweed were 17.59% for nitrogen and 15.25% for phosphorus and by using water lettuce were 17.59% for nitrogen and 15.25% for phosphorus. The pH values had very little or no change by growing all tested plants in wastewaters.

Growth and composition of floating aquatic plants vary with a number of factors, including seasons, crop management techniques, geographic location and the type of wastewater or nutrient medium utilized. Data in Table 2 show that the biomass of duckweed, water hyacinth and green algae was 500, 350 and 168 gm^{-2}, respectively. These plants, duckweed, water hyacinth and green algae enhance the removal of pollutants by absorbing in the form of plant nutrients. The chemical analysis of macrophytes shows that duckweed had high nutritive value and biomass than water hyacinth. However, Green algae had higher heavy metal content and low biomass than duckweed. Clough et al. (9) found that N and P content of the large leaved floating plants

Agricultural Microbiology Department, Agricultural and Biological Research Division, National Research Centre, Dokki, Cairo, Egypt.

Correspondence: Dr. Said M. Badr El-Din, Agricultural Microbiology Department, Agricultural and Biological Research Division, National Research Centre, Dokki, Cairo, Egypt, Telephone: 201005682914, e-mail: badreldinsaid@hotmail.com

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TABLE 1

Chemical analysis of wastewater before and after growing duckweeds, water hyacinth and green algae for 21 days

Constitutes	Initial (mg/l)	After growing					
		Duckweeds		Water hyacinth		Green algae	
		mg/l	Recovery %	mg/l	Recovery %	mg/l	Recovery %
COD	144	82	43	104	28	96	33
BOD_5	42	24	42	28	33	26	38
Total-N	46	25	46	32	30	30	35
NH_4-N	18	10	-	14	-	12	-
NO_3-N	1	1	-	1	-	0	-
Organic-N	37	14	-	15	-	13	-
Total-P	22	12	46	16	27	14	36
PO_4	12	6	-	8	-	9	-
K	14	8	43	11	21	10	29
Fe	22	18	18	20	9	19	14
Zn	0.22	0.19	14	0.2	9	0.19	14
Mn	0.5	0.44	12	0.46	8	0.45	10
Cr	0.21	0.2	5	0.2	5	0.21	-
Cd	0.04	0.04	-	0.04	-	0.04	-
pH	7.45	7.4	-	7.4	-	7.4	-

TABLE 2

Analysis of duckweeds, water hyacinth and green algae

Constitutes	Duckweeds	Water hyacinth	Green algae
Total dry weight (g/m^2)	500	350	168.4
N %	3.4	2.5	2.84
P %	1.1	0.9	1.2
K %	0.8	0.7	1.1
Fe (ppm)	110	120	160
Zn (ppm)	40	42	60
Mn (ppm)	18	20	40
Cr (ppm)	0.3	0.4	0.4
Cd (ppm)	0.1	0.1	0.1
Cu (ppm)	0.1	0.1	0.2
Ash %	12.1	14.6	12.2

typically average 15-40 mg N and 4-10 mg P g^{1}, with pennywort frequently having higher tissue nutrient concentrations than water hyacinth or water lettuce. Tissue N and P levels usually are highest for plants cultured in media containing high concentration of nutrients and also are highest during the winter, the period of slowest plant growth. Although the small-leaved floating species are not productive, tissue N and P level usually are higher than those of the large-leaved species. *Lemina minor* cultivated on secondary sewage effluent was found to contain 45.9 mg N and 8 mg P g^{1}.

CONCLUSION

Aquatic plants (duckweeds, water hyacinth and green algae) are capable of decreasing all tested indicator of water quality in wastewater to level that permit the use of the purified water for irrigation. Chemical oxygen demand (COD) and biological oxygen demand (BOD_5) reduced in wastewater to (43% and 42%) by duckweeds, (28% and 33%) by water hyacinth, and (33% and 38%) by green algae for 21 days. Duckweed was highly efficient in removal of pollutants from wastewater, especially, N, P, K and other heavy metals than water hyacinth and green algae and it can be used as fodder for animal. Duckweed, therefore, was promise to use in wastewater treatments than water hyacinth and green algae.

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