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***Full Length Article***

# Ecological Studies on Hydrophytic Vegetation of Irrigation and Drainage Canal Systems in Beni Suef, Egypt

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## ABSTRACT

The present study analyzed water plant vegetation in the different water bodies of the aquatic habitats associated with the River Nile system in Beni Suef, Egypt. Fifteen species belonging 11 genera and nine families were recorded. Large irrigation canal showed the richest habitat in species number, while small irrigation drain showed the lowest habitat. Higher salinity and macro elements were recorded in sediments and water of drainage canals more than those of irrigation canals. *Eichhornia crassipes*, *Potamogeton pectinatus*, *P. crispus* and *Echinochloa staginina* were the most recorded species in all habitats, while *Myriophyllum spicatum* was recorded in River Nile and large irrigation canal only. Bioaccumulation of heavy metals by some plants was measured. *Potamogeton pectinatus* was the most efficient species to accumulate heavy metal in its tissue. The maximal extent of heavy metal accumulation up to 5807, 4230 and 45 $\mu g g^{-1}$ DW for Mn, Fe and Cu, respectively was found in fully immersed *P. pectinatus*, while the highest value of Mn accumulation (9730 $\mu g g^{-1}$ DW) was recorded by *Ceratophyllum demersum*.

**Key Words:** Hydrophytes; Ecology; Irrigation canals; Phytoremediation; Egypt

## INTRODUCTION

The River Nile is the major regular and voluminous supply of water secured in Egypt. Establishment of Aswan High Dam in the most extreme south of Egypt controls the flow of water in the Nile and its branches, but decreased the amount of silt in the Nile water below the High Dam. Therefore, dredging of canals to remove silt and clay was no longer necessary, a factor, which has been found to cause an increase in the densities of fresh water hydrophytes in the Nile system (Zahran & Willis, 1992). Alteration of the hydrology of the River Nile System after regulation of the Nile water has created water bodies with different water level regimes, an effect, which resulted in difference in the species that dominate each site and also resulted in structural differences in aquatic plant communities and in the whole vegetation. The aquatic plants in the Nile system (River Nile & its branches) number about 35 species belong 19 genera and 15 families (Täckholm, 1974; Zahran & Willis, 1992) and greatly developed in the warm climate prevails in Egypt. The aquatic hydrophytes vegetation is growing so rapidly and densely representing an acute problem causing tremendous loss of water from water bodies like canals and drains through evapo-transpiration, clog gates, pump etc. Aquatic weeds have been found to severely reduce the flow capacity of irrigation canals thereby reducing the availability of water to the farmer's field. On the other hand, macrophytes are considered as important component of the aquatic ecosystem not only as food source for aquatic invertebrates, but also act as an efficient accumulator of heavy metals (Janauer, 2001; Pajević *et al.*, 2001; Samecka-Cymerman & Kempers, 2002; Samecka-Cymerman *et al.*, 2005). Bioavailability and bioaccumulation of heavy metals in aquatic ecosystems is gaining tremendous significance globally. Several of the submerged, emergent and free-floating aquatic macrophytes are known to accumulate and bioconcentrate heavy metals producing an internal concentration several folds greater than their surroundings (Chen *et al.*, 2008).

The aim of present study is to analyze macrophytic plant vegetation in the major water bodies in the irrigation and drainage system in Beni Suef district (Egypt) and testing the ability of some selected species to accumulate heavy metals as a phytoremediation.

## MATERIALS AND METHODS

**The study area.** The present study was carried at Beni Suef Governorate, located at 120 km south Cairo. Many regular visits to the different water bodies in the studied area were done. Five types of water bodies were selected, namely, main stream of the River Nile, Large, small irrigation canal, large and small irrigation drain. Fifty sampled stands were selected in the study area representing the various water bodies. In each stand, all plant species were recorded in five plots (25 $m^2$ each). The identification and nomenclature of

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the recorded species were according to Täckholm (1974) and Boulos (1999).

**Sediment, water and plant analysis.** Sediment and water samples of the different water bodies were collected at the corresponding sampling locations. The samples were collected around each sampling site with a radius of 5 m for water and sediment, respectively. The sediments were collected using a stainless steel collector. Water samples were collected at 20 cm below water surface using a glass bottle. Sediment textures were determined with the hydrometer method, providing quantitative data on the percentage of sand, silt and clay. The concentration of soil minerals $Na^+$, $K^+$, $Ca^{2+}$ and $Mg^{2+}$ in soil were determined using atomic absorption spectrophotometer, Perkin 403 (analytical methods for atomic absorption spectrophotometer, 1983). pH and conductivity of the soil samples were determined in saturated soil paste extract by pH and conductivity meters, respectively. pH values of water samples were calculated with a portable pH meter. The anions chlorides ($Cl^-$), sulphate ($SO_4^{2-}$), carbonate ($CO_3^{2-}$) and bicarbonate ($HCO_3^-$) were measured in water and sediment extract following the standard techniques of analysis (Jackson, 1962).

For testing heavy metals accumulation ability of plants, samples were collected from more than 10 individual plants from the same habitats (Large irrigation drain), within a 10 m stretch of the water body and then they were mixed up to form a composite plant sample. Three plant samples were prepared for each species. The samples were thoroughly cleaned with fresh water and distilled water for removal of soil and other extraneous particles. The products were cut into small pieces and dried in an oven at 65°C for 24 h. Samples of dried and milled plant materials were evaporated in a muffle furnace at 460°C with 24 h. Samples were digested in 10 mL aqua regia (1 $HNO_3$ + 3 HCl) on a hot plate in the following sequence and duration of temperatures; 2 h each at 25, 60, 105 and finally 125ºC. All samples were digested in duplicate, centrifuged and then made up to volume with 1% $HNO_3$ to 25 mL. Determinations of the elements in all samples measured by an atomic absorption spectrophotometer Shimadzu Model AA 640F (Japan).

**Statistical analysis.** SPSS statistical program was used to calculate Pearson's correlation co-efficients of hydrophytic plants to each other and to some sediments and water variables.

## RESULTS

**Vegetation.** Fifteen species belonging 11 genera and nine families were recorded (Table I). Large irrigation canal showed the richest habitat in species number, while small irrigation drain recorded the lowest species number habitat (five species only). *E. crassipes, P. crispus* and *E. staginina* were the most recorded species in all habitats, while *M. spicatum* was recorded in River Nile and large irrigation canal, only. In this study it well observed that the large

**Table I. percentage of the recorded species in the studied water bodies in Beni Suef.**
]

| Species | Life form | Floristic category | Family | River Nile | Large canal | Small canal | Large drain | Small drain |
|---|---|---|---|---|---|---|---|---|
| *Ceratophyllum demersum* L. | HH | ME+ES+IT | Ceratophyllaceae | 25 | 60 | 20 | 50 | 5 |
| *Cyperus alopecuroides* Rottb | GH | TR | Cyperaceae | 0 | 20 | 0 | 0 | 0 |
| *Cyperus articulatus* L. | GH | TR | Cyperaceae | 0 | 10 | 0 | 0 | 0 |
| *Echinochloa stagnina Retz.) P. Beauv.* | GH | TR | Gramineae | 40 | 40 | 50 | 60 | 50 |
| *Eichhornia crassipes*(Mart.)Solms-Laub | GH | TR | Pontederiaceae | 10 | 30 | 40 | 70 | 100 |
| *Lemna gibba* L. | HH | COSM | Lemnaceae | 0 | 0 | 0 | 30 | 0 |
| *Lemna minor* L. | HH | COSM | Lemnaceae | 0 | 0 | 0 | 10 | 0 |
| *Ludwigia stolonifera* Guill. & Perr. Raven | HH | ME+TR | Onagraceae | 10 | 0 | 0 | 0 | |
| *Myriophyllum spicatum* (L.) (Per) | HH | | Haloragidaceae | 10 | 40 | 0 | 0 | 0 |
| *Phragmites australis (Cav.) Trin. ex Steud.* | GH | COSM | Gramineae | 0 | 10 | 0 | 20 | 60 |
| *Potamogeton crispus* L. | HH | COSM | Potamogetonaceae | 20 | 30 | 40 | 50 | 30 |
| *Potamogeton nodosus Poir.* | HH | COSM | Potamogetonaceae | 20 | 10 | 0 | 40 | 0 |
| *potamogeton pectinatus* L. | HH | COSM | Potamogetonaceae | 10 | 10 | 10 | 30 | 0 |
| *Saccharum spontaneum* L. | GH | ME+SA+IT+TR | Gramineae | 30 | 20 | 0 | 0 | 0 |
| *Typha domingensis* Pers | GH | ME + IT | Typhaceae | 10 | 10 | 0 | 5 | 0 |

**The life forms are**: PH: phanerophytes, GH: geophytes-helophytes, HH: hydrophytes
**The floristic regions are**: COSM: cosmopolitan, ES: Euro-Sibarian, IT: Irano-Turanian, ME: Mediterranean, SA: Saharo-Arabian and TR: Tropical

**Table II. Mean and standard error (N = 5) of the different sediment variables in the different studied habitats**
]

| Habitats | (%) | | | | | | pH | EC (µmhos $cm^{-1}$) | mg 100 $g^{-1}$ dry soil | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | sand | Silt | Clay | $Cl^-$ | $CaCO_3$ | O.C | | | $Na^+$ | $K^+$ | $Ca^{2+}$ | $Mg^{2+}$ |
| River Nile | 86.5±0.9 | 12.2±0.9* | 1.3±0.1 | 0.09±0.01 | 8.9±1.8 | 1.1±0.2 | 7.5±0.2 | 431.5±114 | 367.9±120 | 31.3±4.1 | 40.5±8.7 | 89.4±32 |
| Large irrigation canal | 87.6±1.0 | 10.8±1.0 | 1.6±0.1 | 0.18±0.03 | 8.0±0.8 | 1.4±0.1 | 7.5±0.9 | 618±161 | 381±66 | 45.3±5.2 | 97.3±24 | 79.5±19 |
| Small irrigation canal | 84.7±8.5 | 14.2±1.5 | 1.1±0.1 | 0.21±0.05 | 9.8±1.3 | 1.9±0.3 | 7.7±1.4 | 687±102 | 265.3±896 | 47.3±3 | 110.5±15.3 | 95.6±6.8 |
| Large irrigation drain | 83.8±6.7 | 13.8±2.4 | 2.4±0.3 | 0.41±0.09 | 11.2±0.9 | 2.4±0.7 | 8.2±2.1 | 1089±142 | 896.2±53 | 32.1±4.9 | 196.7±62 | 185.2±23 |
| Small irrigation drain | 91.4±1.4 | 7.30±1.4 | 1.3±0.2 | 0.91±0.10 | 12.4±2.1 | 1.2±0.14 | 7.8±0.1 | 1252±250 | 1341±300 | 208.1±56 | 74±229 | 221.1±23 |

* ± S.E.

**Table III. Mean and standard error (N = 5) of the different water variables in the different studied habitats**

| Habitats | (mg $kg^{-1}$) | | | | | | | | pH | EC |
|---|---|---|---|---|---|---|---|---|---|---|
| | $Na^+$ | $K^+$ | $Ca^{2+}$ | $Mg^{2+}$ | $C1^-$ | $CO_3^{--}$ | $HCO_3^-$ | $SO_4^{--}$ | | (µmhos $cm^{-1}$) |
| River Nile | 30±2.3* | 5.4±0.3 | 15± 3.4 | 17±2.4 | 53± 1.3 | Traces | 140±8.2 | 27±3.2 | 7.3±0.5 | 301±353.0 |
| Large Irrigation Canal | 27±1.5 | 6.8 ±0.2 | 18± 2.7 | 24±1.2 | 45±2.5 | Traces | 160±9.6 | 20±2.7 | 8.0±0.9 | 312± 36.1 |
| Small Irrigation Canal | 36±.2 | 6.1 ±0.3 | 32±6.3 | 24 ± 3.1 | 56±3.6 | Traces | 175±8.7 | 23±1.9 | 7.9±0.7 | 430±54.3 |
| Large Irrigation drain | 52±3.4 | 8.41±0.5 | 25 ± 5.2 | 19±1.8 | 61±4.1 | 30±2.3 | 295±8.4 | 175±8.6 | 7.8±0.2 | 801±87.5 |
| Small Irrigation drain | 63 ± 4.6 | 9.22±1.1 | 36±8.6 | 25±7.5 | 70±4.2 | 10±1.3 | 300±10 | 35±2.1 | 8.1±0.6 | 850±96.3 |

* ± S.E.

**Table IV. Significant correlation coefficient between some sediment and water variables with hydrophytic species**

| Species | Water variable | | | | Sediment variable | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | pH | EC | Na | Ca | Sand | Clay | $Cl^-$ | $CaCO_3$ | O.C | pH |
| *Ceratophyllum demersum* L. | | | | | | | | | | |
| *Cyperus alopecuroides* Rottb | | | | | | | | | | |
| *C. articulatus* L. | | | | | | | | | | |
| *Echinochloa stagnina Retz.) P. Beauv.* | | | | | | | | | | + |
| *Eichhornia crassipes*(Mart.)Solms-Laub | | + | ++ | | | | + | + | | |
| *Ludwigia stolonifera* Guill. & Perr. Raven | - | - | | | | + | | | | |
| *Lemna gibba* L. | | | | | | + | | | | |
| *L. minor* L. | | | | | | | | | | |
| *Myriophyllum spicatum* (L.) (Per) | | | | | | | | | | |
| *Phragmites australis (Cav.) Trin. ex Steud.* | | | | | - | | ++ | | | |
| *Potamogeton crispus* L. | | | | | | + | | | ++ | ++ |
| *P. nodosus Poir.* | | | | | | | | | | |
| *P. pectinatus* L. | | | | | | | | | | |
| *Saccharum spontaneum* L. | | | | - | | | | | | |
| *Typha domingensis* Pers | | | | - | | | | | | |

\+ Positive significant correlation at the 0.05 level (2tailed)
\- negative significant correlation at the 0.05 level (2tailed)
++ Positive significant correlation at the 0.01 level (2tailed)

**Table V. Pearson's correlation coefficients of hydrophytic species with each other**

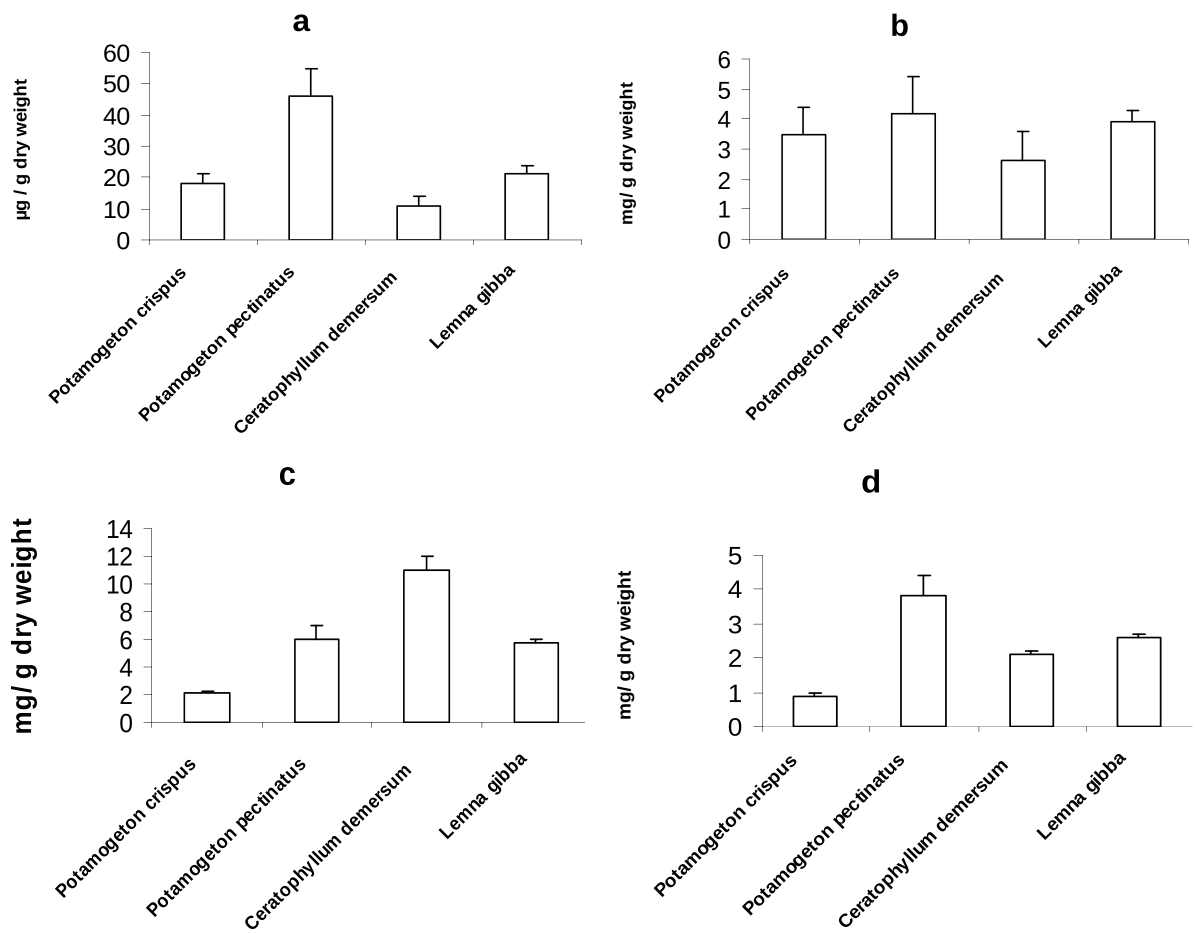
| Species | *Ceratophyllum demersum* | *C. alopecuroides* | *Cyperus articulatus* | *Echinochloa stagnina* | *Eichhornia crassipes* | *Ludwigia stolonifera* | *L. gibba* | *Lemna minor* | *M. spicatum* | *Phragmites australis* | *P. crispus* | *P. nodosus* | *Potamogeton pectinatus.* | *Saccharum spontaneum* | *Typha domingensis* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| *Ceratophyllum demersum* | 1 | | | | | | | | | | | | | | |
| *Cyperus alopecuroides* | | 1 | ++ | | | | | | + | | | | | | |
| *C. articulatus* | | ++ | 1 | | | | | | + | | | | | | |
| *Echinochloa stagnina* | | | | 1 | | | | | | | + | | | | |
| *Eichhornia crassipes* | | | | | 1 | | | | | + | | | | | |
| *Ludwigia stolonifera* | | | | | | 1 | | | | | | | | | |
| *Lemna gibba L.* | | | | | | | 1 | ++ | | | | | + | | |
| *L. minor L.* | | + | | | | | ++ | 1 | | | | | + | | |
| *Myriophyllum spicatum* | | | + | | | | | | 1 | | | | | | |
| *Phragmites australis* | | | | | + | | | | | 1 | | | | | |
| *Potamogeton crispus* | | | | + | | | | | | | 1 | | | | |
| *P. nodosus.* | | | | | | | | | | | | 1 | + | | |
| *P. pectinatus* | | | | | | | + | + | | | | + | 1 | | |
| *Saccharum spontaneum* | | | | | | | | | | | | | | 1 | + |
| *Typha domingensis* | | | | | | | | | | | | | | + | 1 |

\+ Positive significant correlation at the 0.05 level (2tailed)
++ Positive significant correlation at the 0.01 level (2tailed)

irrigation drain is free from vegetation when passing through villages.

**Sediment and water analysis.** Soil texture in all different water bodies are formed mainly of sand and small amount of silt and clay (Table II). The mean percentages of $CaCO_3$ were generally higher in irrigation drains than irrigation canals. The organic carbon content was obviously comparable in all different water bodies. Soil reaction

**Fig.1. Ability of hydrophytes to accumulate Cu (a), Fe (b), Mn (c) and Zn (d), All the values are mean of triplicates ± SE**




recorded the highest value in large irrigation drain, while the lowest value was recorded at small irrigation canal. The highest mean values of EC, $Cl^-$, $Na^+$ and $K^+$ were attained in the small irrigation drain (Table II). Like sediment analysis, water analysis of the studied habitats exhibited the highest mean values of $Cl^-$, $Na^+$, $K^+$ and $Mg^{2+}$ in the small irrigation drain (Table III). At the same time the lowest mean values of the previous parameters were recorded in the main River stream.

**Correlation between hydrophytes and sediment and water variables.** The correlation co-efficient (r) between the different sediment and water variables in the sampled stands is presented in Table (IV). It showed that some hydrosoil and water factors are significantly correlated with some species. *E. crassipes* showed positive correlation with sodium (at the level 0.01) and with $CaCO_3$ (at the level 0.05). *L. stolonifera* exhibited a positive correlation with clay and EC (at the level 0.01). *P. australis* recorded positive correlation with $Cl^-$, $Na^+$ and $K^+$. On the other hand *P. australis* showed negative correlation with sand. Other hydrosoil characteristics (silt) have no correlations with any species.

The correlation of hydrophytes to each other. No negative correlation recorded between plant species. *C. demersum* and *L. stolonifera* did not record significant correlation with any other species. *P. pectinatus* showed positive correlation (at level 0.01) with *L. gibba*, *L. minor* and *P.nodosus* Table (V).

**Heavy metal accumulation.** All the studied species exhibited high ability of heavy metal accumulation. The maximal extent heavy metals accumulation for Fe, Zn and Cu (up to 1.8, 3.7 & 4.2 times, respectively) was found in the fully immersed *P. pectinatus* (Fig. 1). At the same time Mn accumulation in dry biomass of *C. demersum* was up to 4.3 times more effective comparing to the lowest value recorded by *P. crispus*.

## DISCUSSION

Variations in environmental factors affect the distribution and abundance of aquatic plants, as is true of all organisms. The structure and composition of aquatic vegetation is related to the chemical composition of sediment and water (Gacia *et al.*, 1994; Raven, 1988;

Roelofs, 1983). It appears from the obtained results some species such as *E. crassipes*, *P. crispus* and *P. pectinatus* are well distributed in the different habitats. This can be due to their large-scale ability to disperse as well as, their ecological tolerance (Hutchinson, 1975). Spencer and Ksander (1992) reported that many submerged hydrophytes have a wide temperature tolerance for the germination such as *P. pectinatus*. In nature, this is more closely related to sediment temperature than to that of water (Spencer *et al.*, 2000). The vegetation in the small irrigation drain was less diverse, compared to other habitats studied. A reason for that was the dense vegetation of *Eichhornia,* which cover large area of the water surface all-over the year. The thick mat of *Eichhornia* prevents the light to penetrate into the water a factor, which may inhibit the development of many aquatic plants, especially the submerged plants.

It is well known that low-light conditions promote dominance by free-floating and floating-leaf species, rather than submerged ones (Day *et al.*, 1988; Stewart & Freedman, 1989; Skubinna *et al.*, 1995; Toivonen & Huttunen, 1995; Vestergaard & Sand-Jensen, 2000; Squires *et al.*, 2002; Nurminen, 2003). Most species of submerged macrophytes are highly intolerant of shading, while others may grow in gaps beneath a well-established canopy, such as *Ceratophyllum demersum*, *Potamogeton crispus* and *P. pectinatus* (Chambers & Kalff, 1985; Lougheed *et al.*, 2001). The absence of vegetation in drain passing village can be due to the high water and sediment contamination because of anthropogenic influences. Large anthropogenic influences on hydrology are associated with the construction of dams, reservoirs and contamination with toxicity. The hydrologic variations caused by these structures are markedly different from the original natural ones and often the littoral habitats become poorly or non-vegetated by macrophytes (Carpenter *et al.*, 1992; Keddy, 2000).

The present results showed that some of the aquatic plants posse's greater accumulation ability for selected heavy metals. These results agree with the reports of Peverly (1985); Sawidis *et al.* (1995) and Abouel-kheir *et al.* (2007, a & b). *P. pectinatus* was the most effective species in heavy metal accumulation. It was previously recorded that *P. pectinatus* is able to bioaccumulate a variety of metal elements (Kantrud, 1990; Guilizzoni, 1991). Thus the macrophytes association un-doubtedly has its advantages in phytoremediation of waters and sediments. At the same time the annual harvesting and excavation of macrohytes could be the right way to prevent a secondary water contamination.

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