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Elements Accumulation and Nutritive Value of *Phragmites Australis* (Cav.) Trin. ex Steudel in Lake Burullus: A Ramsar site, Egypt

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ABSTRACT

The present study aims to assess the role of *Phragmites australis* in the accumulation of elements and nutritive value to test its suitability to use as a potential forage plant for cattle, goats and sheep in lake Burullus, Egypt. Different plant organs were collected from the sampling sites for estimating seven heavy metals (Mn, Pb, Co, Cu, Cd, Zn, and Fe) and six nutrients (Na, K, Ca, Mg, P and N) as well as the physical and chemical characteristics of water. In addition, seven organic constituents (total ash, carbohydrates, total lipids, crude fibers, crude protein, digestible crude protein and total digestible nutrients) were estimated, and three nutritive values (digestible energy, metabolized energy, net and gross energy) were calculated. The results revealed that an increase in heavy metals accumulation in the rhizome and decreased in the order of rhizome > stem > leaves. Moreover, positive linear relationships were found between these heavy metal concentrations in plant organs and those in water. Thus *P. australis* can serve as a good accumulator and bioindicator of heavy metals in the polluted water bodies. On the other hand, the nutrients are decreased in the order of stems > leaves > rhizomes. The leaves had the highest total ash, crude protein, digestible crude protein, digestible energy, metabolized energy and net energy, while the stems had the highest total carbohydrates and crude fibers. Therefore, the results revealed that the underground rhizomes had the ability to accumulate heavy metals and thereby used as a phytoremediator; while its aboveground parts had the highest nutrient and nutritive values, which consider the plant as good forage for animals.
Key words*:* Bioaccumulation, Common reed, Forage plant, Heavy metals, Phytoremediation.

INTRODUCTION

The common reed, *Phragmites australis* (Cav.) Trin. ex Steudel, is a cosmopolitan angiosperm believed to be one of the most widely distributed and valuable species in the world (Holm *et al*., 1977). In Egypt, it is known to be the major component of reed stands along the shores of Lake Burullus. Green plants of *P. australis* are considered very palatable and readily grazed by sheep, goats, cattle, wildlife and provide important shade, shelter and food for fishes and that common reed litter provides food for molluscs, other crustaceans and aquatic insects (Holm *et al*., 1977; Frankenber, 1997; Shaltout and Al-Sodany, 2008).

Although its stands can maintain important eco-system functions, it is regarded as a harmful plant in other regions (Weis and Weis, 2003; and Bonanno and Giudice, 2010). Thus, different aspects of this species such as biology and ecology have been extensively studied during the last decades. However, until now its nutrient budget in the Mediterranean region receives little attention (Eid *et al*., 2010b). Information on these aspects is important for deriving sound management recommendations for *P. australis* stands aiming at optimizing carbon sequestration and counteracting eutrophication. Phytoremediation means the use of plants to reduce, remove, degrade or immobilize environmental toxins (Raskin *et al*., 1997; Salt *et al*., 1998; Terry *et al*., 2003).

The effectiveness of a phytoremediation system depends on the selection of appropriate plants for the particular environment. Knowledge about the accumulation properties of wetland plant species is useful in choosing appropriate plants for wetland phytoremediation systems (Duman *et al*., 2007). Metal bioaccumulation depends upon numerous biotic and a biotic factors, such as temperature, pH and dissolved ions in water (Lewander *et al*., 1996; Demirezen and Aksoy, 2004). Bioaccumulation of metals varies considerably among species growing in the same area, as well as within the same species during different seasons (Brekken and Steinnes, 2004). Some studies have reported the highest metal contents (Cd, Cu, Ni, Pb, Sn, Zn) during autumn and relatively low levels during spring (Brekken and Steinnes, 2004), whereas others have indicated the highest levels during spring and the lowest during winter (Wilkins, 1978; Martin and Couphtrey, 1982).

P australis has been widely investigated as a bioabsorbent of nutrients and heavy metals (Ruiz and Velasco, 2010). It functions as a filter for reducing pollution sources (Brix and Schierup, 1989; Kiedrzy-nska *et al*., 2008). It is one of the emergent plants most commonly used in constructed wetlands for the enhancement of water quality in water treatment systems (Gómez *et al*., 2000; Borin *et al*., 2001; Meuleman *et al*., 2002; Vyamazal, 2002) due to its high growth rate and

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great capacity for nutrient accumulation in its organs (Asaeda *et al*., 2002; Baldatoni *et al*., 2003; Kiedrzynska *et al*., 2008).

The capacity of natural wetlands to filter waste water and nutrients from arable land also has been demonstrated (Newman and Pietro, 2001; Cirujano *et al*., 2005; Álvarez-Rogel *et al*., 2006). Besides, reed beds have other ecological and conservation value and important wetland functions, such as a major breeding habitat for passerines (Poulin *et al*., 2002) and contributing margin sediment stabilization to aquatic biodiversity (Shaltout and Khalil, 2005). However, reeds tends to form monospecfic and dominant stands and may alter ecological functions by their excessive expansion, adopting an invasive behaviour (Lelong *et al*., 2007), especially in coastal marshes, where there are increase of inputs of freshwater and nutrient loads and the absence of other species (Minchinton and Bertness, 2003).

In Egypt, the serious problem of feed shortage, especially green summer fodder suppresses the improvement of animal production. Therefore, dependence on improving local food and food resources for both animals and humans is necessary for a sound policy. The animal feeding system is depending on the cultivation of Egyptian clover (*Trifolium alexandrinum L.*). It produces around 4.8 million ton of starch year^{-1} and could cover the requirements of animals with surplus of 0.9 million ton of starch. However, in summer period, there will be at least a deficiency of 1.5 million ton of starch and most animals are in fact in a starving condition receiving less than the normal requirements (Gabra *et al.,* 1987). This calls for studying other non-conventional sources of feed.

Little quantitative information is available about the importance of *P. australis* in the nutrient budget of reed marshes and the possible role of this species in the phytoremediation of the Mediterranean wetlands. It is therefore important to evaluate the spatial and organ variation in plant accumulation in wetland system in order to assess the potential capacity of nutrient and metal removal by plant uptake. The present study aims to evaluate the role of *P. australis* in the accumulation of seven heavy metals (Mn, Pb, Co, Cu, Cd, Zn and Fe) and six nutrients elements (Na, K, Ca, Mg, P and N) in Lake Burullus, a Ramsar site along the Deltaic Medit-erranean coast of Egypt.

It also aims to estimate the variation in seven organic constituents (total ash, carbohydrates, total lipids, crude fibres, crude protein, digestible crude protein and total digestible nutrients) and their three nutritive values (digestible energy, metabolized energy, net and gross energy) were calculated to evaluate their forage quality in relation to the space and plant organ.

MATERIALS AND METHODS

Study area

Lake Burullus is one of the Egyptian northern lakes natural outlets connecting with the Mediterranean Sea.

This shallow lake has an oblong shape extending for a distance of 47 km along NE-SW axis. Its main basin is classified into three sections: eastern, middle and western. The western section has less width not exceeding 5 km, and increases in the middle section to reach a maximum of 14 km (Fig. 1).

The depth of this lake varies between 20 cm close to the shore of its eastern section and 200 cm at the middle section and near the sea outlet. A marine sand bar separates the Mediterranean coast from the lake shore, with a depth varying between few hundred meters near the sea outlet and a maximum of 6 km in the west. Some 25 islets of different sizes are distributed within the lake where they form physical isolations between the 3 sections of the lake. The heavy growth of reed and sedge plants (e.g. *P. australis* and *Typha domingensis*) facilitates the merging of the nearby islets (Shaltout and Khalil, 2005).

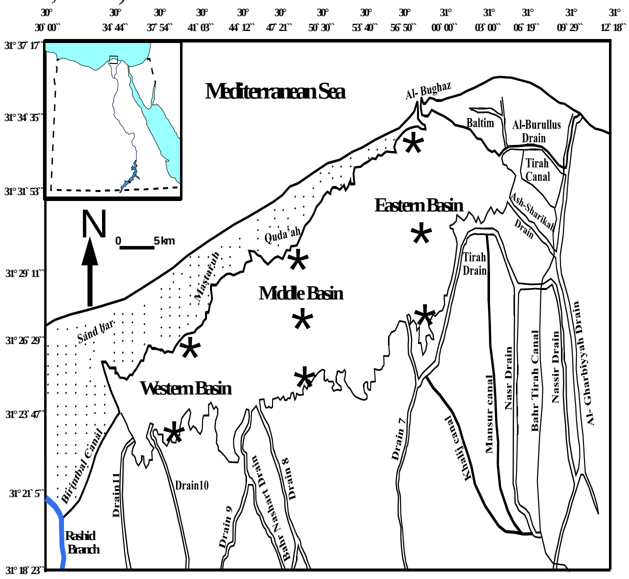

Figure (1): Map of Lake Burullus indicating the location of the eight sampling sites (*).

The Mediterranean Deltaic coast, in which Lake Burullus occupies, belongs to the arid region where the climatic conditions are warm in summer (20 - 30ºC) and mild in winter (10 - 20ºC) with an aridity index ranging between 0.20 and 0.03 (UNESCO, 1977). Generally, the days are sunny and dry. The maximum and minimum mean annual temperatures are 26.5 ºC and 14.4 ºC. The mean relative humidity is about 69%, the mean evaporation is 4.6 mm day^{-1} and the mean rainfall is about 175 mm year $^{-1}$ (Anonymous, 1980).

Plant analysis

The sampling process was carried out in the eastern, middle and western section (E-W) of Lake Burullus. In each section, three sites were selected to represent the north, middle and south (N-S) of the lake, except that of western section where only two sites were selected: one in the north and the other in the south (Fig. 1).

These sites have pure or nearly pure *Phragmites* stands with other aquatic species. In each site, three randomly distributed quadrates (each of 0.5 x 0.5 m size) were sampled with in *P. australis* population. For heavy metal and nutrient contents, samples of the different plant parts (leaves, stems and rhizomes) were collected from the sampling quadrates (12 replicates for each analysis), washed gently once with tap water, and three times with deionised water. Afterwards, the materials were oven-dried (60^{o}C) to constant weight, and powdered in a metal-free plastic mill.

Total ash (TA) percentage was estimated by ignition at 550^{o}C for 2 hrs. Heavy metal and nutrients were extracted from 0.5-1 g samples (leaves, stems and rhizomes) using mixed-acid digestion method. Na and K were analyzed using the flame photometer; Ca, Mg, Mn, Pb, Co, Zn, Cu, Fe and Cd by atomic absorption and P and N by spectrophotometer. All these procedures were according to Allen *et al*. (1989). Total lipids (TL) and crude fibre (CF) were determined by ether extracting with soxhlet extraction method (Allen *et al*., 1989). Crude protein (CP) was calculated following this equation (Öelberg, 1965): CP = IN × 6.25, where IN is insoluble nitrogen.

Digestible crude protein (DCP) was calculated according to the equation of Demarquilly and Weiss (1970): DCP (in % DM) = 0.929 CP (in % DM) - 3.52, where DM is the dry matter. Carbohydrates (Car) or (NFE) were calculated according to Le Houérou (1980): Car (in % DM) = 100 - (CP + CF + TL + MINS), where MINS is the total minerals.

Total digestible nutrients (TDN) were estimated according to the equation applied by (Naga and El-Shazly, 1971): TDN (in % DM) = 0.62 (100 + 1.25 TL) - PK, where TL is the percentage of total lipids or ether extract EE, P is the percentage of crude protein, and K is the coefficient that depends on the protein and fibre contents (0.7). Digestible energy (DE) was estimated following this equation (NRC, 1984b): DE (Mcal kg $^{-1}$) = 0.0504 CP (%) + 0.077 TL (%) + 0.02 CF (%) + 0.000377 (NFE)^2 (%) + 0.011 NFE (%) - 0.152. Metabolized energy (ME) equals 0.82 DE, while net energy (NE) equals 0.5 ME (Garrett, 1980). Gross energy (GE) was calculated following this equation (Garrett, 1980): GE (Kcal kg $^{-1}$) = (5.72 CP +9.5 EE + 4.79 CF +4.03 NFE) /10.

Water analysis

In each site, water depth and water transparency were measured using Seechi disc with a diameter of 30 cm. The disc was lowered slowly from the shaded side of the boat till it disappears for transparency, and lowered again till setting up the bottom of the depth. Water salinity (as electric conductivity) and pH were estimated, in situ, using conductivity and pH meters**.**

Three water samples were collected from each site, in polyethylene bottles. Dissolved oxygen was estim-ated using Winkler's or iodometric method, biochemical oxygen demand (BOD) using 5 day BOD test, and chemical oxygen demand (COD) using titrimetric method.

Alkalinity was determined using the titration against HCl and chlorosity using $AgNO_3$. Dissolved nitrite, nitrate and phosphate were determined using spectrophotometric methods; while reactive silicate using heteropoly blue method. The heavy metals Cu, Fe, Zn, Cd and Pb were estimated in acidified water samples using atomic absorption method. All these methods are outlined in detail in Greenberg *et al.* (1992).

Data analysis

Elements and nutritive data for *P. australis* organs were subjected to a two-way analysis of variance (ANOVA-2) to test the differences between plant organs over spatial variations. The significant of variation in water characteristics over spatial variation was assessed using one-way analysis of variance (ANOVA-1). Simple linear correlation coefficients were calculated to assess the relationship between the population and water characteristics using SPSS software (SPSS, 2006).

RESULTS

Rhizomes exhibit the highest concentrations of heavy metals Mn, Pb, Co, Cu, Cd, Zn and Fe (102.3±12.2, 95.5±9.7, 11.2±3.7, 22.7±16.5, 23.4±18.5, 306.5±33.6 and 2134.4±1338.4 µg g^{-1} dry wt, respe-ctively) (Table1).

For all organs, the heavy metals (Mn, Pb and Co) differ significantly between the different sections of the lake. On the other hand, stem exhibits the highest concentrations of nutrients Na, K, Ca and Mg (8.3±1.6, 13.7±2.5, 8.5±2.1 and 6.6±1.4 mg g^{-1} dry wt, respectively); while leaves exhibit the highest of total nitrogen (2.33± 0.49 mg g^{-1} dry wt.) (Table 2). For all organs, the nutrients (Na, K, Ca, Mg and P) differ significantly between the different sections of the lake (E-W and N-S) ($P < 0.001$); while for the rhizomes Na ($F = 5.1$, $P < 0.05$), K ($F = 7.4$, $P < 0.01$), Ca ($F = 10.6$, $P < 0.01$) and P ($F = 20.8$, $P < 0.001$) differ significantly between different sites.

The total nitrogen differs significantly between the sections ($F = 29.0$, $P < 0.001$) sites ($F = 11.5$, $P < 0.001$) and the interaction ($F = 8.6$, $P < 0.01$) between them for leaves. In general, the heavy metals of *P. australis* organs have the following order: Fe > Zn > Mn > Pb > Cu > Cd > Co while their nutrients have the following order: K > Ca > Na > Mg > N > P (Fig. 2 and 3).

Regarding the water characters in the E-W section of the lake, the west site had the highest values of water transparency (42.2 cm), depth (145.6 cm), COD (5.7 mg l^{-1}), BOD (4.4 mg l^{-1}), and NO_3, NO_2, SiO_2, Cu, Fe and Pb (3.2, 1.8, 37.1, 5.9, 2.0 and 2.4 µg l^{-1}, respectively), but the lowest of EC (2.0 mS cm^{-1}), pH (8.5), alkalinity (211.8 mg l^{-1}), Zn (2.8 µg l^{-1}) and Cl (0.7 g l^{-1}) (Table 3). On the other hand, in the N-S section, the south site had the highest values of alkalinity, COD and BOD (285.3,5.7 and 4.4 mg l^{-1}, respectively), and PO_4, NO_3, NO_2, Cu, Fe, Cd and Pb (1.8, 3.1, 1.6, 5.2, 1.6, 2.4 and 1.9 µg l^{-1}, respectively); but the lowest of water transparency (28.1 cm), EC (4.9 mS cm^{-1}) and SiO_2 (19.1 µg l^{-1}); whereas, the north site in this section N-S had the vic versa of these variables. The simple linear correlations between the heavy metals in the water and the plant organs indicate significant positive correlation of lead in water and all organs ($r = 0.82 - 0.98$, $P < 0.05$ - < 0.001) and Fe in water, stem ($r = 0.89$, $P < 0.01$) and rhizome ($r = 0.93$, $P < 0.01$). Also, the lead has significant positive correlation between the plant organs ($r = 0.83 - 0.96$, $P < 0.05$-<0.01), and Zinc has significant positive correlation ($r = 0.92$, $P < 0.01$) in leaves and stem (Table 4). The leaves attain the highest percentages of total ash (14.15±1.43%), crude protein (14.56±3.10%) and digestible crude protein (10.04±2.91%); stems attain the highest concentrations of total carbohydrates (52.99±4.99%) and crude fibers (35.91±4.46%); and rhizomes attain the highest of total lipids (3.94±0.77%) (Table 5).The organic contents exhibited the following order: carbohydrates > crude fibers > crude protein > total ash> total lipids (Table 5 and Fig. 4).

For the leaves, carbohydrates, crude protein and digestible crude protein differ significantly between the sections and sites of the lake and the interaction between them ($P < 0.001$); while for the stem ($P < 0.01$) and rhizome ($P < 0.001$), the total ash differs significantly between the sites only. On the other hand, the total lipids, carbohydrates and crude fibers differ significantly between the sections and sites for stem ($P < 0.01$) and rhizome ($P < 0.001$).

Regarding the nutritive value, the rhizomes attain the highest percentages of total digestible nutrients and gross energy (49.70±0.53% and 42.71±0.70 Mcal kg^{-1}); while the leaves attain the highest concentrations of digestible energy, metabolized energy and net energy

The gross energy differ significantly between the sections and sites and the interaction between them for leaves ($P < 0.001$); while digestible energy, metabolized energy and net energy differ significantly between the sections and the interaction between sections and sites for stem and rhizome (Table 6).

DISCUSSION

Although, there are a little data on the use of littoral plants as heavy metals bioaccumulators over large areas of the wetlands environment, these littoral plants are commonly used in constructing wetlands for accumulating large amounts of heavy metals (Peverly *et al*., 1995; Southichak *et al*., 2006; Liu *et al*., 2007; Vymazal *et al*., 2009; Drzewiecka *et al*., 2010 and Eid *et al*., 2012).

In the present study, the heavy metal and nutrient concentrations were lower in the water than that in *P. australis* tissues; this indicating the excessive accumulation of the estimated elements in its tissues.

This suggestion is supported by the heavy metal accumulates in the rhizome more than in the stem and leaves. Many authors have similar results and stated that the underground parts of littoral plants such as *P. australis* (Vymazal *et al*., 2007), *Typha angustifolia* L. and *Potamogeton pectinatus* L. (Demirezen and Aksoy, 2004), *Carex rostrata Stokes* (Stoltz and Greger, 2002),

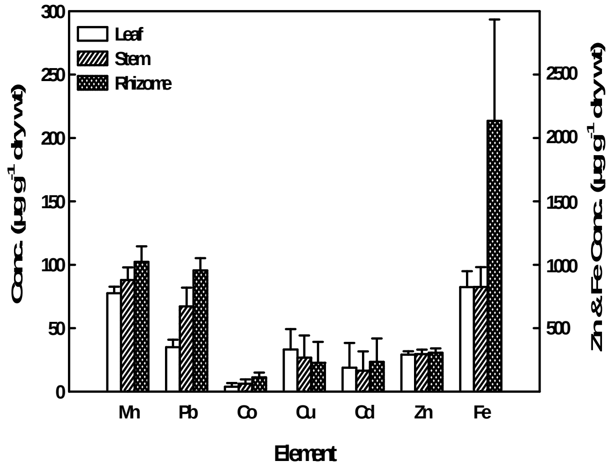

Figure (2): Mean and standard deviation (vertical bars) of the heavy metals in the different organs of P. australis in Lake Burullus.

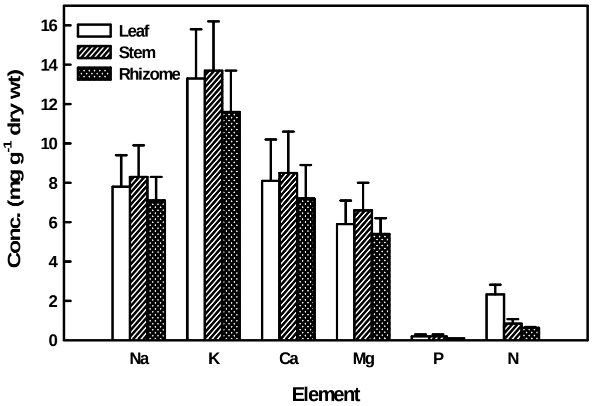

Figure (3): Mean and standard deviation (vertical bars) of the nutrienNB ts in the different organs of *P. australis* in Lake Burullus.

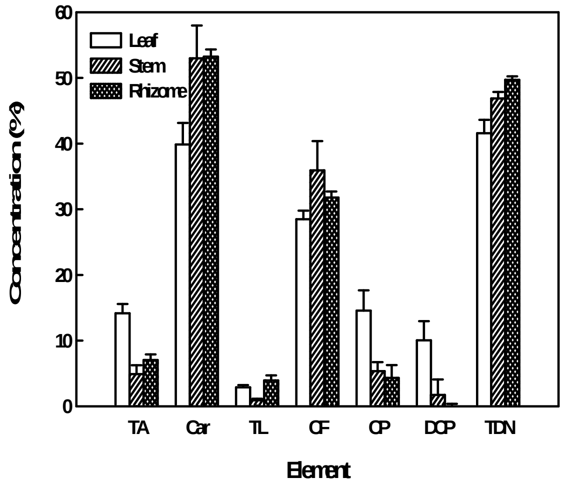

Figure (4): Mean and standard deviation (vertical bars) of the organic contents in the different organs of *P. australis* in Lake Burullus. TA: total ash, Car: total carbohydrates, TL: total lipids, CF: crude fibres, CP: crude protein, DCP: digestible crude protein and TDN: total digestible nutrients.

Table (1): Spatial variation in the mean concentration ± standard deviation of the heavy metals (µg g^{-1} dry wt) in *P. australis* in Lake Burullus. Sc: section, St: site,*;P ≤ 0.05, **;P ≤ 0.01, ***;P ≤ 0.001

	Section (Sc)	Site (St)	Mn	Pb	Co	Cu	Cd	Zn	Fe
		West	77.3±3.7	33.1±6.4	3.6±3.1	35.3±18.9	27.1±27.2	298.2±29.0	913.4±169.0
	E-W	**Middle**	80.2±5.7	32.5±4.4	3.2±3.5	29.4±10.9	15.7±17.4	287.4±24.7	791.0±97.2
		East	75.0±4.7	38.7±5.2	4.6±2.2	36.8±19.9	15.1±11.5	290.3±26.8	782.2±69.2
		South	76.9±5.4	34.0±5.6	2.8±3.5	35.7±14.8	25.9±19.8	294.6±33.9	837.6±167.1
Leaf	**N-S**	**Middle**	80.1±5.6	35.6±6.3	3.8±2.4	25.1±11.6	11.5±14.9	278.3±17.1	825.2±129.6
		North	76.3±4.7	35.5±6.2	4.9±2.4	34.1±18.8	14.4±19.9	293.7±18.2	807.3±69.7
			77.5±5.2	35.0±5.9	3.8±2.9	33.2±16.0	18.8±19.5	291.3±26.0	823.5±125.9
	Total	**Sc**	10.3***	9.6**	5.5**	0.7	2.3	0.3	3.5
	F-Value	**St**	5.1**	0.5	12.6***	0.5	2.7	0.4	0.6
		Sc*St	1.0	4.6*	11.3***	3.1	3.3*	0.5	2.0
		West	82.6±5.3	64.4±17.2	5.4±3.7	32.5±16.9	23.9±16.4	326.9±37.7	861.8±158.8
	E-W	**Middle**	93.8±12.9	58.2±14.0	6.0±4.6	18.7±6.9	13.5±13.9	283.0±25.4	791.8±114.4
		East	83.0±6.6	77.8±4.8	7.5±0.6	30.0±19.7	9.8±19.2	289.4±20.1	924.2±281.4
Stem		**South**	84.9±6.0	63.0±15.7	6.0±3.4	28.5±21.3	16.3±15.4	305.6±30.9	825.0±132.2
	N-S	**Middle**	93.3±15.3	67.3±17.1	5.5±3.5	20.9±11.0	21.5±14.2	269.5±45.6	697.8±70.5
		North	87.3±8.1	71.1±12.3	6.9±3.4	27.4±16.3	14.4±16.4	294.7±33.8	876.2±183.0
			87.9±10.0	**67.1±14.8**	**6.2±3.4**	**26.7±17.5**	**16.4±15.3**	**294.8±35.9**	**824.3±157.3**
	Total	**Sc**	10.8***	50.3***	8.1**	2.5	1.3	7.6**	0.6
	F-Value	**St**	2.9	8.4***	10.1***	0.0	0.9	1.3	2.2
		Sc*St	1.7	5.1**	38.4***	2.2	0.7	2.3	0.5
		West	98.3±8.7	96.8±13.5	9.5±7.4	30.1±1.1	23.7±0.7	325.2±6.9	2373.4±489.5
	E-W	**Middle**	106.0±14.4	89.8±9.0	10.6±2.4	20.8±16.0	29.3±15.6	297.3±26.7	1125.8±328.3
		East	99.4±9.9	101.7±4.1	12.7±2.9	23.4±18.6	21.2±19.9	312.5±40.6	3103.2±1340.7
Rhizome		**South**	106.9±13.6	92.9±12.2	10.4±4.7	26.7±14.2	37.4±12.6	302.9±25.0	2248.3±1365.5
	N-S	**Middle**	103.7±13.3	95.0±7.7	10.6±2.2	23.8±17.0	22.3±22.5	313.8±49.1	1890.4±1560.1
		North	97.1±8.8	98.1±8.8	12.4±3.6	18.7±18.4	13.0±11.9	303.4±26.5	2238.5±1247.3
			102.3±12.2	**95.5±9.7**	**11.2±3.7**	**22.7±16.5**	**23.4±18.5**	**306.5±33.6**	**2134.4±1338.4**
	Total	**Sc**	2.4	21.8***	19.3***	0.3	3.3	0.8	16.8***
	F-value	**St**	3.3	2.8	11.9***	1.0	3.9	0.4	0.4
		Sc*St	1.1	2.5	30.7***	3.3	2.0	0.9	1.0

Table (2): Spatial variation in the mean concentration ± standard deviation of the different nutrients (mg g^{-1} dry wt) in *P. australis* in Lake Burullus. *;P ≤ 0.05, **;P ≤ 0.01, ***;P ≤ 0.001.

	Section (Sc)	Site (St)	Na	K	Ca	Mg	P	N
	E-W	**West**	5.6±0.6	9.8±1.2	6.0±1.7	4.4±0.7	0.3±0.1	2.19±0.55
		Middle	9.2±0.9	14.7±1.1	9.2±1.7	6.6±1.0	0.2±0.1	2.54±0.37
		East	8.0±0.7	14.2±1.8	8.4±1.8	6.4±0.8	0.2±0.1	2.21±0.53
Leaf	**N-S**	**South**	7.6±1.7	13.1±3.1	7.9±2.5	5.9±1.4	0.2±0.1	2.34±0.54
		Middle	8.7±1.3	14.7±1.0	8.9±1.5	6.5±0.9	0.2±0.1	2.22±0.49
		North	7.5±1.5	12.6±2.3	7.8±2.0	5.6±1.1	0.2±0.1	2.40±0.47
			7.8±1.6	**13.3±2.5**	**8.1±2.1**	**5.9±1.2**	**0.2±0.1**	**2.33±0.49**
	Total	**Sc**	106.1***	59.9***	63.8***	27.9***	19.5***	29.0***
	F-Value	**St**	0.5	1.1	0.3	0.6	5.1**	11.5***
		Sc*St	4.3*	5.7**	4.3*	2.7	7.7**	8.6**
	E-W	**West**	6.2±0.9	10.6±1.2	6.5±1.6	4.9±0.6	0.2±0.1	0.85±0.17
		Middle	9.0±1.1	15.2±1.7	9.0±1.8	6.9±1.0	0.2±0.1	0.79±0.07
		East	7.8±0.9	12.1±1.5	8.2±1.1	5.9±0.9	0.2±0.1	0.78±0.09
Stem	**N-S**	**South**	8.0±2.0	13.5±2.7	8.2±2.5	6.5±1.9	0.2±0.1	0.90±0.20
		Middle	8.8±0.5	15.4±1.9	9.1±2.0	7.3±0.9	0.2±0.0	0.94±0.34
		North	8.3±1.6	12.8±2.2	8.4±1.8	6.1±1.1	0.2±0.1	0.76±0.08
			8.3±1.6	**13.7±2.5**	**8.5±2.1**	**6.6±1.4**	**0.2±0.1**	**0.85±0.22**
	Total	**Sc**	136.6***	34.9***	72.6***	36.5***	4.8*	1.8
	F-Value	**St**	2.4	3.0	10.6**	1.9	0.6	2.7
		Sc*St	44.5***	5.3	29.4***	13.5***	3.2*	0.3
	E-W	**West**	5.3±0.4	7.6±0.9	5.8±1.7	4.4±0.6	0.2±0.0	0.64±0.03
		Middle	7.6±1.0	12.7±1.1	7.7±1.8	5.6±0.6	0.1±0.0	0.63±0.04
		East	7.1±0.9	11.8±1.0	7.0±1.3	5.5±0.8	0.1±0.0	0.63±0.05
Rhizon	**N-S**	**South**	7.1±1.3	12.2±2.5	7.2±1.6	5.3±1.0	0.1±0.0	0.65±0.03
		Middle	6.9±0.5	11.7±0.9	7.0±1.7	5.7±0.5	0.1±0.0	0.62±0.05
		North	7.1±1.5	11.0±2.3	7.2±1.9	5.2±0.8	0.2±0.0	0.62±0.04
			7.1±1.2	**11.6±2.1**	**7.2±1.7**	**5.4±0.8**	**0.1±0.0**	**0.63±0.04**
	Total	**Sc**	34.9***	48.1***	72.6***	12.1***	8.8**	0.3
	F-value	**St**	5.1*	7.4**	10.6**	0.8	20.8***	0.9
		Sc*St	11.6***	0.1	29.4***	6.3**	8.6**	1.0

Table (3): Mean ± standard error (SE) of the water characters in Lake Burulluss. DO: Dissolved Oxygen, COD: Chemical Oxygen Demand, BOD: Biochemical Oxygen Demand, *;P ≤ 0.05, **;P ≤ 0.01, ***;P ≤ 0.001.

Element	E-W			F-value	N-S			Mean ±SE	F-value
	East	Middle	West		North	Middle	South		
Air temp. (°C)	26.5	24.1	27.6	5.1**	26.1	25.4	26.2	25.9±0.4	0.3
Water temp. (°C)	26.9	26.5	26.9	0.1	26.4	27.0	26.8	26.8±0.5	0.1
Transparency (cm)	29.9	36.2	42.2	7.4***	40.4	37.2	28.1	34.4±1.2	9.7***
Depth (cm)	110.4	131.3	145.6	2.3	142.9	115.3	119.7	124.4±5.7	1.4
EC (mS cm^{-1})	8.2	2.9	2.0	21.8***	6.0	4.9	4.9	5.2±0.6	0.3
pH	9.1	8.8	8.5	10.4***	8.7	8.9	8.8	8.8±0.1	2.0
Alkalinity	285.5	292.3	211.8	14.1***	251.0	275.9	285.3	273±6.7	1.9
DO (mg l^{-1})	7.9	7.8	8.4	0.2	8.7	7.7	7.9	8.0±1.0	1.1
COD (mg l^{-1})	5.4	5.0	5.7	0.6	5.4	4.8	5.7	5.3±0.2	1.5
BOD (mg l^{-1})	4.3	3.5	4.4	0.9	3.8	3.8	4.4	4.0±0.2	0.5
PO_4 (µg l^{-1})	1.6	0.9	1.3	3.7*	0.7	1.2	1.8	1.3±0.1	9.6***
NO_3 (µg l^{-1})	2.1	2.0	3.2	3.3*	1.3	2.1	3.1	2.3±0.1	11***
NO_2 (µg l^{-1})	1.0	1.0	1.8	4.4**	0.8	0.9	1.6	1.2±0.1	4.7**
SiO_2 (µg l^{-1})	13.4	24.8	37.1	40.0***	26.1	21.9	19.1	21.9±1.6	1.4
Cu (µg l^{-1})	4.5	2.9	5.9	9.1***	3.5	3.7	5.2	4.2±0.2	3.6*
Fe (µg l^{-1})	1.5	0.8	2.0	3.0*	1.3	0.9	1.6	1.3±0.1	1.1
Cd (µg l^{-1})	3.2	1.4	1.5	8.7***	2.3	2.1	2.4	2.3±0.2	0.2
Pb (µg l^{-1})	1.7	0.9	2.4	4.9**	1.0	1.5	1.9	1.5±0.1	2.2
Zn (µg l^{-1})	7.1	3.8	2.8	16.5***	6.0	4.8	4.9	5.2±0.4	0.8
Cl (gm l^{-1})	3.1	0.9	0.7	25.5***	2.2	1.7	1.9	1.9±0.2	0.3

Table (4): Pearson correlation coefficient (r-values) between the water variables and that of *P. australis* in Lake Burullus.*;P ≤ 0.05, **;P ≤ 0.01, ***;P ≤ 0.001.

		Water			Leaf				Stem					Rhizome		
		Fe	**Pb**	**Zn**	**Cu**	**Fe**	**Pb**	**Zn**	**Cu**	**Fe**	**Cd**	**Pb**	**Zn**	**Cu**	**Fe**	**Pb**
Water	**Cu**	0.93**	0.97***	-0.26	0.59	-0.11	0.78	0.32	0.67	0.76	-0.33	0.93**	0.19	-0.09	0.87**	0.98***
	Fe		0.84*	-0.13	0.83*	-0.01	0.67	0.56	0.84*	0.89**	-0.37	0.82*	0.42	0.10	0.93**	0.89**
	Cd		0.02	0.94**	0.23	0.93**	-0.39	0.55	0.57	0.06	0.79	-0.17	0.76	0.61	0.16	0.09
	Pb			-0.31	0.41	-0.11	0.82*	0.13	0.56	0.61	-0.24	0.94**	0.06	-0.07	0.82*	0.98***
	Zn				0.14	0.93**	-0.60	0.50	0.41	-0.13	0.82*	-0.44	0.72	0.68	-0.05	-0.22
Leaf	**Cu**					0.16	0.22	0.87*	0.86*	0.92*	-0.33	0.37	0.72	0.28	0.70	0.50
	Fe						-0.49	0.48	0.51	-0.04	0.87*	-0.32	0.77	0.83*	0.09	-0.04
	Cd						-0.49	0.78	0.63	0.30	0.39	-0.37	0.91	0.80*	0.18	-0.15
	Pb							-0.23	0.27	0.37	-0.49	0.96**	-0.35	-0.25	0.75	0.83*
	Zn								0.79	0.76	0.00	-0.01	0.92**	0.37	0.38	0.21
Stem	**Cu**									0.75	0.10	0.47	0.80*	0.55	0.83*	0.66
	Pb												-0.13	-0.19	0.84*	0.95**
Rhizo	**Fe**															0.90**

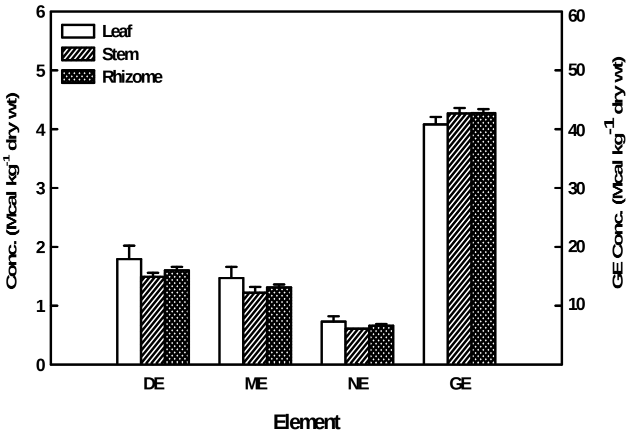

Figure (5): Mean and standard deviation (vertical bars) of the nutritive value in the different organs of P. australis in Lake Burullus. DE: digestible energy, ME: metabolized energy, NE: net energy and GE: gross energy**.**

and *Nuphar lutea* (L.) Sm. and *Potamogeton nodosusPoir*. (Mazej and Germ, 2009) seem to be good retaining filters for several heavy metals.

In addition the positive significant linear correlation between the concentrations of Pb (r = 0.98, P < 0.001) and Fe (r = 0.93, P < 0.01) in the studied plant and in the water indicates bioaccumulation. Eid *et al.* (2012) in the Lake Burullus and Demirezen and Aksoy (2004) in Sultan Marsh reported similar results for Typha.

Therefore, this study suggests that *P. australis* may be used and served as a good bioaccumulator and bioindicator of heavy metals in the underground parts at low metal concentrations in natural and polluted brackish water conditions. Moreover, these positive linear correlations were found between the heavy metal concentrations in all plant organs and those in water, thus indicating the potential use of such organs for monitoring of the polluted water and advantages of using plant species as bio monitors. Our results showed that the underground organs were the primary areas of heavy metal accumulation. In particular, heavy metal concentrations in plant organs decreased in the order of rhizome > stem > leaf and could be are comparable with the study of (Weis *et al.* 2004).

The roots and rhizomes of *P. australis* can accumulate great amount of heavy metals because it has parenchyma with large intercellular air spaces in the cortex (Sawidis *et al*., 1995). Also the roots may be regarded as a heavy metal filter, slowly accumulating these heavy metals and thus partly preventing their transport to aboveground biomass (Tayler, 1971 and Liu *et al*., 2007).

All three organs showed significant differences in concentration of Cu, Fe, Pb, Cd and Zn, and suggesting low mobility from roots to rhizomes and to aboveground organs. Although the organs followed different decreasing trends of element concentration, the trend Fe > Zn > Mn > Pb > Cu > Cd > Co was found in each plant organ.

This trend was comparable with the results of Bonanno and Giudice (2010).

The high concentration of Mg, Mn, Co, Fe and Cd in the rhizome of the common reed in the present study may be due to the presence of an iron plaque around the roots (St-Cyr and Crowder, 1988 and Eid *et al*., 2010a,b). Iron plaque is commonly observed on wetland plant roots and may play a key role to detoxify pollutants and purify water in wetlands constructed (Wang and Peverly, 1996).

This plaque may protect the roots from heavy metals toxicity, probably by co-precipitation or adsorption of toxic metals (Ali *et al*., 2002). More studies in the natural and created wetlands indicated that the majority of wetland plants retain higher amounts of heavy metals and nutrients in their roots than shoots (Windom *et al*.,1976; Breteler and Teal, 1981; Keller *et al*., 1998 and Bonanno and Giudice, 2010).

Wetland plants play an important role in the nutrient cycling due to uptake, storage and release processes. *P. australis* is used as a 'nutrient remover' in wetlands, especially those designed and constructed for waste water treatment and extract large amounts of mineral nutrients to reduce its content of domestic, industrial and agricultural wastewater (Reddy and Smith, 1987; Hammer, 1989; Cooper and Findlater, 1990 and Verhoeven and Van der Toorn, 1990).

Table (5): Spatial variation in the mean concentration ± standard deviation of the organic contents (%) in *Phragmites australis* in Lake Burullus. TA: total ash, Car: total carbohydrates, TL: total lipids, CF: crude fibres, CP: crude protein, DCP: digestible crude protein and TDN: total digestible nutrients. *:P ≤ 0.05, **:P ≤ 0.01, ***:P ≤ 0.001.

	Section (Sc)	Site (St)	TA	Car	TL	CF	CP	DCP	TDN
	E-W	**West**	14.16±1.35	40.81±4.06	2.78±0.42	28.58±1.56	13.68±3.47	9.19±3.22	42.11±2.21
		Middle	14.19±1.50	38.32±2.12	2.95±0.31	28.56±1.19	15.88±2.33	11.33±2.21	40.69±1.62
		East	14.11±1.54	40.79±3.32	2.88±0.35	28.35±1.37	13.82±3.31	9.32±3.07	42.12±2.15
	N-S	**South**	14.04±1.43	40.46±3.85	2.77±0.41	28.14±1.36	14.58±3.43	10.03±3.19	41.49±2.20
Leaf		**Middle**	14.13±1.51	40.47±2.97	2.96±0.29	28.54±1.33	13.85±3.08	9.34±2.86	42.16±2.01
		North	14.28±1.50	38.88±2.84	2.93±0.33	28.79±1.28	15.01±2.94	10.52±2.79	41.28±1.99
	Total		**14.15±1.43**	**39.87±3.28**	**2.88±0.35**	**28.48±1.31**	**14.56±3.10**	**10.04±2.91**	**41.58±2.04**
	F-value	**Sc**	0.5	16.6***	1.6	0.2	29.7***	36.2***	25.8***
		St	4.0*	9.0**	2.1	1.6	11.7***	14.8***	12.0***
		Sc*St	7.6	4.2*	1.8	0.6	8.7***	10.2***	8.9***
	E-W	**West**	4.69±1.31	53.73±5.50	0.88±0.27	35.45±5.05	5.29±1.04	2.56±4.16	46.84±0.79
		Middle	4.93±1.34	52.93±4.77	0.95±0.24	36.28±3.89	4.91±0.46	1.04±0.43	47.24±0.47
		East	4.93±1.65	54.19±5.62	0.75±0.13	35.28±4.55	4.86±0.57	0.98±0.54	47.07±0.34
	N-S	**South**	4.71±1.40	53.11±4.85	0.86±0.26	35.73±4.52	5.60±1.26	2.46±3.41	46.62±0.87
Stem		**Middle**	5.08±1.38	51.94±5.52	0.98±0.21	36.28±5.20	5.85±2.11	1.91±1.96	46.52±1.48
		North	4.94±1.39	53.56±5.10	0.93±0.21	35.85±4.26	4.75±0.49	0.89±0.46	47.34±0.46
	Total		**4.89±1.35**	**52.99±4.99**	**0.91±0.23**	**35.91±4.46**	**5.34±1.37**	**1.73±2.36**	**46.86±1.00**
	F-value	**Sc**	6.9**	1.9	0.6	1.7	1.8	1.2	2.3
		St	7.7**	2.4	1.2	0.3	2.7	1.9	3.2
		Sc*St	2.5	5.4**	5.8**	8.1**	0.3	0.7	0.1
	E-W	**West**	7.63±0.71	53.59±1.60	3.90±0.80	30.88±0.97	4.02±0.21	0.21±0.20	49.63±0.58
		Middle	6.85±0.90	53.22±0.92	3.94±0.78	32.03±0.83	3.91±0.22	0.16±0.14	49.70±0.54
		East	7.05±0.81	53.14±1.17	3.95±0.84	31.84±0.86	4.96±3.13	0.27±0.20	49.73±0.56
Rhizome	**N-S**	**South**	7.16±0.92	53.31±1.20	3.82±0.79	31.67±0.97	4.05±0.18	0.24±0.16	49.55±0.56
		Middle	6.79±0.69	53.34±0.87	3.99±0.74	32.01±0.92	3.88±0.32	0.24±0.17	49.78±0.46
		North	7.13±0.93	53.12±1.23	4.01±0.85	31.71±0.94	4.90±3.14	0.17±0.19	49.77±0.57
	Total		**7.05±0.85**	**53.24±1.09**	**3.94±0.77**	**31.78±0.92**	**4.33±1.95**	**0.21±0.17**	**49.70±0.53**
	F-value	**Sc**	14.7***	0.7	0.1	2.8	0.6	1.4	0.4
		St	1.9	0.4	1.7	0.0	0.5	0.8	3.3
		Sc*St	4.5*	4.3*	5.6*	0.6	0.6	0.8	2.3

Table (6): Spatial variation in the mean concentration ± standard deviation of the nutritive value (Mcal kg $^{-1}$) of the individuals of *P. australis* in Lake Burullus in the north Nile Delta region. DE: digestible energy, ME: metabolized energy NE: net energy and GE: gross energy. *;P≤ 0.05, **:P≤ 0.01, ***;P≤ 0.001.

	Section (Sc)	Site (St)	DE	ME	NE	GE
Leaf	E-W	West	1.70±0.37	1.40±0.31	0.70±0.15	40.59±1.39
		Middle	1.86±0.14	1.53±0.12	0.76±0.06	41.07±1.07
		East	1.77±0.17	1.45±0.14	0.73±0.07	40.66±1.43
	N-S	South	1.72±0.32	1.41±0.26	0.70±0.13	40.76±1.37
		Middle	1.80±0.14	1.48±0.12	0.74±0.06	40.71±1.35
		North	1.85±0.15	1.52±0.12	0.76±0.06	40.89±1.22
			1.79±0.23	**1.47±0.19**	**0.73±0.09**	**40.80±1.27**
	Total F-value	Sc	2.6	2.6	2.6	21.7***
		St	2.3	2.3	2.3	5.9**
		Sc*St	0.7	0.7	0.7	9.9***
Stem	E-W	West	1.45±0.07	1.19±0.05	0.60±0.03	42.50±0.42
		Middle	1.49±0.07	1.22±0.06	0.61±0.03	42.95±1.36
		East	1.46±0.03	1.19±0.03	0.60±0.01	42.23±0.45
	N-S	South	1.48±0.07	1.22±0.06	0.61±0.03	42.54±0.51
		Middle	1.52±0.11	1.25±0.09	0.63±0.05	42.60±0.54
		North	1.48±0.03	1.22±0.03	0.61±0.01	42.83±1.39
			1.49±0.07	**1.22±0.1**	**0.61±0.0**	**42.66±0.93**
	Total F-value	Sc	4.6*	4.8*	4.8*	17.9***
		St	0.9	1.0	1.0	3.5
		Sc*St	6.4**	6.6**	6.7**	14.7***
Rhizome	E-W	West	1.55±0.08	1.27±0.07	0.64±0.03	42.36±0.65
		Middle	1.62±0.05	1.33±0.04	0.66±0.02	42.80±0.73
		East	1.60±0.06	1.31±0.04	0.66±0.02	42.74±0.70
	N-S	South	1.58±0.07	1.30±0.06	0.65±0.03	42.59±0.77
		Middle	1.62±0.06	1.33±0.05	0.67±0.02	42.83±0.68
		North	1.60±0.05	1.31±0.04	0.65±0.02	42.73±0.70
			1.60±0.06	**1.31±0.05**	**0.66±0.03**	**42.71±0.70**
	Total F-value	Sc	12.2***	13.6***	4.9*	17.9***
		St	3.3	3.7	0.3	3.5
		Sc*St	13.2***	14.2***	6.0**	14.7***

Table (7): Comparison between the nutrient and heavy metal contents in the tissues of *P. australis* as estimated in the present study with that of Eid *et al*., (2012).

Element	Present study			Eid *et al*. (2012)		
	leaf	stem	rhizome	leaf	stem	rhizome
Heavy metals (µg g^{-1} dry wt)						
Pb	35.0	67.1	95.5	2202.5	2149.0	2163.5
Cu	33.2	26.7	22.7	36.9	40.2	56.9
Cd	18.8	16.4	23.4	15.3	14.8	14.7
Zn	291.3	294.8	306.5	56.9	49.1	74.8
Fe	823.5	824.3	2134.4	1046.0	1078.0	2045.5
Ash(%)	14.2	4.9	7.1	13.1	7.4	5.7
Nutrients (mg g^{-1} dry wt)						
Na	7.8	8.3	7.1	3.2	3.8	8.0
K	13.3	13.7	11.6	10.8	7.8	7.3
Ca	8.1	8.5	7.2	5.1	2.8	7.0
Mg	5.9	6.6	5.4	3.6	1.4	2.9
P	0.2	0.2	0.1	1.0	0.4	0.5
N	2.3	0.9	0.6	14.8	5.8	7.3

Table (8): Comparison between the organic contents and nutritive values of *P. australis* shoot in the present study and that of (El-Kady, 2000).

Contents	Present study	El-Kady (2000)
Organic contents (%)		
Total ash	9.55	11.0
Total carbohydrates	46.45	50.6
Total lipids	1.9	1.9
Crude fibers	32.2	29.9
Crude protein	9.95	6.7
Digestible crude protein	5.85	2.9
Total digestible nutrients	46.0	31.4
Nutritive value (Mcal/kg)		
Digestible energy	1.65	2.5
Metabolized energy	1.35	2.0
Net energy	0.65	1.0
Gross energy	41.7	40.3

Table (9): Comparison between the total digestible nutrients (TDN) values of *P. australis* in the present study and other related studies of fodder species.

Species	Study	TDN(%)
Phragmites australis	Present study	46.00
Panicum turgidum	Heneidy(1966)	64.03
Fodder crops:	Soliman & El-Shazly (1978)	
Clover (*Trifolium alexandrinu*)		56.00
Barley (*Hordeum vulgar*)		64.00
Corn (*Zea mayz*)		68.00

Table (10): Comparison of *P. australis* forage quality according to Boudet & Riviere (1968).

Nutritivecomparing	**Net energy** (MJ kg^{-1})	**Digestible protein** (%)
Present Study:	4.18	5.85
Forage quality of Boudet & Riviere (1968):		
Poor	< 3 .10	< 2.5
Fair	3.10 – 3.45	2.5 – 3.4
Good	3.45 – 4.15	3.4 – 5.3
Excellent	> 4.15	> 5.3

Several authors showed that production and nutrient storage in shoots and roots of *Phragmites* increase when nutrient availability increases (Mason and Bryant, 1975 and Ulrich and Burton, 1985). The results of the present study indicates the concentrations of nutrients are decreased in the order of stems > leaves > rhizomes. This trend is in accordance with the study of Dinka, (1986) and Eid *et al*., (2012), whereas the underground organs are the most significant accumulators of all heavy metals (Németh and Lakner, 2002).

It is of interest to compare the heavy metals and nutrients in the present study with that of Eid, 2012 on the same plant in the same area (Table **7**). The difference between the two studies could be interpreted in the view that the present study being mainly concerned with the spatial variations (E-W and N-S sections); while the past study dealt with temporal variations. Generally, it seems that heavy metal contents of *Phragmites* in Lake Burullus are higher than the corresponding range found in other studies such as in Egypt (El-Kady, 2000), Hungary (Engloner, 2004) and Turkey (Duman *et al*., 2007).

This might be related to the pollution in Lake Burullus as a result of the input of all domestic, industrial and agri cultural wastes from the reclaimed lands that surround the lake. Furthermore, most of the estimated heavy metal and nutrients increased from north to south due to the accumulation of sewage effluents from the drains at the south of the lake, which agrees with the study of Shaltout *et al*., (2004) and Eid *et al*., (2012).

In the present study, the ash content accumulated in the leaves and rhizomes of population of common reed exhibited high annual mean. This may be due to the higher inorganic elements, which correlated with the ash contents (Ksenofontova, 1988). Thus, the ash value can be taken to give an approximate estimate of total inorganic residue of the plant. The ash content ranged from 4.9 to 14.2 % dry weight, which is comparable to the values reported by Ho. (1981); Best and Dassen (1987); Batanouny *et al.*, (1991) and El-Kady, 2000 (Table 8). The forage value of the consumed plant is the result of its nutritive value, i.e. chemical composition and digestibility. It is highly affected by the stage of maturity, edaphic influence; climate and range condition (Le Houérou, 1980). In addition, the nutritive value of any forage is dependent upon its content of energy-producing nutrients as well as its contents of essential elements to the body.

In the present study, the forage value of *P. australis* was evaluated according to its chemical composition where it indicated that Phragmites is a high-quality forage for domestic animals (such as sheep, goats and cattle), especially young leaves which have the highest percentages of total ash, crude protein and digestible crude protein; and young stems which attain the highest concentrations of total carbohydrates and crude fibers as compared with the same plant in the water courses of Nile Delta (Table 8: El-Kady, 2000). The range of these organic contents was in accordance with that reported by Duke (1998) who indicated that this plant contains 11.4% protein, 2.3% fat, 42.1% carbohydrates, 31.1% crude fiber and 10.8% ash, and hence the common reed is high-quality forage for cattle and horses and may be cut for hay.

The quality of forage can be expressed in several parameters, such as total digestible nutrients (TDN), digestible crude protein and caloric value (Duiven-booden, 1985). The total digestible nutrients are only an appropriate measure of the food energy available to animals after the digestion losses have been deduced (Lofgreen, 1951).

The value of TDN of Phragmites, as indicated in the present study, ranged from 41.6 % in leaf to 49.7 % in the rhizome which was lower than that of some grazed wild plants such as *Panicum turgidum* (Heneidy, 1996) and cultivated common fodder crops such as clover, barley and corn (Soliman and El-Shazly, 1978). However, it approximates the diet requirements for sheep (61.7%; NRC, 1975) and breeding cattle (50.0%; NRC, 1984a) (Table 9).

The Ministry of Agriculture, Fisheries and Food in England (1975) reported that the minimum proteins in the animal diet range between 6 and 12% depending on the animal type. The present study indicates that the protein content of *P. australis* approaches the requirements for the animal diet. Low protein levels efficiency is associated with a relatively low voluntary feed consumption with protein deficient diet.

The metabolism of the rumen microbiota may be depressed by a deficiency in rumen nitrogen. This limitation will retard the rate of removal of organic matter from the rumen which, in turn, may reduce the intake. Low protein levels will affect the wool growth, which is determined by protein absorbed in the intestine, which in turn lends on ingested nitrogen sources (see El-Kady, 1987). The Ministry of Agriculture, Fisheries and Food in England (1975) also reported that the digestible energy should be about 5.4% and the protein requirement is about 4.44 % of the weight. In the present study, protein contents ranged from 4.3 % in rhizomes to 14.6 % in leaves on the average, which is higher than the proper level.

All range nutritionists face the problem of determining the nutritive content of the diet of range animals. Grazing animals often select their forage from a complex mixture of plant species (Edlefsen *et al*., 1960; Hosten, 2007; Shaltout *et al*., 2008; Heneidy, 2012 and Tilley and John. 2012). Öelberg (1965) reported that the nutritive value of any forage is dependent upon its content of energy-producing nutrients as well as its content of nutrients essential to the body, normally protein, minerals and vitamins.

The nutritive value of range forage is influenced in a major way by maturity stage, edaphic influences, plant species, climate, animal class and range condition. It may be suggested that animals should be supplied with supplementary feed rich in protein, particularly during the growth and reproductive stage, in order to maximize their productivity.

In the present study, the forage quality according to Boudet and Riviere (1968) showed that the green parts of *P. australis* are ranked under excellent fodder quality (Table 10), where the net energy are (4.18 MJ kg^{-1}) and digestible protein (5.85%). In general, the organic components and nutritive values of green parts are within the ranges in the feeds commonly used in ratios of sheep, goat and cattle (NRC, 1975; 1978; 1981 and 1984a, b).

CONCLUSION

In general, as accumulation of the analyzed heavy metals was higher in underground organs, there seems to be no danger for animals to feed on the aboveground parts, which are rich in their nutritive value. Hence, the current results are sufficient to indicate that *P. australis* can be use as a potential biological barrier against the spread of heavy metal pollution and can be using as a fodder plant in lakes. Similar conclusion has been made for five lakes in Poland (Drzewiecka *et al.*, 2010).

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