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Suitability of Using *Phragmites australis* and *Tamarix aphylla* as Vegetation Filters in Industrial Areas

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Abstract: Problem Statement: Many soils of different areas of the world are subjected to heavy metal pollution due to human activities especially the industry. These metals are hazardous to human health and could affect ecosystems. Toxic metal pollution in water and soil is a major environmental problem and most conventional remediation approaches do not provide acceptable solution, hence the studies of reducing such effects were launched. Phytoremediation, popularly known as green clean is an ecologically recommended strategy for the removal of toxic contaminations from the environment by using plants. **Approach:** The present study is an attempt to assess the suitability of using two species namely: *Phragmites australis* and *Ttamarix aphylla* as vegetation filterers in an industrial area to reduce the danger of contamination of heavy metals in the environment. The studied species viz. *Phragmites australis* and *Tamarix aphylla* were collected at four different locations (A, B, C and D) around a petrochemical and detergents factory in the industrial areas of Eastern Region, Dammam city, Saudi Arabia. The concentrations of seven heavy metals (Fe, Mn, Zn, Pb, Ni, Cd and Cu) were evaluated in different organs of *Phragmites australis* and *Tamarix aphylla*. Also, Soil samples were collected from each location for the chemical and mechanical analyses. **Results:** The results showed that the concentrations of heavy metals in *Phragmites australis* and *Tamarix aphllya* exhibited the same trend. In shoots of the studied species, Zn accumulated less heavy metals than the under ground parts, creeping rhizome and roots. The highest bioaccumulation factor (BAF) for Cd and Zn was noted in location B. In general, Zn was the most absorbed element followed by Fe, Mn while Ni as well as Pb and Cd were accumulated in lower quantities. In chemical and physical analyses of soil samples, location C showed the highest concentration of all of the investigated elements and it is the most alkaline with more clay and organic carbon. **Conclusion/Recommendation:** The present results demonstrated that both species are significant as vegetation filter and for cleaning the soils from contamination with heavy metals by phytoextraction. There is a great need to use the advantages of these plants in phytoremediation of environment. In the same time continuous harvesting of their shoots could be suitable way to recycling heavy metals.

Key words: Phytoremediation, vegetation filterers, creeping rhizome, *Phragmites australis*, *Tamarix aphylla*

INTRODUCTION

Some trace metals (e.g., Fe, Mn, Zn and Cu) are essential for living organisms. Zinc (Zn) is an essential element for plants and taken up actively by roots[7], while Cadmium (Cd) is a toxic element and exists along with Zn in nature. Iron (Fe) is also an essential micronutrient for plants and animals[21] however, excessive Fe uptake can produce toxic effects. Copper (Cu) is an essential element for plants and animals; however, excessive concentrations of this metal are considered to be highly toxic. Lead (Pb) is not essential but toxic to plants and it is the least mobile among the heavy metals. Air born Pb is readily taken up by plants through foliage[13]. Nickel (Ni) also is one of the toxic metals widely distributed in nature. Depending on the soil properties, the chemical forms of trace metals can strongly vary and influence their uptake by plants[34]. Plants adapt to great variability of chemical properties in their environment and are intermediate reservoirs through which trace elements in soil, water, or air move to animals and humans[17]. The genetic control of metal hyperaccumulation in plants is not well understood. For example, analyses of the heritability of Zn hyperaccumulation in *Thlaspi caerulescens* yielded inconclusive results[30,41].

The pollution of the environment by our industrial, economic or social activities is one of the most important global problems nowadays[19]. Due to their toxic effects the contamination of Heavy Metals (HM) in the environment is consequently a major global concern which has provoked the emergence of phytoremediation technologies for cleaning soils[9,33,36] aqueous streams[14]; mine wastes and sewage[1,37,42] by use of plants. About 400 plant species have been reported to accumulate toxic heavy metals.

Heavy metals may be added to the soil as a consequence of a nearby activity, such as smelting aerosol deposition, industrial wastes or fuel hydrocarbons from petrochemical factories. In urban areas both natural and artificial poor-drained inland ponds became the objects of heavy metals pollution. Phytoremediation the use of plants and their associated microbes for environmental cleanup[29]. Phytoremediation means depleting contaminated soils, water from contaminants with plants able to absorb, degrade or eliminate metals, pesticides, solvents, explosives, crude oil and its derivatives and various other contaminants from the media that contain them. It is clean, efficient, inexpensive and non-environmentally disruptive. With regard to emergence of heavy metals contaminations in environment, remediation of contaminated places is serious challenge. These compounds are not degraded and removed and their remediation depends on their removal from the environment incurring high expenses. In addition, during metal removal stage, one should use chemicals or physiochemical material preventing fertilization of soil and having negative effect on ecosystem and biodiversity[22]. Phytoremediation is an effective, cheap and biocompatible method with considerable dynamic capability[4,15,38,]. Phytoremediation can be specified into many applications including: Phytoextraction, in which plants decontaminate soil through uptake of heavy metals into aerial part and then can be harvested and removed from the site; Phytostabilization, in which plants are used to minimize heavy metal mobility in contaminated soil; and Phytovolatilization, in which plants extract volatile metals from soil and volatilize them from foliage[12]. This technique uses plants that absorb large amounts of water and thus prevent the spread of contaminated wastewater into adjacent uncontaminated areas. Phraeatophytes can be used for cleaning saturated soils and contaminated aquifers[31]. [10]reported that atmospheric pollutions produced by industrial factories contain traces of volatilizable heavy metals. These particles make landing on the vegetation surfaces and produce an alkaline micro-environment.

Many reports referred to the use of some plants in phytoremediation e.g.: *Phragmites*, *Tamarix*, tobacco, sunflower, cordgrass, *Salix*, *Typha*, *Arabis gemmifera* and *Thlaspi caerulescens*[3,20,25,41]. In the present study two of these plants viz. *Phragmites australis* and *Tamarix aphylla* were abundant in the study area. *Phragmites australis* (cav.) Trin. ex Steud. belongs to Graminae, it is a stout reed-swamp perennial with woody hollow culms, grows up to 3 m above water surface; in dry localities much shorter; it spreads vegetatively by below-ground rhizomes[24]. [39] reported that *Phragmites australis* is an invasive species in the northeast US sequesters more metals belowground than the native *Spartina alterniflora*, which also releases more via leaf excretion. *Phragmites australis* is a low coast propagation plant. The other species under study is *Tamarix aphylla* (L.) Karst. It is a shrub or high tree up to 15 m high and 2-5 m wide; leafless or its leaves being reduced to sheaths without blades. Slender branchlets usually closely jointed. Flowers small, sessile, in lax interrupted spikes; appearing in late summer. This plant was reported by[25] to excrete heavy metals through salt glands on the surface of their shoots. However, the present study is an attempt to assess the suitability of using the two species as vegetation filterers in the study area to reduce the danger of getting contamination by heavy metals in to the environment.

Fig. 1: The study area at 30 Km west of Dammam city, Saudi Arabia

Fig. 2: Satellite image showing the 2nd industrial area under the study

The study area: The study area is located in the second industrial rector area in the Eastern region of Saudi Arabia at 30 Km west of Dammam (Fig. 1). Locations (sites) A, B, C and D were about 3 km northern of the factory, 450 m west, 30m south and 50 m east of the factory respectively (Fig. 2). The contaminates reports of the factories showed that most portion of the volatized heavy metals are Cu, Ni, Fe, Zn where as Pb and Cd are present in traces.

MATERIALS AND METHODS

The studied species viz. *Phragmites australis* and *Tamarix aphylla* were collected at four different locations around a petrochemical and detergents factory in the study area. Soil samples were collected from each location for the chemical and mechanical analyses. These samples were collected from the surface to a depth of 50 cm.

Soil samples were air dried, thoroughly mixed and passed through 2 mm sieve to remove gravels and debris. Mechanical analyses were made using serial sieves. Determination of pH was made using a pH-meter. The Electrical Conductivity (EC) was measured using electric conductivity meter at 25°C. Analytical procedures for soil chemical analysis followed those of[6].

Five samples of the investigated species were also collected randomly from each of the four study sites. Each plant is separated into different organs (shoots and roots), air dried powdered and prepared for the determination of heavy metal content.

Analytical procedures for plant chemical analyses followed those of[5]. In the present investigation, the Bioaccumulation Factor (BAF) was calculated using the formula outlined by[32]:

$$\text{BAF} = \frac{\text{Element concentration in plant}}{\text{Element concentration in soil}}$$

Statistical analyses: All statistical analyses were performed using the software developed by the SPSS (ver. 11), (SPSS Inc., Chicago, IL) packages.

RESULTS

Physical and chemical properties of soil are given in Table 1. Location C showed the highest concentration of all of the investigated elements and it is the most alkaline with more clay and organic carbon. This site is located 3 m south of the factory and hence the most affected by HM vapors evolved from the factory since it is in the wind direction. While site A contains the lowest concentration of heavy metals (except for Cd which is at minimum in site B). This means that site A is the least contaminated, it is located 3km north of the factory, consequently the less affected by the air born HM.

Concentration of Cd and Pb in the soil ranged from 0.075-0.28 and 0.15-0.55 $\mu g\ g^{-1}$, respectively, which are (to ascertain limit) in accordance with the reports of the factory. Means of Cd Concentration in the two plants in the four sits are shown in Fig. 3.

It is also evident that the concentration of Fe in creeping rhizome of *Ph. Australis* (50.22 $\mu g\ g^{-1}$) and roots of *T. aphylla* (42.90 $\mu g\ g^{-1}$) is higher than that in shoots (Tables 2, 3 and Fig. 3). The distribution pattern of Cu in the two species (Fig. 3 and 4), indicate that there are higher concentrations of Cu in creeping rhizome *Ph. australis* (17.66 $\mu g\ g^{-1}$) and roots of *T. aphylla* (15.06 $\mu g\ g^{-1}$).

However, it is clear that the concentration of metals within *Phragmites* is proportionally related to the concentration of metals in the soil. The same is also true for *Tamarix* except its roots in site B contain slightly more Zn than that in site C. In addition, Fig. 3 shows that the extraction capacity of *Tamarix aphylla* for HM in roots and the translocation capacity to shoots were nearly of similar proportion for all locations. The highest amount of HM was recorded for the roots in site C.

Higher accumulation of Ni content than that the accumulated in the plant is also recorded. Fig. 3 also shows that the phytoextration capacity of Mn in *Tamarix aphylla* roots, translocation capacity in to shoots was nearby of similar proportion for all location.

Table 1: Variations in the chemical and physical properties of soil at different sites (A, B, C and D) in the study area

	Sites			
Parameters	A	B	C	D
Sand (%)	90	92	84	84
Silt (%)	6	6	6	8
Clay (%)	4	2	10	8
pH	6.810±0.10	7.130±0.23	8.17±0.40	7.900±.15
EC ($\mu s\ cm^{-1}$)	925.000±0.11	1233.000±0.16	1620.00±0.21	1027.000±0.05
Organic carbon ($\mu g\ g^{-1}$)	5.000±0.16	6.000±0.22	11.00±0.30	8.000±0.10
Cu ($\mu g\ g^{-1}$)	1.500±0.12	1.650±0.11	3.42±0.30	1.800±0.17
Fe ($\mu g\ g^{-1}$)	30.650±0.15	34.210±0.40	61.10±0.15	34.840±0.33
Zn ($\mu g\ g^{-1}$)	4.000±0.23	6.600±0.14	10.03±0.52	8.000±0.13
Mn ($\mu g\ g^{-1}$)	2.700±0.66	3.540±0.52	9.33±0.10	6.100±0.01
Ni ($\mu g\ g^{-1}$)	3.020±0.22	8.310±0.31	11.19±0.12	7.610±0.62
Cd ($\mu g\ g^{-1}$)	0.092±0.22	0.075±0.15	0.28±0.13	0.100±0.31
Pb ($\mu g\ g^{-1}$)	0.150±0.11	0.260±0.16	0.55±0.31	0.340±0.42

Table 2: Variations in heavy metal contents ($\mu g\ g^{-1}$) in different organs of *Ph. australis* at different Sites (A, B, C and D) in the study area

	Sites							
Elements concentration ($\mu g\ g^{-1}$)	A		B		C		D	
	Aerial shoot	Creeping rhizome	Aerial shoot	Creeping rhizome	Aerial shoot	Creeping rhizome	Aerial shoot	Creeping rhizome
Cu	2.22±0.35	5.11±0.36	4.33±0.15	10.58±0.21	8.29±0.10	17.66±0.11	3.00±0.12	9.82±0.22
Fe	9.30±0.26	22.01±0.15	15.15±0.13	28.15±0.11	35.01±0.30	50.22±0.30	12.05±0.26	30.60±0.12
Zn	20.66±0.16	37.00±0.11	33.05±0.22	61.40±0.14	40.98±0.52	72.71±0.31	36.81±0.11	50.15±0.17
Mn	9.15±0.26	21.60±0.30	10.10±0.66	32.20±0.32	30.83±0.45	45.90±0.11	12.80±0.41	61.75±0.26
Ni	3.52±0.13	10.00±0.16	6.67±0.62	13.43±0.22	9.55±0.15	19.00±0.31	6.51±0.60	13.33±0.11
Cd	0.39±0.02	0.70±0.01	0.52±0.06	1.084±0.03	0.732±0.05	1.33±0.01	0.55±0.04	1.25±0.01
Pb	0.51±0.02	1.12±0.05	0.82±0.04	2.20±0.00	1.04±0.03	3.85±0.06	0.11±0.00	1.02±0.02

Table 3: Variations in heavy metal contents ($\mu g\ g^{-1}$) in different organs of *T. aphylla* at different Sites (A, B, C and D) in the study area

	Sites							
Elements concentration ($\mu g\ g^{-1}$)	A		B		C		D	
	Aerial shoot	Creeping rhizome	Aerial shoot	Creeping rhizome	Aerial shoot	Creeping rhizome	Aerial shoot	Creeping rhizome
Cu	2.60±0.22	6.25±0.13	3.52±0.23	11.90±0.61	0.13±6.87	15.06±0.11	4.00±0.22	10.55±0.13
Fe	5.74±0.17	15.60±0.15`	9.93±0.15	23.20±0.19	28.22±0.23	42.90±0.15	10.63±0.25	25.12±0.26
Zn	16.35±0.52	20.90±0.41	25.74±0.15	69.50±0.32	35.88±`0.80	66.37±0.61	28.37±0.14	45.14±0.36
Mn	10.05±0.12	16.77±0.51	14.91±0.23	23.83±0.16	33.93±0.17	44.60±0.26	20.59±0.33	25.71±0.18
Ni	2.5±0.43	4.85±0.16	3.93±0.27	10.46±0.38	5.58±0.31	19.90±0.25	2.81±0.22	15.06±0.40
Cd	0.24±0.02	0.80±0.11	0.489±0.03	0.99±0.13	0.352±0.01	1.05±0.10	0.08±0.04	0.95±0.08
Pb	0.50±0.06	0.95±0.32	0.75±0.01	1.03±0.15	1.00±0.05	2.00±0.66	0.69±0.03	1.31±0.12

Table 4: Bioaccumulation Factor (BAF) of different elements in *Ph. australis* and *T. aphylla* at different Sites (A, B, C and D) in the study area

	BAF							
	A		B		C		D	
Elements	*Ph. australis*	*T. aphylla*	*Ph. australis*	*T. aphylla*	*Ph. australis*	*T. aphylla*	*Ph. australis*	*T. aphylla*
Cu	4.89	5.9	9.04	9.34	7.58	6.42	7.12	8.08
Fe	1.02	0.69	1.27	0.97	1.39	1.16	1.22	1.03
Zn	14.42	9.31	14.31	14.43	11.33	10.19	10.87	9.19
Mn	11.38	9.93	11.95	10.94	8.22	8.42	12.22	7.59
Ni	4.48	2.43	2.41	1.73	2.55	2.28	2.6	2.35
Cd	11.85	11.3	21.38	19.72	7.36	5.01	18	10.3
Pb	10.87	9.67	11.62	6.85	8.89	5.46	3.32	5.88

The highest amount was recorded for site C. Mn concentrations in *Ph. Australis* creeping rhizome of site D is the highest. The data obtained from the present study indicate that Zn in creeping rhizome of

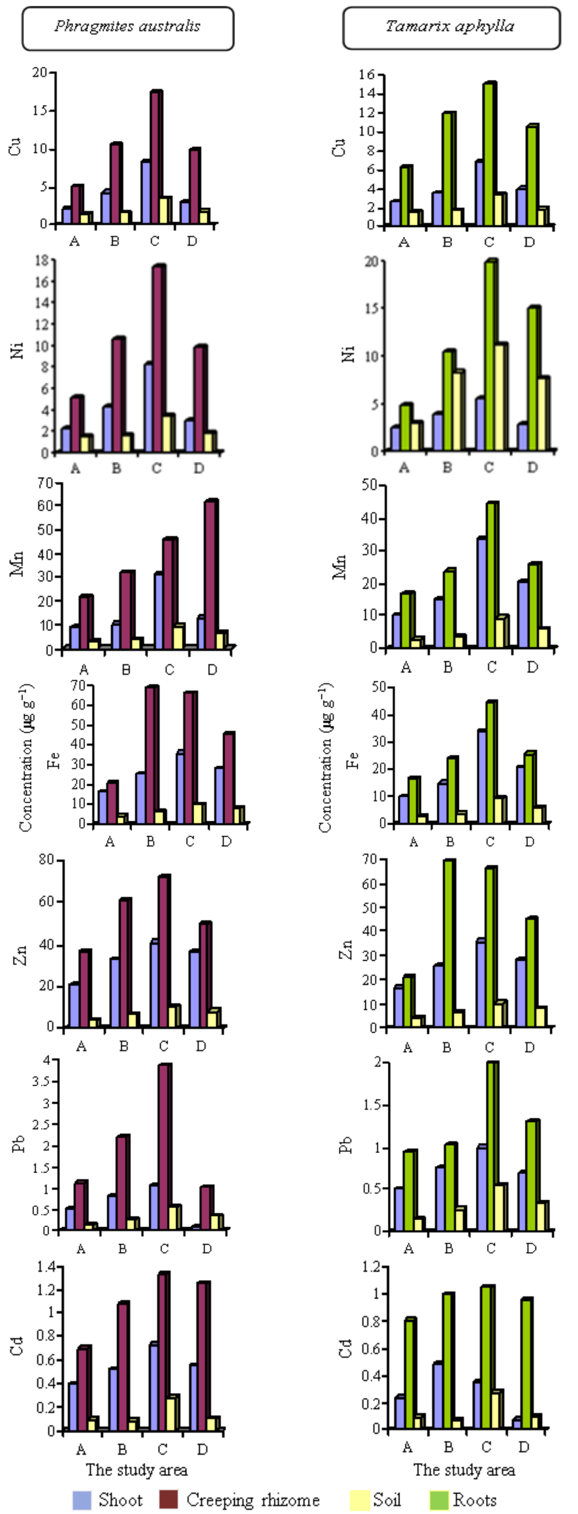

Fig. 3: Concentrations of elements accumulated in different plant parts of *Phragmites australis* and *Tamarix aphylla* in the study area (A, B, C and D)

Ph. Australis (72.71 µg g^{-1}) and roots of *T. aphylla* (66.37 µg g^{-1}) is higher than that in shoots (Tables 2, 3 and Fig. 3) of the tow studies species attained the highest amounts of Zn in all sites. The opposite trend was observed in the soil. Measurements of soil PH indicated that the soil solution in the four locations was highly alkaline. It was notable that *Ph. australis* does not occur where the water is acidic as it tolerant to brackish water.

Bioaccumulation factor is a general term that describes the phenomenon by which chemical substances accumulate in living organism. In this study, *Ph. australis* and *T. aphylla* attained the highest Bioaccumulation Factor (BAF) for Cd and Zn in site B, being 21.38 and 14.42 for *Ph. australis* and it is 19.72 and 14.43 respectively for *T. aphylla* (Table 4).

DISCUSSION

The highest recorded Cd concentrations were at site C. Metals may be translocated via the apoplast in the phloem and acropetally in the xylem[16] and such translocation may differ greatly between plant species and metal ions. On a study on the submerged species *Potamogaton pectinatus* reported high translocation of Cd in both directions[16], while Wolterbeek and Van der Meer[28] reported quite low, slowly acropetal translocation of Cd.

Since Diehl[13] suggested that Pb is readily taken up through foliage and reported that Pb is the least mobile among the heavy metals, one may assume that some of Pb in shoots of *Ph. australis* is not absorbed by roots. In contrary, Kabata-Pendias and Pendais[17] reported that Pb is the most highly accumulated metal in root tissue while Pb shoot accumulation is much lower in most plant species.

Generally, the concentration of elements (except Fe) in plants in all sites are more than that of soil and these concentrations are less than that reported by Marcshner[40] to be toxic for sheep. The concentration of Fe in creeping rhizome of *Ph. Australis* and roots of *T. aphylla* is higher than that in shoots. However, this may be due to its precipitation in iron-plague on the root surface[11,35]. This means that the translocation of metals to the shoot system occurs at relatively low rate than the absorption. Also, the present results showed that the samples of both creeping rhizome and aerial shoots of *Ph. Australis* collected from site C accumulated the highest concentration of all analyzed metals, except the concentration of Mn in creeping rhizomes of site D is the highest. It may be worth mentioning that the concentration of Mn in the soil of C is the highest among different sites, as are other metals, while Mn concentration in *Phragmites* rhizomes of site D is the highest. Cu concentration in plants above 10-30 $\mu g\ g^{-1}$ d.w. regarded as poisonous[23]. This absorption reveals that soluble Zn fractions may be translocated directly to the shoots or residual Zn from industrial factories deposited on leaves and shoots of these plants.

The highest Bioaccumulation Factor (BAF) for Cd and Zn in site B, these values are higher than that recorded by Bader and Ahmed[8] for *Phragmites pectinatus* and *Ceratophyllum demersum.* This higher BAF of plants growing in site B may be due to the prevailing of some other environmental factors, probably high sandy with less clay, or probably it may refer to the presence of different genotypes in site B. However it is worth mentioning that in this site the amount of surface water is higher than other sites, it is almost flooded and this suggests that the absorbed metals is related to the amount of available water.

Accumulations of heavy metals in different plants parts of the studied species assessed their suitability of both phytoremedation and vegetation filters especially in polluted sites. Many scientific reports refer to the tolerance of *Ph. australis* to waste water treatment in plant biomass production[1,2,7]. The results of the present investigation recommended the idea of using *Ph. australis* as a vegetation filter of HM.

Additionally, the present study illustrates the phytoextration capacity of the two studied species and their ability to absorb contaminants in their roots. Although their translocation into shoots, which can be harvested and burned, is not as much as root capabilities to sustain high concentrations of HM, the high amounts of HM in roots minimizes the toxic effects of free HM on other biota. Introducing *Ph. australis* and *T. apllya* as phytoextractors in the polluted areas is thus recommended. Beside the low-cost approach of propagation of *Ph. Australis,* its vegetative spread and highly competitive colonization of it especially in wetland would make it a recommended vegetative filter and easy procedure to clean up soil. Moreover, Manousaki *et al*.[26,27] and Kadukova *et al*.[18] reported that *Tamarix smyrnesis* excretes significant amount of metals on the leaf surface. However, shoots of *T. aphylla* in the present study accumulated metal less than that of roots. In addition that some of the plants such as *Ph. australis* and *T. apllya* can be used for control and prevention from distribution of HM contamination (phytostabilization) and phytoexraction methods can be used by identification of native and nonagricultural plants which are hyperaccumulator for phytoremediation of the contaminated area. Potential of phytoremediation depends on interactions of soil, heavy metals, bacteria and plants. Recognition of these factors and mechanism of their influence can have important role in development of phytoremediation application.

CONCLUSION

Many opportunities have been identified for research and development to improve the efficiency of phytoremediation. This technique is still in its early development stages and full scale applications are still limited. New commercial firms are moving into this field and phytoremediation technologies will be increasingly applied commercially in near term . Phytoremediation offers excellent perspectives for the development of plants with the potential for cleaning metal-contaminated soils, at least under certain, favorable conditions and for using adequate crop management systems. The present results already obtained have indicate that *Ph. australis* and *T. apllyhave* significant as vegetation filter and for phytoremeded its proposes. There is a great need to use the advantages of these plants in phytoremediation of environment. Exploiting the detoxification mechanism that the studied species have. In the same time continuous harvesting of their shoots could be suitable way to recycling heavy metals. Although it appears to be common sense among scientists, engineers, and regulators about the more widespread future use of this technique, it is important that public awareness about this technology is considered and clear and precise information is made available to the general public to enhance its acceptability as a global sustainable technology to be widely used.

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