

Phytoremediation of flashlight manufacturing effluent through aquatic macrophytes

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ABSTRACT

Three aquatic macrophytes viz. *Eichhornia crassipes*, *Pistia stratiotes* and *Lemna gibba* were studied for their potential to remove heavy metals from Flashlight manufacturing industry effluent. Plants were exposed to 100%, 75%, 50%, 25% and 0% (distilled water) concentration of effluent for 5 weeks. Results revealed that the macrophytes under study were highly efficient in the removal of Hg, Mn, Zn and Pb. Translocation factor expressed that metals were largely retained in the roots of *Pistia stratiotes* and *Lemna gibba* while *Eichhornia crassipes* concentrated most of the metals in shoots. Analytical results showed that *Eichhornia crassipes* removed approximately 67.535, 89.30, 80.84 and 69.80% of Hg, Pb, Zn and Mn, respectively, from 100% concentrated effluent which shows its higher metals removal efficiency compared to *Pistia stratiotes* (65.44%, 87.109%, 70.23%, 63.242%) and *Lemna gibba* (71.84%, 89.074%, 70.97%, 73.97%), respectively. These plants were also subjected to toxicity assessment and no symptoms of metal toxicity were found. Therefore, these macrophytes can be applied on the large scale treatment of waste water where volumes generated are very high and concentrations of pollutants are low.

1. INTRODUCTION

Large numbers of industries like tannery, battery, textile, electroplating, iron steel, pesticides, paints etc. use high quantity of water and chemicals and subsequently discharge it into water bodies such as river, lakes, ponds, and canals and cause water pollution. This pollution leads to major concern especially in developing country like India, where most of the activities are water dependent. Among various water pollutants heavy metals are major concern due to its persistence and accumulative nature. (Change et al. (2009), Yadav et al. (2009), Sood et al. (2012). These metals are added into water through discharge untreated or partially treated effluent directly into the water bodies. Hence, restoration of polluted water bodies needs cost effective and eco-friendly remediation technologies.

Phytoremediation is an attractive and applicable method for metal removals from the water using plants. It is cost effective, less destructive, being applicable in large range and environmental friendly technology. In the presented study these macrophytes viz. *Eichhornia crassipes*, *Pistia stratiotes* and *Lemna gibba* are selected and tested for their heavy metal removal efficiency from flashlight manufacturing industry effluent. These macrophytes have been tested due to their easy availability

and their adaptability to local climate change. *Eichhornia crassipes* was emerged aquatic macrophyte commonly known as water hyacinth, found all over the world. In the last few years great interest has been shown for the research of water hyacinth because it is a good candidate for pollutant removal and even as a bioindicator of heavy metals in aquatic ecosystems. *Lemna gibba* is free floating, fast growing macrophytes and adapts easily to various aquatic conditions, globally distributed in lakes, ponds, wetlands and some effluents lagoon. The capacity of duckweed (*Lemna* sp.) to remove toxic heavy metals from water plays an important role in removal and accumulation of metals from contaminated water. *Pistia stratiotes* genus of aquatic macrophytes in the family Araceae, commonly called as water lettuce. It Float on the surface of the water and root are hanging beneath floating leaves. They are natural hyperaccumulators of many toxic heavy metals. This paper is enlightening Zn, Mn, Hg and Pb removal abilities of three macrophytes viz. *Eichhornia crassipes*, *Pistia stratiotes* and *Lemna gibba* from flashlight manufacturing industry effluent.

2 MATERIALS AND METHODS

2.1 Study Location- The wastewater sample for the study was collected from outlet pipes of a Flashlight

manufacturing industry situated at Aishbagh Park, Lucknow, U.P., India. Effluent sample was collected in pre-cleaned 10L plastic containers.

2.2 Plant sampling - *Pistia stratiotes*, *Eichhornia crassipes* and *Lemna gibba* were collected from river Gomti, Lucknow, U.P., India. All the collected plants were put in hydroponic system containing tap water for one week acclimatization before being exposed to heavy metals.

2.3 Experimental setup and Data Analysis

Experimental setup was carried out in 25 plastic tubs. All 25 tubs were setup in five lines like stairs and each line contains five tubs including 100, 75, 50, 25 and 0% effluent, after a week treated effluent was transferred to next tubs with fresh plants and determination of Zn, Pb, Mn and Hg was carried out by atomic absorption spectrophotometer (Varian, AA240FS). All the plants samples were washed by distilled water and cut into small pieces and dried in oven at 60°C temperature and then homogenized using mortar and pestle. One gram of powdered sample digested with aquaregia (HNO₃ and HClO₄ acid in 3: 1 ratio v/v) until sample became clear and white, fumes of HClO₄ appeared and then diluted with 0.1 N HNO₃ and filter with 0.45 µm filter paper before analysis on AAS.

2.4 Removal Efficiency (RE)

After five weeks of treatment metals concentration in the effluent was analysed and the removal efficiency was calculated following the formula giving by Tanhan et al (2007); Khellaf and Zerdaoui (2009).

$$\text{Removal efficiency (\%)} = \frac{\text{initial concentration} - \text{final concentration}}{\text{initial concentration}} \times 100$$

2.5 Translocation factor (TF)

Translocation factor (TF) is the ratio of heavy metal in root to shoot, and is used to determine the plants potential for heavy metals accumulation (Gupta et al. (2008).

$$TF = \frac{\text{Concentration of metal in plants in shoots}}{\text{Concentration of metal in corresponding plant roots}}$$

2.6 Enrichment coefficient (EC)

Enrichment coefficients are a very important factor, indicate the relationship of metals in macrophytes and water also

named as bioconcentration factor (Sasmaz et al. 2008). The Enrichment coefficient (EC) was calculated as follows-

$$\text{Enrichment coefficient} = \frac{\text{Metal accumulated in plants parts}}{\text{Metal concentration in water}}$$

2.7 Statistical Analysis

Statistical significance of removal efficiency for heavy metals was examined by one-way ANOVA by using IBM SPSS 20 computer software. Treatment means were compared using Duncan's 95% simultaneous test. Differences were statistically significant when $p < 0.05$.

3 RESULTS AND DISCUSSION

3.1 Heavy metal removal from wastewater

Hg, Zn, Mn and Pb are common metals in flashlight manufacturing industry effluent. It was found that the initial concentration of these metals in the effluent to be Zn = 1.752 mg/l Pb = 2.27 mg/l Hg = 6.33 mg/l Mn = 1.09 mg/l, which are further found in decreasing order up to 5th weeks of analysis indicate the continuous absorption of metals by macrophytes. *E. crassipes*, *P. stratiotes* and *L. gibba* used in this study showed wide range of metals tolerance and also indicated effluent did not affect the growth of macrophytes. Occurrence of variation of metal accumulation in macrophytes perhaps associated with difference in absorption efficiency of metal, duration and plant growth. Analysis of variance indicates removal efficiency of metal in different experiment setup significantly ($p < 0.05$) varied.

Zinc is an essential micronutrient used in activation of enzyme and protein synthesis in plants, actively taken up by roots (Deng and Wong (2004). Concentration of Zn in effluent after 5th week are 0.44, 0.37, 0.246, 0.14; 0.34, 0.271, 0.201, 0.11; 0.544, 0.417, 0.321, 0.21 mg/l by *E. crassipes*, *L. gibba*, and *P. stratiotes* at 100, 75, 50 and 25% effluent concentration respectively. Maximum removal efficiency of Zn showed at 25% effluent concentration which is >90 by all studied macrophytes. Zn concentration depends on the modification of the chemical in the root system caused by the availability of different metals in the water (Cacador et al. (2000). Hg accumulation in macrophytes is highest may be due to its concentration in effluent compared to other metals. Hg is non-essential and toxic metal which are harmful for photosynthesis and oxidative metabolism of plants. *E. crassipes*, *P. stratiotes* and *L. gibba* removed >60% of mercury from the effluent, but *E. crassipes* good accumulator

considered because the concentration of mercury in their tissues are higher due to higher biomass, broad leaf and fibrous roots. Highest removal efficiency was found *L. gibba* (75%) at 50% concentration effluent whereas lowest efficiency found in *P. stratiotes* (62%) at 25% concentration. *L. gibba* removed 4.33, 4.11, 3.15, 2.43 mg/l; *P. stratiotes* removed 4.16, 3.76, 2.87, 2.18 mg/l and *E. Crassipes* removed 4.16, 4.03, 3.05, 2.33 mg/l after five weeks from 100, 75, 50 and 25% effluent concentration.

Mn is another essential metal for plants and also involved in Photosynthesis and enzyme activity (Bonanno and Giudice (2010). Concentration of Mn in *E. crassipes*, *P. stratiotes* and *L. gibba* varied with duration and

concentration. *E. crassipes* removed 69.80, 69.42, 75.45, and 77.36% of Mn from effluent, *P. stratiotes* removed 70.23, 69.80, 71.56 and 81.72% while *L. gibba* removed 70.23, 67.46, 70.90 and 95.07% Mn from effluent to 100, 75, 50 and 25% of effluent. Highest Mn removal efficiency was noticed at 25% effluent concentration while lowest of 69% was observed at 100% effluent concentration. This result showed that if the metal concentration is lower removal efficiency was increased. Mn easily moves within plants, and accumulates mainly in green parts of plant organs and its permissible limit 30 ppb as per WHO (Demirezen and Aksoy (2006). Lead is one of the toxic and non-essential metals for plants growth (Demirezen and Aksoy 2004). Concentration of Pb in

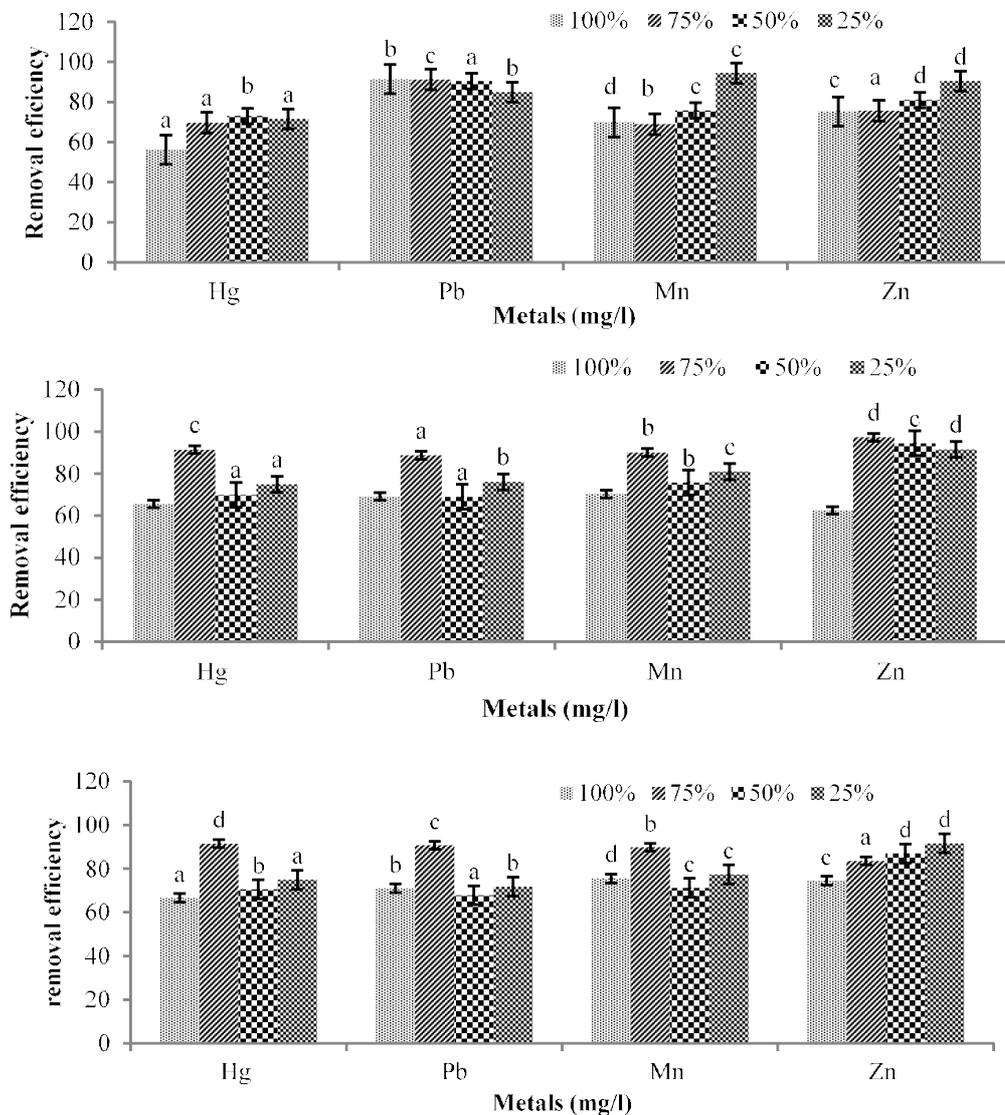


Fig. 1. Efficiency of *E. crassipes*, *P. stratiotes* and *L. gibba* for removing metals.

Table 1. Enrichment coefficients (EC) and Translocation factor of metal (TF) for root and shoot of studied macrophytes in flashlight manufacturing effluent.

Effluent Concentration	1 st week			2 nd week			3 rd week			4 th week			5 th week		
	ECR	ECS	TF	ECR	ECS	TF	ECR	ECS	TF	ECR	ECS	TF	ECR	ECS	TF
<i>Eichhornia crassipes</i>															
Zn															
100%	0.95	0.74	0.78	0.77	0.72	0.94	0.57	0.65	1.14	1	0.9	0.9	0.73	0.73	1
75%	0.99	0.48	0.48	0.81	0.76	0.94	0.53	0.74	1.39	0.86	0.8	0.93	0.74	0.71	0.95
50%	0.68	0.37	0.54	0.73	0.78	1.08	0.52	0.62	1.19	0.91	0.81	0.89	0.94	0.95	1.02
25%	0.63	0.38	0.59	0.86	1	1.16	0.65	0.62	0.95	1	1	1	0.81	1.89	2.35
0%	0.86	0.86	1.01	0.92	0.85	0.93	0.28	0.3	1.06	0.76	0.76	1.01	1.23	1.22	0.99
Hg															
100%	0.9	0.86	0.96	1.02	0.86	0.85	0.96	0.9	0.93	0.71	0.64	0.9	0.93	0.94	1.02
75%	0.94	0.87	0.93	0.96	0.88	0.92	0.91	0.85	0.93	0.72	0.7	0.97	0.82	0.85	1.05
50%	1.03	0.86	0.84	0.98	0.79	0.8	0.94	0.98	1.04	0.67	0.66	0.98	0.89	0.82	0.93
25%	1	1.17	1.17	0.9	0.76	0.85	0.96	0.93	0.97	0.5	0.53	1.05	0.86	0.72	0.84
0%	0.02	0.02	1.05	0.01	0.02	1.53	0.04	0.02	0.6	0.02	0.18	9.94	0.01	0.01	0.96
Mn															
100%	1.03	0.93	0.9	0.9	1.26	1.4	0.88	0.84	0.96	0.86	0.85	0.98	0.74	0.73	0.99
75%	0.74	0.75	1.02	0.64	0.97	1.53	0.71	0.69	0.98	0.69	0.72	1.04	0.88	0.93	1.06
50%	0.77	0.74	0.95	0.68	1.02	1.51	0.84	0.75	0.89	0.74	0.82	1.12	0.83	0.76	0.91
25%	0.94	0.98	1.04	0.92	1.46	1.58	0.87	0.89	1.02	0.92	1.02	1.11	0.72	0.06	0.08
0%	7.78	6.78	0.87	7.78	6.89	0.89	0.88	0.75	0.86	0.78	0.56	0.71	0.4	4	1.18
Pb															
100%	1.18	0.89	0.75	1.89	1.8	0.95	2.23	1.62	0.73	2.1	1.47	0.7	5	3.34	0.67
75%	0.96	0.98	1.01	2.13	1.95	0.92	2.29	2.06	0.9	2.28	1.37	0.6	4.82	3.1	0.64
50%	0.98	1.13	1.15	1.91	2.24	1.17	3.33	2.94	0.88	3.08	1.6	0.52	4.9	3.29	0.67
25%	1.02	1.02	1	2.91	3.4	1.17	2.07	1.8	0.87	5.95	1.75	0.29	5.99	3.44	0.57
0%	0.98	1.31	1.33	1.15	1.14	0.99	1.35	1.19	0.88	1.51	1.13	0.75	1.36	1.08	0.79
<i>Lemna gibba</i>															
Zn															
100%	1.38	1.38	1	1.3	1.31	0.99	1.59	1.49	1.06	1.62	2.01	0.81	0.96	1.37	0.7
75%	1.1	1.24	0.89	1.13	1.23	0.91	1.65	1.19	1.39	1.16	0.89	1.3	1.72	1.42	1.21
50%	1.45	1.83	0.79	1.22	1.36	0.9	2.68	1.63	1.64	0.99	1.07	0.93	1.35	1.23	1.1
25%	1.49	2.43	0.61	0.84	1.17	0.72	2.88	16.98	0.17	2.01	1.69	1.19	0.57	0.49	1.16
0%	1.05	1.06	0.99	1.04	1.15	0.9	9.45	10.96	0.86	9.21	9.35	0.98	1.03	0.82	1.25
Hg															
100%	1.12	1.09	1.04	1.13	1.16	0.98	1.1	1.08	1.02	1.13	1.1	1.03	1.04	0.99	1.07
75%	1.23	1.16	1.06	1.04	1.13	0.92	1.21	1.12	1.09	0.97	1.06	0.92	1.14	1.14	1.15
50%	1.05	0.93	1.14	1.01	1.26	0.8	1.07	1.02	1.05	1.14	1.15	0.99	0.9	1.04	1.17
25%	1.23	1.1	1.12	1.03	1.17	0.88	0.98	1.06	0.93	1	1.02	0.98	1.06	1.09	1.04
0%	20	12.79	1.56	23.94	24.32	0.98	22.27	24.36	0.91	24.91	24.4	1.02	25.57	22.97	23.9

Effluent Concentration	1 st week			2 nd week			3 rd week			4 th week			5 th week		
	ECR	ECS	TF	ECR	ECS	TF									
Mn															
100%	0.75	0.75	0.99	1.27	1.15	1.11	12.58	1.49	8.46	1.66	2.18	0.76	1.28	1.35	0.94
75%	0.91	0.92	0.99	1.39	1.22	1.13	16	1.66	9.62	1.68	1.72	0.98	1.21	1.24	0.97
50%	1.15	0.96	1.19	1.46	1.23	1.19	12.74	1.34	9.52	1.24	1.35	0.92	1.14	1.07	1.06
25%	2.94	3.3	0.89	1.09	1.1	0.99	11.41	1.19	9.58	1	1.17	0.86	0.14	0.16	0.86
0%	9.08	1.06	8.57	12.86	1.5	8.57	11.43	13.33	0.86	8.57	12	0.71	10	10	1
Pb															
100%	1.5	1.67	0.9	2.23	1.59	1.4	1.29	1.35	0.96	1.15	1.17	0.98	1.29	1.3	0.99
75%	3.25	3.18	1.02	2.88	1.88	1.53	1.67	1.71	0.98	1.43	1.37	1.04	1.67	1.58	1.06
50%	3.53	3.71	0.95	2.98	1.97	1.51	1.73	1.94	0.89	1.24	1.11	1.12	1.74	1.92	0.91
25%	2.8	2.68	1.04	3.43	2.17	1.58	1.98	1.94	1.02	1.5	1.35	1.11	2.24	28	0.08
0%	1	1.15	0.87	0.97	1.1	0.89	0.94	1.1	0.86	8.71	12.2	0.71	10.12	1.47	6.9
Pistia stratiotes															
Zn															
100%	1.05	1.07	0.98	1.12	1.15	0.97	1.15	1.21	0.95	0.87	0.95	0.92	0.9	0.89	1.01
75%	1.16	1.21	0.96	1.65	1.52	1.08	1.06	1.05	1.01	0.66	0.89	0.75	0.89	0.91	0.97
50%	1.54	1.86	0.83	2.06	1.47	1.4	1.46	1.61	0.9	0.61	0.98	0.62	0.94	1.01	0.94
25%	2.56	2.7	0.95	2.38	3.05	0.78	2.5	1.73	1.44	0.61	0.88	0.69	0.92	0.91	1.01
0%	10.11	11.03	0.92	10.07	11.67	0.86	12.08	9.33	1.3	11.44	12.19	0.94	10	8.9	1.12
Hg															
100%	1.13	1.13	1	1.09	1.14	0.95	1.07	1.13	0.95	1.11	1.16	0.96	1.1	1.17	0.93
75%	1.07	1.05	1.01	1.04	1.06	0.98	1.15	1.14	1.01	1.16	1.45	0.8	1.08	1.48	0.73
50%	1.1	1.34	0.82	1.17	1.04	1.12	1.12	1.11	1.01	1.24	1.57	0.79	0.97	1.54	0.63
25%	2.02	1.78	1.14	1.74	1.77	0.98	2.14	1.54	1.39	2.07	2.01	1.03	1.53	2.7	0.57
0%	2.81	22.99	0.12	28.85	28.85	1	35.91	28.14	1.28	29.11	32.88	0.89	34.93	3.11	11.22
Mn															
100%	1	1.04	1.04	1.23	0.78	0.63	0.84	0.52	0.62	0.83	1.24	1.49	0.83	0.81	0.97
75%	1.11	1.01	0.91	1.13	0.79	0.7	0.89	0.45	0.5	0.69	0.66	0.96	3.57	0.84	0.24
50%	1	1.12	1.12	0.86	0.78	0.91	0.75	0.43	0.57	0.86	0.88	1.02	0.61	0.69	1.12
25%	1.36	1.26	0.93	0.97	0.95	0.98	0.79	1.21	1.53	0.74	0.71	0.97	0.76	0.59	0.78
0%	7.78	6.67	0.86	7.78	6.67	0.86	8.75	7.5	0.86	5.56	5.56	1	4	4	1
Pb															
100%	1.18	1.18	1	2.01	1.6	0.8	2.24	2.09	0.93	2.06	1.45	0.7	3.18	2.13	0.22
75%	0.95	1.04	1.09	1.97	1.33	0.68	2.35	2.55	1.08	2.27	2.14	0.95	4.06	2.62	0.23
50%	0.95	1.1	1.15	1.4	1.1	0.79	3.34	3.74	1.12	3.12	2.46	0.79	3.94	3.08	0.2
25%	1.02	1.21	1.18	2.02	1.27	0.63	2.27	2.11	0.93	3.54	2.72	0.77	2.28	2.32	0.34
0%	0.1	0.1	1	0.1	0.07	0.69	0.05	0.05	1	0.05	0.05	1	0.05	0.05	18.57

ECR= Enrichment coefficient for root, ECS= Enrichment coefficient for shoot, TF= Translocation factor

effluent after 5th week of treatment are 0.175, 0.165, 0.14, 0.11; 0.178, 0.168, 0.15, 0.11; 0.27, 0.19, 0.15, 0.12 mg/l at 100, 75, 50 and 25% effluent concentration respectively by *E. crassipes*, *L. gibba*, and *P. stratiotes*. Brix (1993), has observed that *E. crassipes* has been used successfully in wastewater treatment system to improve the water quality by reducing the levels of Pb. Thus, water hyacinth would probably have high tolerance and should be capable of removing large amounts of Pb. Results revealed the maximum Pb removal at 25 and 50% and minimum at 100% and 75% effluent concentration, which indicates that higher concentration of metal in effluent slow down the phytoremediation process.

3.2 Translocation factors and Enrichment coefficient (EC)

There were slight differences in metal concentration between shoot and root, which indicates internal transportation of metal from root to shoot. Baker (1981) explains that metal immobilized in root and emphasized by the root to shoot >1 is related to an exclusion strategy. All the metals Zn, Hg, Pb and Mn are accumulated in *E. crassipes*, *P. stratiotes* and *L. gibba* and it was found that all macrophytes showed higher translocation ability for Zn and Mn and lower for Pb and Hg probably because Zn and Mn are essential element for plants while Hg and Pb are not. Results showed that root of macrophytes have higher metals concentration. Kuperberg et al. (1999) explained that plants with higher concentration in shoot known as phytoextractors while other plant which maintain metal in root known as rhizofiltrator in phytoremediation classification. Thus selected macrophytes translocation factor suits for rhizofiltration for Hg and Pb. Data presented in table 1 represents the value of translocation factor of Hg, Zn, Mn, and Pb in root and shoot of the *E. crassipes*, *P. stratiotes* and *L. gibba*.

Enrichment coefficient is important measures for considering the potential macrophytes and basically depends on the soluble fraction of metals in water and there translocation in tissues (Khan et al. 2006). *E. crassipes* and *Lemna gibba* recorded higher enrichment coefficient value for Pb after 5th weeks which are: 5.00, 4.82, 4.90, 5.99, 1.36; 3.34, 3.10, 3.29, 3.44, 1.08; 3.18, 4.06, 3.99, 2.28, 0.05; 2.13, 2.62, 3.08, 2.32, 0.05 respectively for root and shoot but *P. stratiotes* showed higher value for Mn after 3th week only for root which are 1, 1.11, 1, 1.36 & 7.78 respectively at 100, 75, 50, 25 and 0% effluent while Hg showed lower value by all macrophytes.

4. CONCLUSION

Present study provides an eco-friendly approach for the

removal of Hg, Zn, Mn and Pb from flashlight industry effluent. Three macrophytes proved highly effective in removing these four metals during 5 weeks experiment. *Lemna gibba* is appreciably to removed Hg, *Pistia stratiotes* effectively removed Zn and Pb and *Eichhornia crassipes* significantly removed Mn from effluent. The results of present study also indicated that metal removal efficiency were highest at 25% effluent concentration for all the three macrophytes for most of the times. Translocation factor also revealed that roots of the macrophytes is better accumulator of metals contains higher Zn, Pb and Hg in root and Mn in shoot of macrophytes which indicate that low transportation of metal from root to shoot. The tested macrophytes can be used for the treatment of wildly contaminated wastewater. However, it should be varified with on-field trials for best application.

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