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# Assessment of Heavy Metal Pollution in Urban Pond Ecosystems

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## Abstract:
**The study was conducted to determine the seasonal changes of heavy metals (Cu, Cd, Fe, Mn, Ni and Zn) in urban lentic water bodies (ponds) of Lucknow city. Owing to the unplanned development and urbanization, the ponds of this city are struggling for their existence. In spite of the global alarm for restoration of the water bodies, the ponds in the city are facing neglectance. For the study period four pond water bodies were selected. The study concludes that the water quality of ponds of Lucknow city is polluted as some of the results are above permissible limits. The city sewage discharge, agriculture and urban runoff and continuous dumping of waste materials especially sanitary waste are affecting the water quality of these urban water bodies. The toxicological implications of this finding in relation to aquatic ecosystem and human health are discussed. There is considerable need for better understanding of these small impoundments so that they can be managed effectively.**

**Keywords:** Agricultural runoff; Sewage; Sanitary waste; Urbanization; Water quality.

## 1.0 Introduction:
Water defects and contamination of existing water supplies threaten to be critical environmental issues today for agricultural, domestic and industrial uses. Metals constitute an important group of environmentally hazardous substances. During this century, many lakes and ponds in India have received elevated inputs of heavy metals as a result of an increase in atmospheric deposition and anthropogenic activities around these water bodies. Increasing awareness of ecological hazard of toxic metals from urban and industrial sources has involved considerable interest in the study of levels and fate of heavy metals in the aquatic environment (Ahmed *et al*., 2003). The potential toxic metal elements such as chromium, lead, copper, zinc *etc*., are identified to cause health hazards in animals (Lowe, 1970; Bryan, 1976; Sivakumar *et al*., 2001). So, it is necessary to know the heavy metal concentration in all trophic levels as well as sediments of the aquatic ecosystem.

Both aquatic and terrestrial habitats are becoming progressively polluted due to indiscriminate discharge of pollutants generated from various industries, transportation and fossil fuel burning (Issa *et al.,* 1995). Polluted aqueous discharges, both point and non-point, pose a tremendous hazard to natural ecosystems and to human health. Most wastes dumped on lands are often times washed into natural water bodies by rain runoff, therefore the aquatic ecosystem receive the bulk of contaminants from anthropogenic sources. Treatment technologies for metal contaminated soils and wastewater, which are based on physical and/or electrochemical treatments, are expensive and only partially effective. In addition, they commonly produce hazardous by-products (Qian *et al.,* 1999).

Heavy metals, industrial pollutants, in contrast with organic materials cannot be degraded and therefore accumulate in water, soil, bottom sediments and living organisms. Water contamination with heavy metals is a very important problem in the current world. Occurrence of toxic metals in pond, ditch and river water affect the lives of local people that depend upon these water sources for their daily requirements (Rai *et al.,* 2002). Consumption of such aquatic food stuff enriched with toxic metals may cause serious health hazards through food chain magnification (Khan *et al.,* 2000). Metals enter the aquatic environment from a variety of sources. Although most metals are naturally occurring through the biogeochemical cycle (Garret, 2000) , they may also be added to environment through anthropogenic sources, including industrial and domestic effluents, urban stormwater runoff, landfill leachate, atmospheric sources and boating activities (Furstner and Wittmann, 1979). Trace elements, and especially the so-called heavy metals, are among the most common environmental pollutants, and their occurrence in waters and biota indicate the presence of natural or anthropogenic sources (Solomons and Forstner, 1984). The main natural sources of metals in waters are weathering of minerals. However, concentrations of metals and their actual impacts can be greatly modified due the interaction with natural water constituents. Therefore, knowledge of the concentration of heavy metals is desirable for the estimation of pollution levels in waters and the determination of background values of metal concentrations in corresponding regions (Hansen *et al.,* 1995).

## 2.0 Materials and Methods:

### *2.1 Study Area:*

Lucknow, the capital of Uttar Pradesh ($26^{o}5/N$ latitude, $80^{o}56/E$ longitude, 128 m above the sea level), is spread over an area of 310 $km^2$ in the central plain of the Indian subcontinent, supporting a population of 36.48 lakhs. It has distinct tropical climate with a marked monsoonal effect. The year is divided into three distinct seasons *i.e*., summer (March to June), Rainy (July to October) and winter (November to February). The temperature ranges from a minimum of $5^{0}C$ in winter to a maximum of $47^{0}C$ in summer. The mean average relative humidity is 60% with a rainfall of 1006.8 mm. There are number of surface water bodies (*i.e*., pond *etc.*) both in the rural as well as in urban areas of the city but unfortunately there is a lack of sufficient information of the water quality of these water bodies. Lucknow Urban Agglomeration (LUA) became a million-plus city in 1981. The Master Plan 2021 is the basis of information for the projected population and land use in peripheral areas where considerable private development has been taking place. Growth rates have been arrived at through adding an additional population of 100,000 every five years for additional areas that might get incorporated within the city. According to the Land Records of the Lucknow Nagar Nigam, the city has 846 tanks and ponds, the majority of which are unidentifiable due to reclamation (Lucknow City Development Plan, 2006).

For the study of seasonal variations in heavy metal concentration, four pond water bodies designated as A, C, E and F were selected from different areas, which are permanent in nature regarding water input mentioned as:

- Maviyahia pond called as cheer sagar near PGI (pond **A**)
- At Telebagh infront of Rambarose Intercollege (pond **C**)
- At Ruchikhand near Shardhanagar (pond **E**)
- At Aurangabad Jageer behind Ambedkar Maidan (pond **F**)

### *2.2 Sampling and Analysis:*

Samples were collected and stored following the Standard Methods for the Examination of Water and Wastewater (APHA, 2005). Water samples were sampled in jerry canes and the metal concentration was estimated using Varian Model Spectra AA-250 plus Atomic Absorption Spectrophotometer.

## 3.0 Results and Discussion:

To study the seasonal variation in heavy metals, four pond water bodies designated as A, C, E and F were selected depending upon the water input and also the catchment sources as it was observed in the preliminary study that the water bodies are prone to major sources of pollution like highway runoff, sewage, urban runoff *etc.,* (Bhat *et al.,* 2009)**.** Three replicates data were summarized as Mean ± SD (Figure 1*)*. Groups were compared by two factor analysis of variance (ANOVA) and the significance of mean difference within and between the groups was done by Newman-Keuls post hoc test. A two-tailed ($\alpha$=2) probability (p) values less than p<0.05 were considered to be statistically significant. Analysis was performed on SPSS (version 13.0).

### *3.1 Copper (Cu):*

During summer maximum amount of copper concentration was found in pond C (2.48 ± 0.43 mg $^{-}$l) followed by pond E (2.25 ± 0.46 mg $^{-}$l), pond F (2.17 ± 0.40 mg $^{-}$l) and pond A (2.12 ± 0.94 mg $^{-}$l), however the change was not statistically significant (*p>0.05*). In rainy season pond E recorded maximum value followed by pond F, pond C and pond A (*Table 1*). However, during winters, the concentration was found maximum in pond C (3.11 ± 0.45 mg $^{-}$l) and minimum in pond A (2.30 ± 0.55 mg $^{-}$l).

**Table 1:** Seasonal variation (Mean ± SD, n=3) of copper (mg ¯l) in four selected ponds (A, C, E, F)

| Season | Ponds | | | |
|---|---|---|---|---|
| | **A** | **C** | **E** | **F** |
| Summer | 2.12 ± 0.94 | 2.48 ± 0.43 | 2.25 ± 0.46 | 2.17 ± 0.40 |
| Rainy | 2.41 ± 0.58 | 2.63 ± 0.47 | 3.03 ± 0.41 | 2.95 ± 0.32 |
| Winter | 2.30 ± 0.55 | 3.11 ± 0.45 | 2.89 ± 0.30 | 2.74 ± 0.37 |

Seasonal variation in copper (between ponds and between seasons)- not significant ($p>0.05$).

### *3.2 Cadmium (Cd):*

In summer the cadmium concentration was found maximum in pond C (0.85 ± 0.23 mg ¯l) which is significant than pond A (0.45 ± 0.29 mg ¯l) and also pond E (0.38 ± 0.21 mg ¯l) and pond F (0.10 ± 0.07 mg ¯l) recorded significant change in comparison with pond C. It was observed that in rainy season pond A recorded significantly higher concentration than in summer which also decreased significantly in winter. Beside in winters pond F detected highly significant variation when compared with ponds A, C, and E (*Table 2*).

**Table 2:** Seasonal variation (Mean ± SD, n=3) of cadmium (mg ¯l) in four selected ponds (A, C, E, F)

| Seasons | Ponds | | | |
|---|---|---|---|---|
| | **A** | **C** | **E** | **F** |
| Summer | 0.45 ± 0.29 | 0.85 ± 0.23$^{A}$ | 0.38 ± 0.21$^{C}$ | 0.10 ± 0.07$^{\mathbf{C}}$ |
| Rainy | $^{S}$0.93 ± 0.22 | 1.11 ± 0.14 | 0.61 ± 0.09$^{C}$ | 0.15 ± 0.11$^{\mathbf{ACE}}$ |
| Winter | $^{S}$0.91 ± 0.25 | 1.03 ± 0.17 | $^{S}$0.87 ± 0.20 | 0.11 ± 0.09$^{\mathbf{ACE}}$ |

$^{A}$p<0.05 or $^{\mathbf{A}}$p<0.01- in comparison with pond "A", $^{C}$p<0.05 or $^{\mathbf{C}}$p<0.01- in comparison with pond "C" and $^{E}$p<0.05 or $^{\mathbf{E}}$p<0.01- in comparison with pond "E"
$^{S}$p<0.05 or $^{\mathbf{S}}$p<0.01- in comparison with season "Summer" and $^{R}$p<0.05 or $^{\mathbf{R}}$p<0.01- in comparison with season "Rainy".

### *3.3 Iron (Fe):*

It was recorded that in summer season pond E (4.02 ± 0.56 mg ¯l) showed maximum value followed by pond C (3.92 ± 0.34 mg ¯l), pond F (3.86 ± 1.06 mg ¯l) and pond A (2.79 ± 1.16 mg ¯l). But in rainy season maximum amount of iron was found in pond C and minimum in pond F. During winters pond E recorded maximum value followed by ponds C, A, and F (*Table 3*).

**Table 3:** Seasonal variation (Mean ± SD, n=3) of iron (mg ¯l) in four selected ponds (A, C, E, F)

| Seasons | Ponds | | | |
|---|---|---|---|---|
| | **A** | **C** | **E** | **F** |
| Summer | 2.79 ± 1.16 | 3.92 ± 0.34 | 4.02 ± 0.56 | 3.86 ± 1.06 |
| Rainy | 4.57 ± 0.70 | 4.95 ± 1.10 | 4.73 ± 0.53 | 4.32 ± 1.11 |
| Winter | 3.53 ± 0.68 | 4.18 ± 1.06 | 5.06 ± 1.03 | 3.49 ± 0.71 |

Seasonal variation in Iron (between ponds and between seasons)- not significant ($p>0.05$).

## *3.4 Manganese (Mn):*

The manganese concentration was found maximum in pond C (2.58 ± 0.23 mg $^{-}$l) and pond F (1.57 ± 0.52 mg $^{-}$l) recorded lowest concentration in summer. Similar trend was observed in rainy season. But in winter it was found that pond E (4.54 ± 0.61 mg $^{-}$l) showed significantly higher concentration than pond A and C and also in comparison with summer and rainy. Besides pond F (2.72 ± 0.52 mg $^{-}$l) recorded significantly lower value than pond E during winter season (*Table 4*).

**Table 4:** Seasonal variation (Mean ± SD, n=3) of manganese (mg $^{-}$l) in four selected ponds (A, C, E, F)

| Seasons | Ponds | | | |
|---|---|---|---|---|
| | **A** | **C** | **E** | **F** |
| Summer | 2.32 ± 0.20 | 2.58 ± 0.23 | 2.09 ± 0.29 | 1.57 ± 0.52 |
| Rainy | 3.02 ± 0.46 | 3.40 ± 0.28 | 2.96 ± 0.49 | 2.65 ± 0.68 |
| Winter | 2.59 ± 0.49 | 2.91 ± 0.66 | $^{\mathbf{SR}}$4.54 ± 0.61$^{\mathbf{AC}}$ | 2.72 ± 0.52$^{\mathbf{E}}$ |

$^{A}$p<0.05 or $^{\mathbf{A}}$p<0.01- in comparison with pond "A", $^{C}$p<0.05 or $^{\mathbf{C}}$p<0.01- in comparison with pond "C" and $^{E}$p<0.05 or $^{\mathbf{E}}$p<0.01- in comparison with pond "E".
$^{S}$p<0.05 or $^{\mathbf{S}}$p<0.01- in comparison with season "Summer" and $^{R}$p<0.05 or $^{\mathbf{R}}$p<0.01- in comparison with season "Rainy".

## *3.5 Nickel (Ni):*

During summer pond C (0.99 ± 0.29 mg $^{-}$l) recorded maximum value followed by ponds E, A and F. It was observed that the pond F (0.21 ± 0.12 mg $^{-}$l) showed significantly lower concentration in comparison with pond C. However, in rainy season maximum amount of nickel was recorded in pond E (1.73 ± 0.27 mg $^{-}$l), which is significantly higher than in summer. Same trend was observed in pond A. Besides pond F (0.20 ± 0.14 mg $^{-}$l) recorded significantly lower concentration when compared with ponds A, C, and E (*Table 5*).

**Table 5:** Seasonal variation (Mean ± SD, n=3) of nickel (mg $^{-}$l) in four selected ponds (A, C, E, F)

| Seasons | Ponds | | | |
|---|---|---|---|---|
| | **A** | **C** | **E** | **F** |
| Summer | 0.59 ± 0.50 | 0.99 ± 0.29 | 0.63 ± 0.25 | 0.21 ± 0.12$^{C}$ |
| Rainy | $^{S}$1.43 ± 0.39 | 1.20 ± 0.23 | $^{\mathbf{S}}$1.73 ± 0.27 | 0.20 ± 0.14$^{\mathbf{ACE}}$ |
| Winter | 1.11 ± 0.37 | 1.39 ± 0.32 | $^{S}$1.58 ± 0.31 | 0.22 ± 0.11$^{\mathbf{ACE}}$ |

$^{A}$p<0.05 or $^{\mathbf{A}}$p<0.01- in comparison with pond "A", $^{C}$p<0.05 or $^{\mathbf{C}}$p<0.01- in comparison with pond "C" and $^{E}$p<0.05 or $^{\mathbf{E}}$p<0.01- in comparison with pond "E".
$^{S}$p<0.05 or $^{\mathbf{S}}$p<0.01- in comparison with season "Summer" and $^{R}$p<0.05 or $^{\mathbf{R}}$p<0.01- in comparison with season "Rainy".

## *3.6 Zinc (Zn):*

The maximum amount of zinc in summer was recorded in pond C (0.99 ± 0.29 mg $^{-}$l) followed by pond E (0.63 ± 0.25 mg $^{-}$l), pond A (0.59 ± 0.50 mg $^{-}$l) and pond F (0.21 ± 0.12 mg $^{-}$l). It was found that pond F showed significantly lower concentration of zinc than pond C in summer season. In rainy season pond A and E recorded significantly higher concentration than in summer. Further, pond F recorded significantly lower concentration in comparison with ponds A, C, and E. During winter season pond E (1.58 ± 0.31 mg $^{-}$l) recorded significantly lower concentration than in summer and also the pond F (0.22 ± 0.1 mg $^{-}$l) showed significantly lower value when compared with other three ponds (*Table 6*).

**Table 6:** Seasonal variation (Mean ± SD, n=3) of zinc (mg $^{-}$l) in four selected ponds (A, C, E, F)

| Seasons | Ponds | | | |
|---|---|---|---|---|
| | **A** | **C** | **E** | **F** |
| Summer | 3.24 ± 0.82 | 2.99 ± 0.48 | 2.59 ± 0.75 | 1.42 ± 0.44$^{A}$ |
| Rainy | 2.53 ± 0.74 | 3.32 ± 0.60 | 3.34 ± 0.71 | 2.60 ± 0.76 |
| Winter | 2.42 ± 0.81 | 3.50 ± 0.57 | 3.51 ± 0.55 | 2.51 ± 0.60 |

$^{A}p<0.05$ or $^{\mathbf{A}}p<0.01$- in comparison with pond "A", $^{C}p<0.05$ or $^{\mathbf{C}}p<0.01$- in comparison with pond "C" and $^{E}p<0.05$ or $^{\mathbf{E}}p<0.01$- in comparison with pond "E".
$^{S}p<0.05$ or $^{\mathbf{S}}p<0.01$- in comparison with season "Summer" and $^{R}p<0.05$ or $^{\mathbf{R}}p<0.01$- in comparison with season "Rainy".

During the study period, a marked variation in copper content was observed along three seasons in all the ponds. The maximum concentration was detected in pond C in rainy season. The chronic level of Cu is 0.02-0.2 mg $^{-}$l (Moore, 1984). Copper becomes toxic for organisms when the rate of absorption is greater than the rate of excretion and as copper is readily accumulated by plants and animals, it is very important to minimize the levels of copper in the waterway. Bordoloi *et al.* (2002) had reported that metals deposited in the sediments come out during heavy rainfall and flow into the water system. Roberto *et al.* (2008) had also reported that rainfall infiltrate the soil and underlying geologic formations, dissolve metals like Fe causing them to seep into aquifers and finally water system thus increasing their concentrations. Fe, Cu and Zn form substantial part of the wastes and effluents from workshops, industries and markets around the lake and may have been carried to the lake during the rains thus resulting in their higher concentration during the rainy season. Shivkumar and Biksham (1995) analyzed the industrial effluents, surface water and subsurface ground water for Cu content. The concentration of Cu was 5 to 10 times above the permissible limits.

Cadmium was also detected above the permissible standards and there were significant variations in all the four ponds and also along the seasons. Maximum value was recorded in rainy season in pond C. Cadmium is contributed to the surface waters through paints, pigments, glass enamel, deterioration of the galvanized pipes *etc*. The wear of studded tires has been identified as a source of cadmium deposited on road surfaces. There are a few recorded instances of Cd poisoning in human beings following consumption of contaminated fishes. It is less toxic to plants than Cu, similar in toxicity to Pb and Cr. It is equally toxic to invertebrates and fishes (Moore, 1984). Setia *et al.* (1998) concluded that sewage water contain 4 to 10 times more Cd content than tube well water.

In this study, it was observed that the concentration of iron is beyond the permissible level of water quality standard in all the four ponds. Seasonally the concentration gradually increases from summer to winter, however, the variations are not statistically significant. Gobler and Cosper (1996) and several Indian workers (Munnawar, 1970; Khan, 1993; Choudhury *et al.*, 1998; Khan and Bhat, 2000), have recorded much higher concentration of iron in lake and pond waters. (Reemtsma *et al.,* 2000) reported a high concentration of Fe content in urban runoff provided by municipal wastewater.

Manganese**,** although is not a toxic metal, it imparts objectionable and tenacious stains to laundry plumbing fixtures. It is found to occur in the domestic waste water. The concentration of manganese does not show much significant changes in summer and rainy season, but in winters it was observed that the increase is significant in pond E. The high trace metal concentration may originate from anthropogenic sources such as waste incineration, vehicle operation, combustible consumption, and fertilizers use (Councell *et al.,* 2004), which likely come from the upper basin of the lotic systems that flow into the wetland.

Nickel is easily accumulated in the biota, particularly in the phytoplankton or other aquatic plants, which are sensitive bioindicators of water pollution. It can be deposited in the sediment by such processes as precipitation, complexation and adsorption on clay particles and via uptake by biota (Barałk *et al.,* 1999). Nickel and nickel compounds have many industrial and commercial uses and the progress of industrialization has led to increased emission into ecosystems. During the present investigation, the concentration of Ni was found maximum in rainy season in pond E which is highly significant in comparison with summer in the same pond. Also the pond F recorded significantly less amount in summer than in rainy and winter season.

Zinc was found in all the ponds along the three seasons and there was not much significant variation, however, the pond F recorded significantly less concentration in summer than in rainy and winter season. Besides, higher values were found in winter season in ponds C and E. Though zinc is involved in nucleic acid synthesis and participates in a variety of metabolic processes involving carbohydrates, lipids, proteins and nucleic acid (Mc. Dowell, 1992), it can be toxic also when present in excess amount as changes in blood parameters and tissue structures have been reported on exposure to zinc (Gupta and Chakraborty, 1995; Banerjee, 1998).

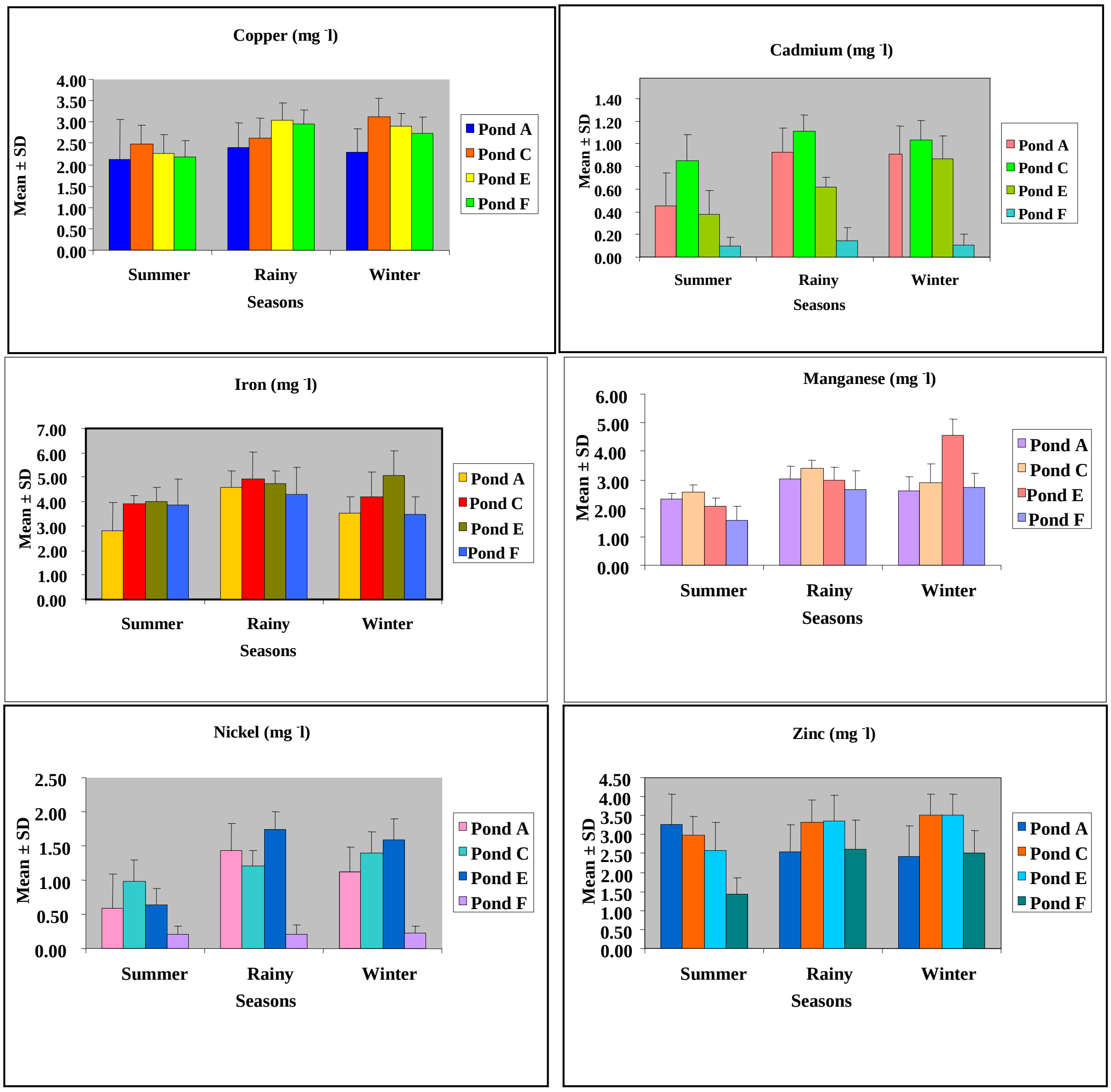


**Figure 1: Seasonal variation of heavy metals (mg l) in ponds A, C, E and F**

## 4.0 Conclusion:

The study concludes that the water quality of ponds of Lucknow city is polluted as the results are above the permissible limits. The city sewage discharge, agriculture and urban runoff and continuous dumping of waste materials especially sanitary waste are affecting the water quality of these urban water bodies. There is considerable need for better understanding of these small impoundments so that they can be managed effectively. Of the technologies available for remediating contaminated soil and water, phytoremediation using aquatic plants is promising because of its low cost compared to conventional physical or chemical methods, fewer negative effects and suitability for removal of low concentration pollutants at a large scale, which is the next step of our study. Biological technologies for wastewater remediation techniques employed to remove contaminants in urban stream water are increasingly receiving attention worldwide (Sekabira *et al.,* 2011).

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