Science of the Total Environment 635 (2018) 878–891

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Biomass decaying and elemental release of aquatic macrophyte detritus in waterways of the Indian River Lagoon basin, South Florida, USA

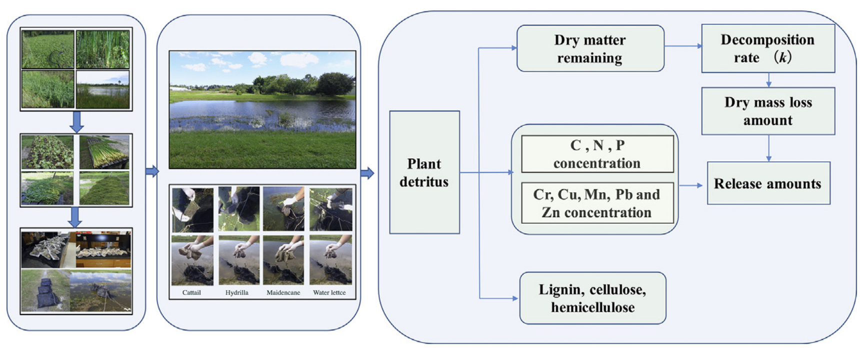
Xiaohong Zhou [a,b], Zhenli He [a,*], Fenghua Ding [a,c], Liguang Li [a], Peter J. Stoffella [a]

[a] Indian River Research and Education Center, Institute of Food and Agricultural Sciences, University of Florida, Fort Pierce, FL 34945-3138, USA
[b] School of the Environment and Safety Engineering, Jiangsu University, Zhenjiang, Jiangsu 212013, China
[c] Lishui University, Lishui, Zhejiang 323000, China

HIGHLIGHTS

- The decomposition rates (k) of detritus varied with plant species and decaying time.
- Effects of plant species were greater than decaying time on mass loss.
- Concentrations of nutrients and metals showed temporal changes.
- Water lettuce contributed most to the release of nutrient and Zn, Pb and Mn.
- Cattail contributed most to the release of Cr and Cu.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 21 October 2017
Received in revised form 4 April 2018
Accepted 4 April 2018
Available online xxxx

Keywords:
Aquatic macrophyte plants
Decomposition rates
Detritus
Freshwater ecosystems
Nutrient and metals released amount

ABSTRACT

Decaying experiments of four major aquatic macrophyte detritus, namely cattail (*Typha orientalis*), water lettuce (*Pistia stratiotes*), hydrilla (*Hydrilla verticillata*) and maidencane (*Panicum hemitomon*), were conducted using the litterbag technique in the stormwater detention pond of South Florida, USA. Dry weight and chemical composition of remaining biomass were dynamically determined during the 185-day decay experiment. The results showed that decomposition rates (k), and the derived turnover ($t_{50\%}$ and $t_{95\%}$) were species specific. The k values decreased in the order of hydrilla (0.0123 g day^{-1}) > water lettuce (0.0082 g day^{-1}) > maidencane (0.0049 g day^{-1}) > cattail (0.0031 g day^{-1}), whereas $t_{50\%}$ and $t_{95\%}$ varied in the reverse way. Biomass properties including concentrations of C, N, P, lignin, cellulose, hemicellulose, and the ratios of C/N, C/P, N/P and lignin/N affected decaying rate of the studied aquatic plants. The dry mass loss and concentrations of C, N, P, lead (Pb), chromium (Cr), copper (Cu), manganese (Mn), zinc (Zn), lignin, cellulose, hemicellulose and ratios C/N, C/P, N/P and Lignin/N of plant detritus were significantly affected by species, decaying time, and their interactions. However, the influence of species differences was greater than that of decaying time on those indexes. The estimated amounts (kg) of nutrients and metals released based on k values for the waterways of the IRL basin (water surface area 15.6 km^2) were N 126.85 × 10^3, P 8.89 × 10^3, Zn 408.20, Pb 97.95, Cr 128.99, Mn 313.03, and Cu 82.40. Water lettuce contributed most, accounting for 52.13% N, 56.81% P, 74.95% Zn, 59.58% Pb, and 74.65% Mn, followed by hydrilla, cattail and maidencane. For Cr and Cu, cattail had the greatest contribution of 65.77% and 54.15%, respectively, followed by water lettuce, hydrilla and maidencane.

* Corresponding author.
E-mail address: zhe@ufl.edu. (Z. He).

https://doi.org/10.1016/j.scitotenv.2018.04.047
0048-9697/

1. Introduction

Biomass decaying is a fundamental process in the life cycles of aquatic plants and plays a pivot role in the carbon and nutrient cycling of aquatic ecosystems (Richardson, 1994; Oliveira et al., 2016; Cheesman et al., 2010; X.H. Zhang et al., 2017, W.Q. Zhang et al.,2017). Decomposition of plant detritus releases inorganic or non-biotic organic compounds into water column, sediment and atmosphere (Belova, 1993; Li et al., 2014; Polechońska and Samecka-Cymerman, 2015), alters N/P ratio in sediment and water (Polechońska and Samecka-Cymerman, 2015), enhancing microbial activity (Longhi et al., 2008) in various ecosystems. Therefore, management of aquatic macrophytes is necessary to avoid undesirable ecological consequences of nutrient flush from littering and decaying.

In the Indian River Lagoon basin (IRL) of south Florida, waterways such as retention ponds, farm ditches and canals are often fully grown with aquatic weeds due to warm weather, abundance of solar radiation and nutrient supply from the eutrophic stormwater (Zhou et al., 2017). Dominating aquatic macrophytes in the waterways included submerged (i.e. hydrilla-*Hydrilla verticillata*), free-floating (i.e. water lettuce-*Pistia stratiotes*) and emergent plants (i.e. cattail-*Typha* spp., maidencane-*Panicum hemitomon*). Growth of abundant aquatic plants facilitated the removal of contaminants from water column and rendered the waterways like a natural phytoremediation system. According to our previous survey and evaluation (Zhou et al., 2017), the mean harvestable biomass of four plants were 579 g/m^2 (hydrilla), 719 g/m^2 (water lettuce), 901 g/m^2 (cattail) and 254 g/m^2 (maidencane), respectively. The storage of N and P (g/m^2) in the plant biomass was estimated at 12.6 and 1.04 for hydrilla, 14.6 and 0.97 for water lettuce, 8.4 and 0.57 for cattail and 4.7 and 0.22 for maidencane. If their biomass is timely harvested from the waterways, approximately 129.24×10^3 kg N, 9.13×10^3 kg P could be removed annually (Zhou et al., 2017). Harvest of the aquatic plants is a common practice in the IRL basin for maintaining hydrological efficiency of the waterways; but a large amount of aquatic plant biomass remained in waterways since only one harvest was annually performed, owing to transportation costs of the plant biomass off the sites. Furthermore, external disturbance, for example, animal grazing, often produced a large amount of litters. The remained plus regeneration of plants serve as potential secondary pollution source for aquatic ecosystems of the IRL in south Florida. However, no information is available regarding the dynamics of nutrients and heavy metal release from the decomposition of aquatic macrophytes in waterways. In addition, the contribution of each plant species to nutrients and heavy metals release is varied but not yet known. Moreover, previous studies revealed that decomposition dynamics (dry mass loss and nutrient release) changed with the decaying time and external environmental conditions (Lee and Bukaveckas, 2002; Geurts et al., 2010; Balasubramanian et al., 2012; Hildebrandt et al., 2012; Li et al., 2012, 2013; Song et al., 2013; Zhang et al., 2014; Bottino et al., 2016; Deng et al., 2016; Elmore et al., 2016; Sun et al., 2016; Yue et al., 2016; X.H. Zhang et al., 2017; W.Q. Zhang et al.,2017). In the IRL basin, it is still unclear how plant litters decay over time and subsequent flush of nutrients and heavy metals is affected by the tropical/subtropical climate. This information is essential for developing best management practice to control aquatic macrophytes and clean up eutrophic stormwater from agricultural production systems before it is discharged to the IRL.

Therefore, the overall goal of this study was to investigate the decomposition dynamic of four aquatic plants and to determine the amounts of nutrients and heavy metals release during this process. Consequently, the contribution of dominating aquatic plants was evaluated in the specific environment of IRL.

2. Materials and methods

2.1. Aquatic macrophytes

Four aquatic macrophytes including cattail (*Typha orientalis*), water lettuce (*Pistia stratiotes*), hydrilla (*Hydrilla verticillata*) and maidencane (*Panicum hemitomon*) were selected for this study. They are the dominant aquatic plant species in the waterways of the IRL basin, South Florida, USA (Zhou et al., 2017).

Fresh samples of the aboveground tissue of maidencane, cattail and whole tissue of water lettuce, hydrilla were separately collected from the basin in September 2014. They were rinsed thoroughly with tap water to remove any adhered impurities. Water lettuce was further separated into roots and leaves (plus stems), other plants were cut into approximately 50 cm long pieces. Plant samples were oven dried at 70 °C for 7 days to constant weight before they were cut into pieces of about 5 cm in length. Samples of each plant species were thoroughly mixed to give a homogenous starting material before they were divided into two portions, one being powdered for analysis of physicochemical properties, the other used for decay experiment.

2.2. Experiment design

Decomposition experiment was conducted using the litterbag techniques (Chimney and Pietro, 2006; Balasubramanian et al., 2012; Deng et al., 2016). Briefly, 15 g of dry plant samples for each species were placed into a 15 cm × 15 cm nylon litterbag of 0.4 mm pore size. The litterbags of maidencane or cattail were filled with mixed stems and leaves, whereas those of water lettuce were filled with roots (6 g) and leaves (9 g), and litterbags of hydrilla were filled with mixed stems, leaves and roots. The materials represented the initial state of plant detritus to be decomposed in water body. The litterbags with plant samples were submerged 0.6–1 m below water surface but out of touch with sediment in a stormwater detention pond, located at the University of Florida, Indian River Research and Education Center (IRREC) in Fort Pierce (27°25′34″N, 80°24′34″W) within the Indian River Lagoon basin, South Florida, USA. During the experiment period litterbags in four replications were randomly collected for each species at the intervals of 6, 14, 28, 45, 65, 90, 125, 145, 165 and 185 days after decaying. The collected litterbags were immediately transported in an iced chest to the IRREC Soil and Water Science Laboratory and rinsed thoroughly with tap water to remove any adhered impurities. The plant litters were then removed completely from the litterbags and oven-dried at 65–70 °C to constant weight. The oven-dried plant samples were weighed to record dry weight of remaining biomass and then powdered for chemical analyses.

2.3. Physicochemical analysis

Samples of plant litters before and after each decaying period were analyzed for concentrations of C, N, P, Cr, Cu, Mn, Pb and Zn, cellulose, hemicellulose, and lignin. Total C and N concentrations in plant material were determined using C/N analyzer (vario MAX C/N elementar Analysensysteme GmbH, Hanau, Germany). For measurement of total P and heavy metals, plant sample (0.4 g each) was placed into a 100 mL digestion tube, 5 mL concentrated nitric acid (HNO_3) was added. The samples were left overnight before being digested at 80 °Cfor 180 min (Ramp: 5 °C/min), and 140°Cfor 140 min (Ramp: 5 °C/min) on a digestion block with a programmable controller (AIM 500, A.I. Scientific Inc., Australia). The digested sample was diluted to 100 mL with deionized water after cooling to room temperature. Concentrations of P and heavy metals (Pb, Cr, Cu, Mn and Zn) in the digested solutions were determined using inductively coupled plasma optical emission spectroscopy (ICP-OES, Ultima, JY Horiba, Edison, NJ). Cellulose, hemicellulose, and lignin concentration in plants samples were determined using the Elisa kits by Shanghai Xinyu Biological Technology Co., Led (Shanghai, China). The University of Florida Soil and Water Science Laboratory is NELAC certified with high quality assurance and quality control standards. Standard methods were adopted for digestion of plant samples and analysis of nutrients and metals in the digested solution. The acceptable recovery of spiked standard is 95–105% for macro-elements (N, P, Ca, Mg, K) and 90–110% for micro-elements