

Effect of Heavy Metal Pollution on Leaf Litter Decomposition of Two Species of Mangroves, *Avicennia marina* and *Rhizophora mucronata*

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Abstract: Decomposition of litter is influenced by physicochemical characteristics of the habitat which is affected by pollution. In this study the effect of heavy metals on leaf litter decomposition of two mangrove species, *Avicennia marina* and *Rhizophora mucronata* is investigated. An experiment was conducted in which litter bags were half-buried in mangrove soil in earthen pots in a greenhouse in which close to natural conditions were maintained and they were treated with 0, 5 and 10 ppm Ni and Pb as a solution of sea water for 16 weeks. Periodic observations were taken on the dry weight remaining and the four factor ANOVA was performed. All four factors (species, heavy metals, concentrations, time) were found to be significant (P at the most 0.05) while some of the interactions were also significant. Half-life and rate of decomposition, k were calculated on the basis of 12 periodic weight loss observations. The litter decomposition followed an exponential decay curve in all cases. The highest rate of decomposition (0.0155 gDWd^{-1}) and the shortest half life (7.44 days) were found for the control of *Avicennia marina*. In general, decomposition rate of *A. marina* was more rapid compared to that of *R. mucronata*. Whereas, the decomposition in treatments with heavy metals were found to be slower than in the controls, the minimum of which (0.0105 gDWd^{-1}) and the longest half life (18.17 days) were found in *Rhizophora mucronata* leaves treated with 10 ppm Pb. Lead appears to be more inhibitory to the process of litter decomposition compared to nickel. The two mangrove species responded differentially to the heavy metal concentrations. The influence of heavy metals in the decomposition process is discussed.

Keywords: Litter Decomposition, Heavy metals, *Avicennia marina*, *Rhizophora mucronata*.

INTRODUCTION

Mangroves sustain a variety of marine and estuarine ecosystems and most of the primary production, consisting primarily of mangrove leaves, becomes available to consumers in the form of litter. Decomposition of this litter is one of the prime functions of ecosystems [1]. Leaf litter production has a significant effect on nutrient cycling in mangrove ecosystems. Generally, inorganic nutrients come from landwards to the mangroves and organic matter from the mangroves is exported to the sea [2]. Litter fall is a good indicator of the mangrove productivity, and its decomposition rate is of great significance as it reflects the nutrient recycling in the estuarine ecosystems [3].

Decomposition of plant detritus is mostly carried out by microorganisms for e.g. bacteria and fungi [4], and therefore several factors influence this activity. These may be broken up, [5], into abiotic factors, the physico-chemical conditions in which the decomposition takes place, and the substrate quality (e.g. biochemical composition of litter), which limits its aptness for microbial growth. Photosynthetic plant parts can directly affect decomposition rates due to their chemical or biochemical composition [6]. These

physicochemical conditions can be influenced by all types of pollution, including land based marine pollution.

The mangrove sediments bind a number of pollutants due to their physical properties, particularly the organic pollutants adsorbed to the clay and silt surfaces that are provided by the sediments of estuaries. Metals are also trapped in the mangrove sediments by the formation of sulphide complexes, particulate organic carbon or iron oxyhydroxides [7, 8].

The present study is based on the hypothesis that the heavy metal pollutants will reduce the rate of microbial decomposition of litter. In-order to establish this hypothesis, experiments were carried out using two heavy metals, namely lead and nickel to examine the influence of these pollutants on the rate of litter decomposition.

MATERIAL AND METHODS

Experimental

In this study the effect of two heavy metals, namely nickel (Ni) and lead (Pb) was investigated on leaf litter decomposition of two mangrove species, *Avicennia marina* and *Rhizophora mucronata*. Nylon litter bags (10 cm x 20 cm) were used following the practice of earlier workers [9, 10], the mesh size used was 0.5 mm

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which served to protect the leaves from being lost, and at the same time, allowed the decomposition near to natural conditions, for example, exchange of water, sediments and microorganisms. Senescent leaves of *R. mucronata* and *A. marina* (yellow leaves which were still attached to branches but were ready to abscise) were collected from the field, dried in air in laboratory for 7 days. Twenty gram leaves of both species were weighed to nearest 0.001 g and packed into above mentioned nylon litter bags.

The experiment was carried out in a greenhouse, in University of Karachi during July to Nov 2011. Litter bags were then half-buried in Creek soil contained in 30 cm diameter earthen pots. The pots were placed on greenhouse benches and were randomized. Creek soil was collected from a mangrove swamp of an almost pollution free area, away from Karachi towards the east. In each pot two litter bags were half-buried in soil that simulated the natural situation of the litter. Three treatments of Ni and Pb were given to the litter including controls. These were 0, 5 and 10 ppm (Ni) as $\text{Ni}(\text{NO}_3)_2$ or Pb as $\text{Pb}(\text{NO}_3)_2$ in sea-salt solution (3.5 percent) in water. These treatments were applied to pots twice weekly. Whereas for the four days watering was done using 3.5 percent sea-salt water. Once a week pots were flooded with tap water in order to wash the excessive salt accumulated during the week.

Replicates of litter bags were retrieved from each treatment randomly along with controls. The attached sediments were gently removed by washing the litter bags with the tap water [10, 11]. The undecomposed litter was dried in a hot air oven at 70°C to constant weight.

Decomposition rates were calculated using the weight loss and time data. Decomposition rate (k , natural log units day^{-1}) were expressed from the variation in litter dry weight (W) with time (t , days) since the beginning of the experiments by using the following equation,

$$W_t = W_0 e^{-kt}$$

This model has been used earlier [12]. Graphs were plotted between remaining dry weight vs time elapsed.

Decomposition rates for all the treatments were also found as the half-life of plant detritus ($T_{1/2}$, days), which was described by Enriquez *et al.* [6] as:

$$T_{1/2} = k^{-1} \cdot \ln 2$$

Statistical Analysis

The data of litter decomposition were subjected to Factorial analysis of variance (FANOVA) using a generalized linear model (GLIM). Four factors i.e. species (2), heavy metals (2), concentrations (3) and time (12) and four replicates per treatment were used. The Analysis of Variance was performed using the software COSTAT6400, Tulsa Oklahoma. Decomposition curves for each treatment were drawn using Origin 8.0. Curve fitting was done and equations were developed using the same software.

RESULTS

Litter Decomposition

The decomposition rate of the two species of *Avicennia* and *Rhizophora* leaves were found to differ significantly with the metal treatments ($P < 0.05$). The average rate of decomposition (k) for *A. marina* leaf litter, (control group) (Figure 1a) was 0.0155 g dry weight per day (gDWd^{-1}), while the maximum decomposition rate (k_{max}) was found to be 0.093 gDWd^{-1} and the half life ($T_{1/2}$) for this control group was 7.44 days. Whereas *A. marina* litter treated with 5 ppm Ni, showed a k value of 0.0153 gDWd^{-1} (Figure 1b), maximum decomposition rate of 0.083 gDWd^{-1} while a half life equal to 8.27 days. Those treated with 10 ppm Ni were decomposed at a rate of 0.0138 gDWd^{-1} , and a k_{max} of 0.081 gDWd^{-1} while the half life this time was 8.56 days. The effect of 5 ppm Pb was that the average rate of decomposition was 0.0127 gDWd^{-1} and the maximum was 0.055 gDWd^{-1} while the half life was 12.48 days. Similarly, the effect of 10 ppm Pb was found with an average rate of 0.0129 gDWd^{-1} and maximum of 0.053 gDWd^{-1} and the half life of 12.85 days.

The effect of heavy metals on *R. mucronata* leaf litter was also observed to be variable. k value of the control group was 0.0134 gDWd^{-1} , k_{max} of 0.089 gDWd^{-1} and a half life of 7.81 days. For 5 ppm Ni treatment average k was found to be 0.0129 gDWd^{-1} , maximum of 0.085 gDWd^{-1} and a half life of 7.84 days. While the 10 ppm Ni showed an average k of 0.0123 gDWd^{-1} maximum of 0.08 gDWd^{-1} and half life of 8.99 days. The treatment of 5 ppm Pb showed an average rate of 0.011 gDWd^{-1} , maximum of 0.057 gDWd^{-1} and half life of 12.05 days. But the adverse effect was more pronounced in 10 ppm Pb treatment, where the average rate of decomposition was 0.0105 gDWd^{-1} maximum of 0.0391 gDWd^{-1} and a half life of 18.17 days.

Table 1: Summary of Factorial ANOVA for Effect of Heavy Metals on Litter Decomposition of *A marina* and *R mucronata* Leaves

Source	df	Sum of Squares	Mean Square	F-ratio	P
Species	1	555.47	555.47	6.96	0.01 **
Heavy Metals	1	1607.36	1607.36	20.14	0.001 ***
Species*Heavy Metals	1	285.54	285.54	3.57	0.0592 ns
Concentrations	2	6232.37	3116.18	39.06	0.001 ***
Species*Concentrations	2	208.72	104.36	1.30	0.2714 ns
Heavy Metals*Concentrations	2	897.17	448.58	5.62	0.01 **
Species*Heavy Metals*Concen.	2	348.26	174.13	2.18	0.1140 ns
Time (Weeks)	11	310416.41	28219.67	353.68	0.001 ***
Species*Time (Weeks)	11	1325.73	120.52	1.51	0.1245 ns
Heavy Metals*Time (Weeks)	11	1596.05	145.09	1.81	0.05 *
Species*Heavy Metals*Time (Weeks)	11	632.80	57.5	0.72	0.7186 ns
Concentrations*Time (Weeks)	22	2045.79	92.99	1.16	0.2747 ns
Species*Concentrations*Time	22	2107.98	95.81	1.20	0.2419 ns
Heavy Metals*Concentrations	22	2332.33	106.01	1.32	0.1468 ns
Species*Heavy Metals*Concentrations	22	1943.36	88.33	1.10	0.3349 ns
Error	431	34388.05	79.78	<-	
Total	574	367959.23			
Model	143	333571.17	2332.66	29.23	0.001***

Analysis of variance revealed many important effects on litter decomposition. *Avicennia marina* showed the higher rate of decomposition than *R. mucronata* (Table 1). Lead reduced the decomposition rate more than did nickel (Table 1). Concentrations were also found significant ($p < 0.001$). Expectedly, 10 ppm lead more dramatically affected the rate of decomposition than did 5 ppm lead which only slightly but significantly reduced the decomposition rate compared to the controls. Whereas there was no significant effect of the interaction of species with concentrations and/or heavy metals on the rate of litter decomposition. But the interaction between heavy metals and their concentrations was found to be significant ($p < 0.01$). The effect of time was significant for obvious reasons and also its interaction with heavy metals. But time and species or time, species and heavy metals interactions were non-significant (Table 1).

DISCUSSION

The pattern of decomposition of both species was somewhat similar with high rate of decomposition (k) in the beginning which kept on decreasing slowly and steadily after the first week till the rest of the time of

experiment (Figures 1a and 2a). However, they differed in the rate of decomposition and half-life. *Avicennia marina* exhibited higher decomposition rate (greater k value) compared to *Rhizophora mucronata*.

The high initial rate of decomposition of litter in the first or up to second week is likely to be caused by leaching of soluble organic materials [13] and inorganic compounds [14, 15].

The average k values were found to vary with different treatments and controls for both the species. These average k values ranged between 0.0099 to 0.0163 gDWd^{-1} . with the highest in the controls and the lower ones were found in the heavy metal treatments. Although this range was lower than reported by an earlier study in arid mangroves of Gulf of California [16] whose average decomposition rate was $0.032 \pm 0.004 \text{ gDWd}^{-1}$, but approached the ranges reported by other studies [11, 17-19]. Zhang *et al.* [20] reported that the litter decomposition rate of mangroves can be between 0.006 to 4.993 $\text{gg}^{-1}\text{yr}^{-1}$. The maximum decomposition rate in this study was found in the control of *Avicennia marina* which was 0.093 gDWd^{-1} .

The Shortest half life of the leaf litter was found in *A marina* controls which was 7.44 days. It was observed

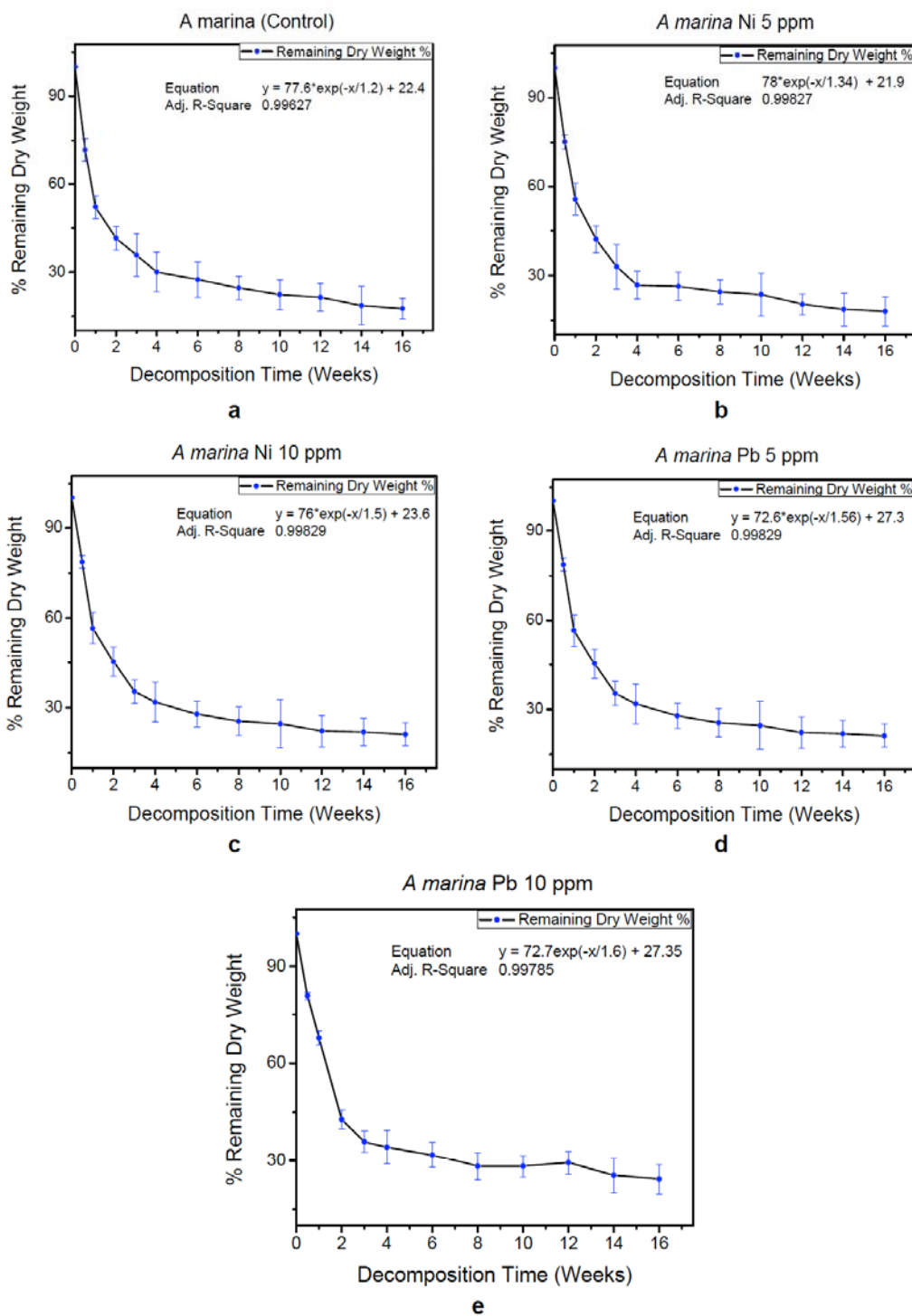


Figure 1: a. Decomposition Curve of *A marina* (Control). b. Decomposition curve of *A marina* leaves treated with 5 ppm Ni. c. Decomposition curve of *A marina* leaves treated with 10 ppm Ni. d. Decomposition curve of *A marina* leaves treated with 5 ppm Pb. e. Decomposition curve of *A marina* leaves treated with 10 ppm Pb.

that the heavy metals significantly affected the litter decomposition rate and the half life of heavy metal treatments were longer. The longest half life (18.17 days) and smallest value of k (0.0105 gDwd^{-1}) was found in *R mucronata* leaves treated with 10 ppm Pb. It is known that heavy metals have adverse influence on

growth and activity of natural populations of bacteria [21]. Among the two heavy metals, the effect of lead was greater than that of nickel at both the concentrations. The least effect was that of 5 ppm Ni in both the species whose values of k and half life were closer to that of the controls in both the species.

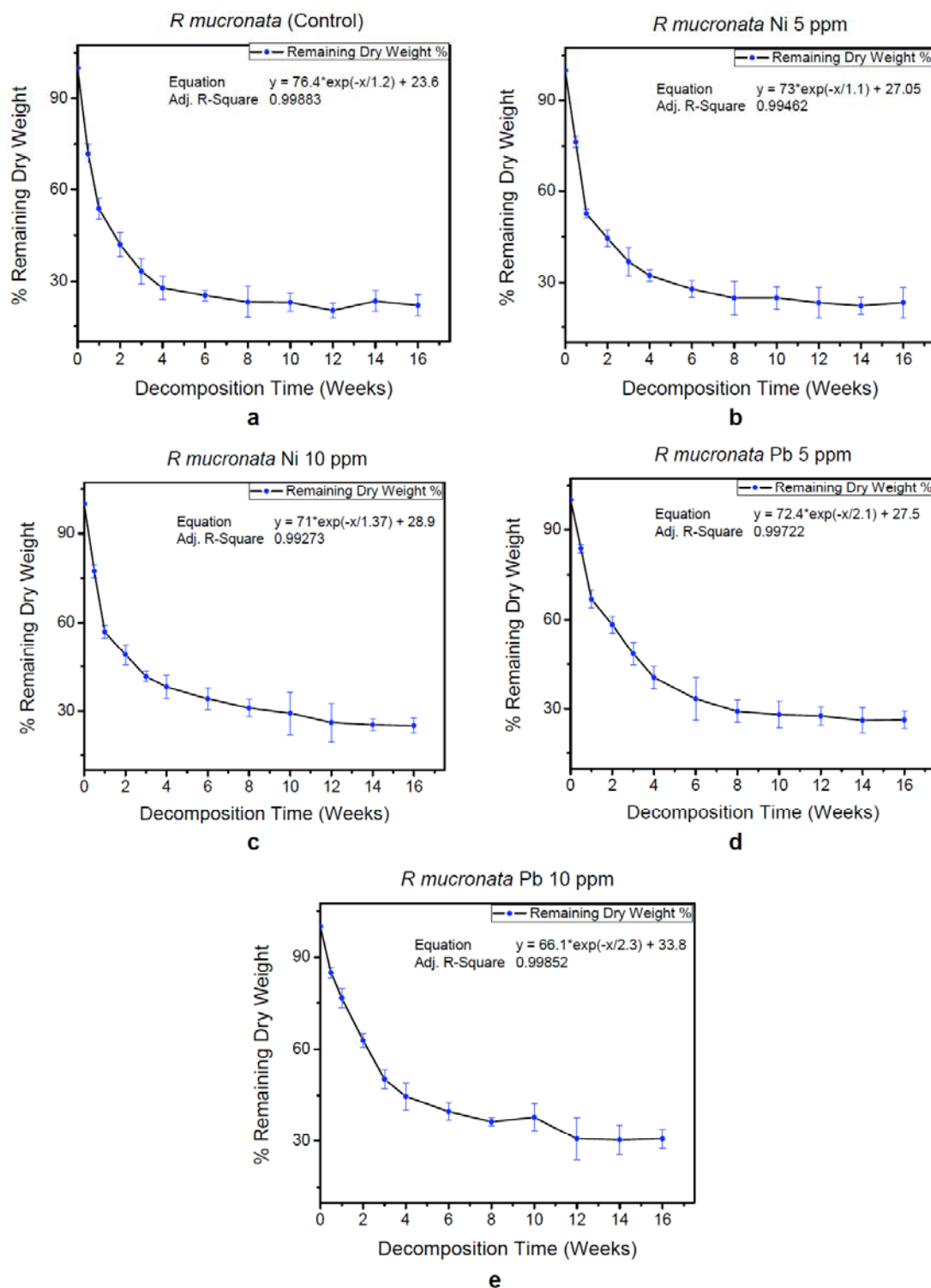


Figure 2: a. Decomposition Curve of *R mucronata* (Control). b. Decomposition Curve of *R mucronata* leaves treated with 5 ppm Ni. c. Decomposition Curve of *R mucronata* leaves treated with 10 ppm Ni. d. Decomposition Curve of *R mucronata* leaves treated with 5 ppm Pb. e. Decomposition Curve of *R mucronata* leaves treated with 10 ppm Pb.

It may be concluded that the heavy metal pollutants and their different concentrations may affect the litter decomposition rate in the natural ecosystems as per findings of previous studies. In another such study [22], bacterial and fungal activities in soil were found to be

reduced by 30 – 90 % during heavy metal exposure. Heavy metals affected the bacterial activity by decreasing the thymidine incorporation rate and the fungal activity by reducing the acetate-in-ergosterol incorporation rate. Another study also reported highly

significant negative correlations of various heavy metals (including Pb and Ni) concentrations with rate of CO₂ evolution or dehydrogenase activity [23].

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