EnvironmentAsia
The international journal by the Thai Society of Higher Education Institutes on Environment

EnvironmentAsia 11(2) (2018) 91-108
DOI 10.14456/ea.2018.25
ISSN 1906-1714; ONLINE ISSN: 2586-8861

Floral and Algal Species Composition in An Abandoned Mine Tailings Pond at BGY. Mogpog, Marinduque, Philippines

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Received: February 20, 2018; Accepted: March 11, 2018

ABSTRACT

Copper contamination by mining activities of CMI in soils and waters of Bgy. Mogpog, Marinduque should be addressed. There is a need to assess the area to identify organisms that have potential to rehabilitate copper contaminated waters and soils. This study aims to assess potential phytoremediators present in the Ino-Capayang Mine-made pond at Bgy. Mogpog, Marinduque. Three stations were established at the site. Copper concentrations in soil and water were determined, as well as other abiotic parameters such as pH, DO, COD, TSS and temperature. Microalgal samples were collected using plankton net and were identified. Importance Values (IV) of dominating plant species at the stations were determined. The study revealed 12 identified taxa of microalgae in water. Diatoms dominated the microalgal community, accounting for 70% of the overall total cell abundance. Station 3 had the most number of algal taxa. However, the microalgal diversity is low, which can be attributed to the presence of copper (mean of 0.097 ppm) and high TSS in the water. On the other hand, there is an immediate need to remediate the soil in the area since copper concentration in the sites were significantly higher in soil (663.78 ppm) than in water (0.097 ppm). The pH concentrations were also relatively acidic in soil than in water. A total of 27 species belonging to 19 genera from 11 families were recorded under the division Ancerophyta. Under division Pteridophyta, a total of 3 species belonging to 3 genera from 3 families were recorded from the sampling site. Among the angiosperm families observed, the most represented families were Poaceae (5 spp.), Compositae (4 spp.), Leguminosae (4 spp.), Convulvulaceae (4 spp.) and Cyperaceae (3 spp.). Among the identified grass species that are capable of dominating the site are: Bamboo (IV=0.40), followed by *Synedrella nodiflora* (IV=0.36), *Axonopus compressus* (IV=0.36), *Mimosa pudica* (IV=0.35), and the 5th in rank is Poaceae sp. 1. The high Importance Values of these plant species revealed its capability to tolerate soils with high copper concentration, hence can be potential phytoremediators in the area.

Keywords: Mine tailings pond; Marinduque; Diatoms; Phytoremediation; Copper contamination

INTRODUCTION

With the increasing phase of urbanization, modernization and technological innovation, necessities for metal ores are also increasing, which is supplied by mining and other mineral exploration techniques. The Philippines, being very rich in mineral deposits, ranked second to Indonesia in 2000 in terms of prospective minerals and resources (Kuo *et al.,* 2000). Thus, mining operations in the country are numerous. These kinds of human activities have been demonstrated to cause disturbances in natural ecosystems. These disturbances include the complete loss of natural vegetation, soil acidification and deterioration of the organic and microbial soil attributes, as well as heavy metal contamination both of the terrestrial and nearby aquatic ecosystems (Brown *et al.,* 2003).

Heavy metals can be naturally found in the earth's soil and crust. Although some of these heavy metals function as micronutrients (eg. Cu, Zn, Mn, Ni, and Co) that are important in many physiological functions of plants and microbes, when in high concentration in the environment, toxicity can also be observed (Priyadarshani *et al.,* 2011; Gaur and Adholeya, 2004). According to Herrera-Estrella and Guevara-Garcia (2009), heavy metals can be categorized as metals or metalloids that causes environmental pollution, which are either (a) necessary at low concentration, but toxic in high concentration (eg. Cu and Mo), or (b) they have no known vital function and toxic even at low concentration (eg. Pb and Hg).

Marinduque is one of the heavily mineralized areas for important heavy metals such as iron, gold, and copper (Mines and Geoscience Bureau, 2007). Consolidated Mining Incorporated (CMI) is one of the mining companies in Bgy. Mogpog, Marinduque which has harvested ores by open-pit mining since 1968 to 1980. The operation has left disastrous effects to the environment in the form of heavy metal contamination (Llamado *et al.,* 2013). The mining in this area has been inactive since 1997, leaving a man-made pond near the dump of infertile, and acidic soil. The oval, bowl-shaped pit is called the Ino-Capayang Mine-made lake (Medianista and Labay, 2017). The soil sample taken from the site was reported to have a pH of 5.1 ± 1.11, 0.52 ± 0.17% organic matter, P (Bray) = 103.12 ± 74.27 ppm, K = 0.25 ± 0.24 cmol/kg -1 soil, and a copper content of 70.97 ± 14.30 mg/kg -1 soil (Llamado *et al.,* 2013).

Although mining can boost a nation's economy, it is faced with issues related to rehabilitation and restoration of degraded ecosystems (Llamado *et al.,* 2013). Since heavy metal pollution caused by mining activities poses both environmental and human health risks, mitigation and development of decontamination measure is of utmost importance.

Microalgae have been identified as one of the most efficient environmental mitigator (Shakoori and Muneer, 2002). The performance of microalgae as pollution indicator and as phycoremediator has been studied widely using different heavy metal contamination singly or in combination. The propensity for sequestration of heavy metals by their cell wall makes them an ideal source of the complex multifunctional polymers which can be used to sequester many different metals through adsorption or ion-exchange processes (Priyadarshani *et al.,* 2011).

Microalgae have the potential practical use in remediation process over a wide range of heavy metal pollution by adsorption to cell surface or intracellular accumulation (Shakoori and Muneer, 2002). They are cheaper, natural, non-pathogenic and mining environmental mitigators that can enzymatically degrade pollutants and can detoxify, transform or volatilize heavy metals (Dominic *et al.,* 2009). Microalgae that are generally used for phycoremediation of heavy metals are *Tetraselmis* sp., *Chlorella* sp., *Scenedesmus* sp., *Padina* sp., *Synechoccystis* sp., *Gloeocapsa* sp., *Chroococcus* sp., *Anabaena* sp., *Lyngbya* sp., *Oscillatoria* sp., and *Spirulina* sp. (Dominic *et al.,* 2009 and Priyadarshani *et al.,* 2011). These algae could be phycoremediator species in mine tailings pond and can reduce environmental damage generated by the grinding and processing of ores and rocks.

This study determined the chemical properties of the water in the manmade pond as well as the soil in its immediate surroundings. Also, the study identified potential microalgae for remediation. The use of algae in the implementation of phytoremediation is an innovative and cost-effective way to mitigate heavy metal contamination. The floral composition of the area was also determined. All information that were obtained can be utilized in identifying organisms both algal and vegetal species for future remediation practices in the area.

The study was conducted to give an assessment on the microalgae and plants present in the mine tailings pond located at Bgy. Mogpog, Marinduque. It specifically aims to:

1) Generate data on the chemical properties of water and soil obtained from the selected stations at the mine tailings pond contaminated with copper;
2) Identify microalgae that are possible phytoremediating agents and;
3) To determine the floristic composition of species found along the mine tailings pond.

MATERIALS AND METHODS

Study Site

A reconnaissance survey was done last June 2017 in order to identify the sampling stations within the site. Three (3) stations were established around the man-made pond which would represent the total area of the sampling site. Geographic positioning system (GPS) was used to obtain the geographical reference site of the selected sampling sites. Figure 1, shows the geographic location of the study wherein the three stations are indicated. The collection of algal and vegetal samples were done during the raining season (August 5-6, 2017).

Figure 1. Photo showing Bgy. Mogpog, Marinduque and the relative positions of site 1, site 2, and site 3. Source: https://www.google.com.ph/maps/@13.5032833,121.8599613,780m/data=!3m1!1e3?hl=en

Chemical Parameters

Water Sample Collection

The following parameters were measured *in situ* in each station: pH, dissolved oxygen (DO), and water temperature (C^o) using a thermometer Water samples were collected by dipping a 1-L bottle with a 2 cm diameter opening from the surface. Five liters of water sample were pooled in a pail and designated as the integrated sample per station. Four 1-L polyethylene bottled were filled with water drawn from the integrated sample and kept in ice prior to subsequent laboratory analyses. Upon reaching the laboratory 500 mL of each water sample was membrane-filtered (Whatman GF/C, 1.2 μm pore size) with the help of a vacuum pump. The filter paper was stored in 90% acetone for chlorophyll analysis as described in APHA *et. al.* (1995). Water samples were brought to the BIOTECH-CASL for the determination of the copper concentration using Atomic Absorption Spectrophotometry (AAS). The chemical oxygen demand (COD) and Total suspended solids (TSS) were also determined.

Soil Sample Collection

Composite samples from the surface soil at a depth of 0-20 cm were obtained from each sampling site. pH and air temperature were recorded on site. Exchangeable copper concentration of the soil samples were done at the Soil Analytical Chemistry Laboratory, Agricultural System Cluster, College of Agriculture, University of the Philippines Los Baños (UPLB). Soil copper concentration was determined at the Central Analytical Services Laboratory of the National Institute of Molecular Biology and Biotechnology (BIOTECH), UPLB Science Park.

Biological Parameters

Algal Diversity

Plankton samples were collected by casting and towing a Wisconsin (Birge) townet with truncated cone ten times, equivalent to 9 liters of water sample, which was concentrated to a final volume of 100-150 mL. This was done thrice per sampling station. Lugol's iodine solution was added as fixative to the samples.

Algal samples were microscopically examined under a compound microscope. The genera were identified morphologically using Smith (1950), Desikachary (1959), Prescott (1962), and Tiffany and Britton (1971). Estimates of abundance of each identified microalgae were determined quantitatively using a Neubauer-type Hemocytometer, following procedure of Martinez et al. (1975). The abundance was expressed as density (units L/1). Twenty cells of filamentous algae were counted as one unit. Photomicrographs of all species found in water samples were also taken.

Riparian Vegetation

In determining the plant species found thriving along the sampling stations The Quadrat Method was used. The quadrat was 20x20 m^2 with three (3) 3x5 m2 nested subquadtrats per station. A total of 9 subquadtrats was established for the entire study area. At each station, the following data were obtained: (a) species name and (b) total cover. Voucher specimens were also collected and identified. Herbarium specimens with their corresponding accession numbers have been deposited to the Systematics Laboratory, Plant Biology Division, Institute of Biological Sciences of the University of the Philippines Los Baños. Taxonomic information regarding the plant samples were verified from references authored by Moody, Munroe, Lubigan and Paller (1984). On-line data bases were also consulted.

The dominating plant species in the area were determined by obtaining the following parameters: Relative Cover (RC), Relative Density, and Relative Frequency (RF). These parameters were then utilized to compute for the Importance Values (IV) using the formula adapted from Mueller-Dombois and Ellenberg (1974):

$$v = \frac{\text{Relative Cover} + \text{Relative Density} + \text{Relative Frequence}}{3}$$

Statistical Analysis

The quantitative data obtained from the water, soil and plant analysis were subjected to Analysis of Variance (ANOVA) and post-hoc test (Scheffe's).

RESULTS AND DISCUSSION

I. *Chemical Characteristics of the Pond*

Water chemical properties

Water samples were collected and analyzed to generate data on the chemical characteristic properties of the pond (Table 1). Site 1 had the highest mean copper (0.11 ppm), TSS (59.4 ppm), and water temperature among the sites (33.7 °C). These values can be attributed to Site 1 location being nearest to the dump of mined-out soil. The dust from the dumped loose soil was observed to be easily flown by breeze, which explains the high TSS in the water. Also, this explains why station 1 has the highest copper concentration. However, the copper concentration of the water is within the accepted level of 1.3 mg/L (or ppm) (WQA, 2013). COD is a rough estimation of the oxygen needed to oxidize

Table 1. Chemical properties of the water samples obtained from the three stations established at the man-made pond of Bgy. Mogpog, Marinduque.

Parameters	Station 1	Station 2	Station 3
Cu (ppm)	0.11	0.10	0.08
TSS (ppm)	59.4*	19.67	5.14
COD (ppm)	19.18	**	30.68
DO	4.5	4.5	4.3
pH	8.1	8.3	8.0
Temperature (°C)	33.7	32	32.3

* Significantly different at the 0.05 level

** Error in obtaining values

organic material in the water. The higher value for COD was found to be analyzed from station 3 (30.68 ppm) and the lower COD value was recorded to be from station 1 (19.18 ppm). There are more materials that can be oxidized in station 3 as compared to stations 1. In station 1 there are less materials that can be oxidized chemically.

Comparative statistical analyses of the copper concentration among the three sites revealed no significant difference (p=0.903). However, it was also observed that total suspended solids in the water is significantly higher in Site 1 than in both Site 2 (p=0.006) and Site 3 (p=0.001). Meanwhile, Site 2 and Site 3 are not significantly different with each other in terms of TSS (p=0.237).

There is minimal concern to remediate the pond water since water analysis revealed that the pond had an average copper concentration of 0.097 ppm. It could be that the copper has been chelated or has settled at the bottom of the pond.

Soil Chemical Properties

The chemical properties of the soil samples were also obtained and recorded (Table 2). Station 1 was recorded to have the highest values for exchangeable Cu, mean pH, and mean soil temperature than that of the other two (2) stations. The copper concentration in the soil of Site 1 is significantly higher than that of the measurement of samples from Sites 2 (p=0.026) and 3 (p=0.015). The TSS and copper concentrations of Sites 2 and 3 are also not significantly different (p=0.881). Theoretically, soil with high Cu value is integrated with low soil pH (acidic). However, data from this study shows high Cu value of 1234.33 ppm is incorporated with a highly basic soil pH value of 8.1. This may be due to its location which is at the edge of the mind tailing pond near vegetation. Presence of leguminous plants in the site such as *Acacia auriculiformis* which have bacteria in their root nodules capable of nitrogen fixing, can be the source of soil basicity in station 1. Soil pH directly controls the solubility of metal hydroxides, as well as metal carbonates and phosphates, and higher pH facilitates the precipitation and immobilization of metals (Yang *et. al.,* 2016). In the study of Domingo and David, (2014), legumes can significantly reduce heavy metal

Table 2. Chemical properties of the soil samples obtained from the three stations established at the man-made pond of Bgy. Mogpog, Marinduque.

Parameters	Station 1	Station 2	Station 3
Cu (ppm)	1234.33*	432.33	324.67
pH	8.1	6.9	7.8
Temperature	31.3	29.8	29.3

* Significantly different at the 0.05 level

concentrations in the mine tailings, indicating the possibility of metal hyper accumulation in the plant tissue. Although the Cu concentration in this station is high, legumes and other plants present in the site may have already adapted to the poor soil condition of the tailing site and the litters of these legumes that have accumulated in the site contribute to the alkalinity of the soil. Another study is that of Sracek *et. al.,* (2010) where two (2) sulfidic mine tailings within the Zambian Copperbelt have been studied. Results show that the neutralization capacity based on solid wastes carbonates on both sites remains high thus neutral to alkaline conditions (pH up to 8.5) pre-dominates. Oxidation of sulfides like pyrites occur in the process of generating mine drainage and in the presence of neutralization minerals like calcite, the acidity produces by the said oxidation have been neutralized. In the unsaturated zone of mine tailings with high pH condition, precipitation of ferric hydroxides occur. This event is associated with high concentration of Ca and sulfate but low concentration of Fe. Since ferric oxides and hydroxides efficiently adsorb Cu and Co, and chalcopyrite being oxidized, it initially hinders the production of acidity.

II. *Algal Diversity*

Algal composition

A total of 12 taxa from 2 classes of microalgae were identified and recorded from the site. Diatoms were the dominant group of microalgae, accounting for 70% of the overall total cell abundance (Table 3). All 10 genera of diatoms observed were pennate diatoms (Figure 2). Few diatoms remained unidentified but were dominant in Site 2. The rest were blue-green filamentous algae, *Anabaena* sp., *Leptolyngbya* sp., and two unidentified species (Figure 3 and Figure 4).

Table 3. Table 3. Taxonomic composition of microalgae at the three stations established at the man-made pond of Bgy. Mogpog, Marinduque.

Class	Species	Sampling Location		
		Site 1	Site 2	Site 3
Cyanophyceae (blue-green)	*Anabaena* sp.		✓	✓
	Leptolyngbya sp.	✓	✓	✓
Bacillariophyceae (diatoms)	*Cymbella* sp.			✓
	Fragilaria sp.	✓		✓
	Hantzschia sp.	✓	✓	✓
	Navicula sp.	✓	✓	✓
	Nitzschia sp.	✓	✓	✓
	Pinnularia sp.	✓	✓	✓
	Rhopalodia	✓	✓	✓
	Surirella sp.	✓	✓	✓
	Synedra sp.	✓		
	Terpsinöe sp.			✓
Unidentified	Unknown sp. 1	✓		
	Unknown sp. 2			✓
	Unknown sp. 3	✓	✓	✓
	Unknown sp. 4		✓	✓
	Unknown sp. 5			✓

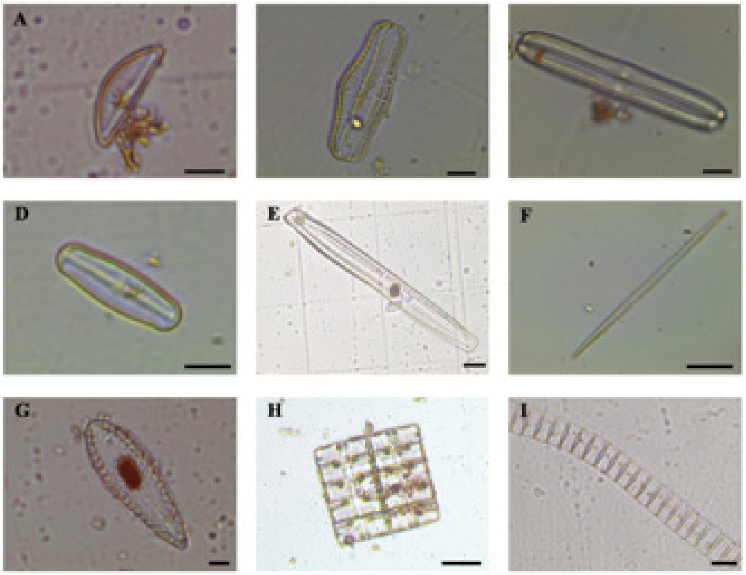

Figure 2. Microscopic photographs of Bacillariophyceae. **A:** *Cymbella* sp. (100x), **B:** *Rhopalodia* sp. (100x), **C:** *Pinnularia* sp. (400x), **D:** *Navicula* sp. (400x), **E:** *Hantzschia* sp. (100x), **F:** *Synedra* sp. (100x), **G:** *Surirella* sp. (100x), **H:** *Terpsinöe* sp. (100x), **I:** *Fragilaria* sp. (100x). Scale bar is 10 μm.

Figure 3. Microscopic photographs of Cyanophyceae. **A:** *Anabaena* sp. (100x), **B:** *Leptolyngbya* sp. (100x), **C:** unidentified filamentous algae (unid4) (100x). Scale bar is 10 μm.

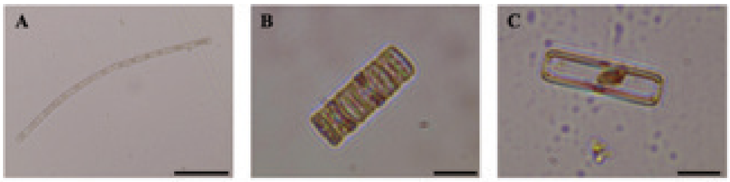

Figure 4. Microscopic photographs of unidentified microalgae. **A:** filamentous algae (unid1) (100x), **B:** centric diatom (unid2) (girdle view) (100x), **C:** pennate diatom (unid3) (girdle view) (100x). Scale bar is 10 μm.

The algal diversity of the mine tailing pond is relatively low with only 12 taxa. Seven taxa occurred in all sampling sites, while three taxa were sighted only in one site. Station 3 had the most number of algae taxa resulting to 11 identified and 4 unidentified algal taxa. This may be due to the high COD value of station 3 which was recorded to be 30.68 ppm. Dominating algal species in the area were identified to be: a) *Fragilaria* sp. (8,029 units L/1), b) *Unknown* sp. 3 (4,167 units L/1), c) *Leptolyngbya* sp. (2,746 units L/1), d) *Unknown* sp. 5 (1,667 units L/1), e) *Leptolyngbya* sp. (1,448 units L/1), f) *Terpsinöe* sp. (1,294 units L/1), and g) *Hantzschia* sp. (1,242 units L/1) (Table 4).

Aside from plants, fungi, aquatic macrophytes and other microalgae, emerging researches on phytoremediation of heavy metals in aquatic systems show the potential of diatoms in removing certain heavy metals (Bozarth *et al.,* 2009; Chekroun and Baghour, 2013; Chen *et al.,* 2014). Most of the identified species were bioindicators of organic pollution. For example, some species of *Fragilaria* and *Surirella* are less-tolerant diatoms and indicators of moderate nutrient pollution (Bellinger and Sigee, 2015. Increase in Rhopalodia gibba and blue green algae are typical in nitrogen limited areas (Vaithiyanathan and Richardson, 1997). Diatoms which were relatively abundant and sighted in three stations (*Fragilaria* sp., *Rhopalodia* sp., *Navicula* sp., *Hantzschia* sp., and *Surirella* sp) might be potentially capable of phytoremediation of copper in the area.

Table 4. Abundance of microalgae the three stations established at the man-made pond of Bgy. Mogpog, Marinduque. Abundance expressed as density (units L/1).

Class	Species	Sampling Location		
		Site 1	Site 2	Site 3
Cyanophyceae (blue-green)	*Anabaena sp.*	0	821	833
	Leptolyngbya sp.	1,448	2,746	833
Bacillariophyceae (diatoms)	*Cymbella sp.*	0	0	821
	Fragilaria sp.	833	0	8,029
	Hantzschia sp.	1,063	846	1,242
	Navicula sp.	1,117	825	909
	Nitzschia sp.	831	830	833
	Pinnularia sp.	852	846	827
	Rhopalodia sp.	1,278	846	1,074
	Surirella sp.	1,190	840	824
	Synedra sp.	852	0	0
	Terpsinöe sp.	0	0	1,294
Unidentified	Unknown sp. 1	852	0	0
	Unknown sp. 2	0	0	833
	Unknown sp. 3	833	4,167	1,103
	Unknown sp. 4	0	2,114	833
	Unknown sp. 5	0	0	1,667

III. Riparian Vegetation

Floristic Inventory

A total of 27 species belonging to 19 genera from 11 families were recorded under the division Ancerophyta. Under the division Pteridophyta, a total of 3 species belonging to 3 genera from 3 families were recorded from the sampling site. Among the angiosperm families observed, the most represented families were Poaceae (5 spp.), Compositae (4 spp.), Leguminosae (4 spp.), Convulvulaceae (4 spp.) and Cyperaceae (3 spp.) (Table 5).

Table 5. Recorded plant species found along the three stations established along the man-made pond of Bgy. Mogpog, Marinduque.

Division	Order	Taxa/Species	Accession Number
*Pteridophyta	Polypodiales	**Dennstaedtiaceae**	
		Shpenomeris chinensis (L.) Maxon	-
		Blechnaceae	
		Blechnum sp.	-
		Unknown	
		Fern sp.1	-
	Hymenophyllales	**Hymenophyllaceae**	
		Hymenophyllum sp.	-
**Ancerophyta	Poales	**Poaceae**	
		Axonopus compressus	-
		Bamboo	-
		Panicum maximum	-
		Paspalum sp.	6731
		Poaceae sp.1	-
		Cyperaceae	
		Cyperus rotundus L.	6728
		Kyllinga odorata	6727
		Fimbristylis littoralis Gaudich.	6737
		Typhaceae	
		Typha sp.	-
	Alismatales	**Araceae**	
		Syngonium podophyllum Schott.	6734
	Fabales	**Leguminosae**	
		Acacia auriculiformis Benth.	6736
		Arachis pintoi	-
		Desmodium sp.	-
		Mimosa pudica	-
	Rosales	**Moraceae**	
		Moraceae sp.1	-
	Malpighiales	**Euphorbiaceae**	
		Euphorbia hirta	-
		Macaranga tanarius	6735

Asterales	**Compositae**	
	Chromolaena odorata	-
	Emilia sp.	-
	Pseudelephantopus sp.	6733
	Synedrella nodiflora	-
Apiales	**Apiaceae**	
	Centella asiatica	6729
Solanales	**Convulvulaceae**	
	Convulvulaceae sp.1	-
	Convulvulaceae sp.2	-
	Convulvulaceae sp.3	
	Convulvulaceae sp.4	
Gentianales	**Rubiaceae**	
	Rubiaceae sp.1	-
	Unknown	
	Unknown sp.1	-

* - based on the Pteridophyte Phylogeny Group (2016); ** - based on the Angiosperm Phylogeny Group Classification for the orders and families of flowering plants: APG IV (2016)

Dominating Plant Species

These plant species can be considered as pioneers since they are capable of surviving in very harsh environments of high soil copper concentrations. Different species of grasses were found to dominate the study area. The plant species with the highest importance value was a species of Bamboo (IV=0.40), followed by *Synedrella nodiflora* (IV=0.36), *Axonopus compressus* (IV=0.36), *Mimosa pudica* (IV=0.35), and the 5th in rank is Poaceae sp. 1 (IV=0.35) (Table 6). The high importance value of Bamboo can be attributed to its high values for Relative Cover (0.398), Relative Density (0.125), and Relative Frequency (0.667) (Figure 5). Weeds and grasses were noted to be the most dominating and were well represented families at the area. These identified plant species have the potential to be used for phytoremediation due to its high Importance Values and its capability to tolerate soils with high copper concentration.

Common weeds with phytoremediation potential were recorded by Napaldet and Buot (2017) at Balili River, La Trinidad, Benguet. These plants were: *Alternanthera sessilis, Pennisetum purpureum, Eleusine indica, Cyperus distans, Amaranthus spinosus.* In a study by Nazareno and Buot (2015), different plant species from a landfill collected from Cebu were found to have potential for Cd and Cr uptake. Their results reveal that *Cyperus odoratus* has potential for Cd uptake and internal transfer; *Cenchrus echina- tus, Vernonia cinerea* and *Terminalia catappa* for Cr uptake, and *Cynodon dactylon* for Cr internal transfer.

Table 6. Importance value and rank of dominant plant species collected from Bgy. Mogpog, Marinduque.

Plant Species	Relative Cover (RC)	Relative Density (RD)	Relative Frequency (RF)	IV	Rank
Bamboo	0.398	0.125	0.667	0.40	1
Synedrella nodiflora	0.195	0.056	0.333	0.36	2
Axonopus compressus	0.195	0.056	0.333	0.36	3
Mimosa pudica	0.073	0.167	0.333	0.35	4
Poaceae sp.1	0.146	0.091	0.667	0.30	5
Syngonium podophyllum	0.122	0.056	0.333	0.29	6
Cyperus rotundus	0.006	0.056	0.667	0.28	7
Macaranga tanarius	0.056	0.091	0.667	0.27	8
Convulvulaceae sp.1	0.097	0.056	0.333	0.26	9
Typha sp.	0.266	0.125	0.333	0.24	10
Kyllinga monocephala	0.074	0.056	0.333	0.24	11
Panicum maximum	0.075	0.25	0.333	0.22	12
Paspalum sp.	0.199	0.125	0.333	0.22	13
Desmodium sp.	0.05	0.056	0.333	0.22	14
Pseudelephantopus	0.049	0.056	0.333	0.22	15
Unknown sp.1	0.049	0.056	0.333	0.22	16
Blechnum sp.	0.223	0.091	0.333	0.22	17
Hymenophyllum sp.	0.172	0.091	0.333	0.20	18
Emilia sp.	0.031	0.056	0.333	0.20	19
Arachis pintoi	0.025	0.056	0.333	0.19	20
Acacia auriculiformis	0.136	0.091	0.333	0.19	21
Fimbristylis littoralis	0.128	0.091	0.333	0.18	22
Macaranga tanarius	0.015	0.056	0.333	0.18	23
Euphorbia hirta	0.01	0.056	0.333	0.18	24
Chromolaena odorata	0.009	0.056	0.333	0.18	25
Convulvulaceae sp.2	0.091	0.091	0.333	0.17	26
Convulvulaceae sp.4	0.053	0.125	0.333	0.17	27
Centella asiatica	0.001	0.056	0.333	0.17	28
Hymenophyllum sp.	0.007	0.125	0.333	0.15	29
Fern sp.1	0.002	0.125	0.333	0.15	30
Shpenomeris chinensis (L.) Maxon	0.018	0.091	0.333	0.15	31
Moraceae sp.1	0.011	0.091	0.333	0.15	32
Convulvulaceae sp.3	0.011	0.091	0.333	0.15	33
Rubiaceae sp.1	0.007	0.091	0.333	0.14	34

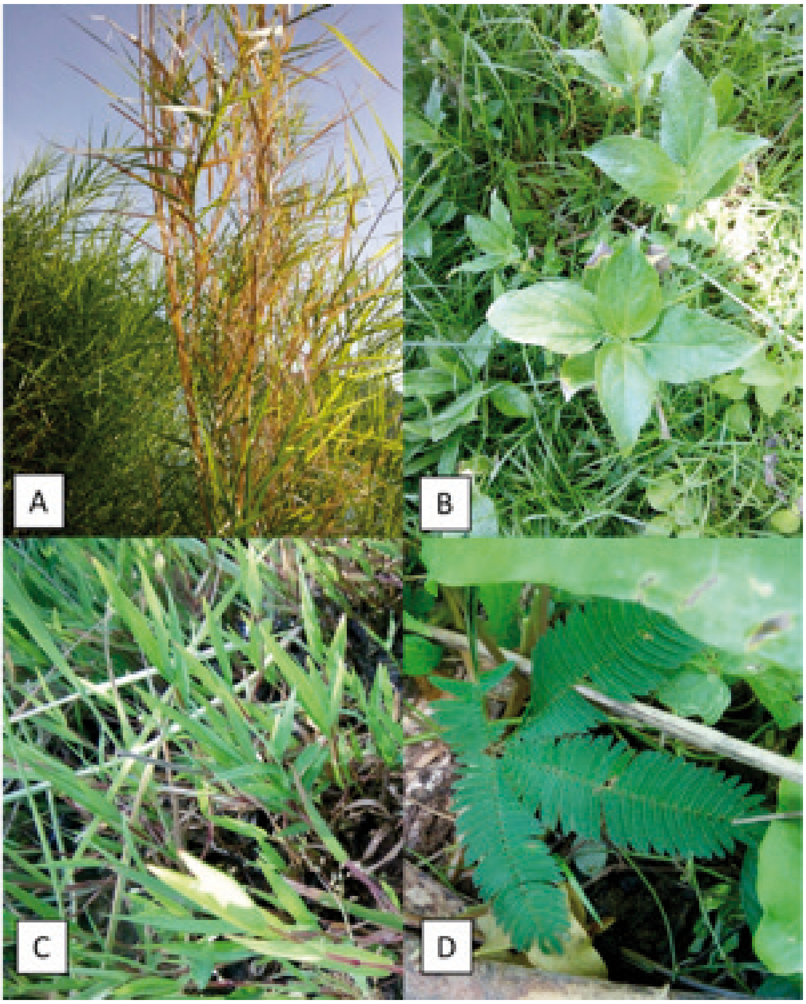

Figure 5. The dominating plant species based on IV: a) Bamboo; b) *Synedrella nodiflora;* c) *Axonopus compressus* and; d) *Mimosa pudica*.

SUMMARY AND CONCLUSION

The Ino-Capayang Mine-made lake is one of the many abandoned mine-tailing pond in the Philippines that needs rehabilitation. The twelve years of mining operation of Consolidated Mining Incorporated (CMI) from 1968 to 1980 created the current Ino-Capayang Mine-made lake, which has currently of no importance to the local communities. Examination of copper contamination in three sampling sites of the abandoned mine tailing pond of Ino-Capayang Mine-made lake revealed higher concentrations in soil than in water. Since the mining operation has been inactive for 20 years, the copper contaminants could have been chelated or settled at the bottom of the pond, hence higher concentrations were found in soil. The pH concentrations were also relatively acidic in soil than in water. Among the three sites, Station 1 had highest copper concentrations and TSS and Station 3 had the least.

Preliminary assessment of microalgal and plant diversity in the Ino-Capayang Mine-made lake revealed potential phytoremediator species, as indicated by their importance values and dominance. For microalgal species in the pond water, a total of 12 identified taxa were recorded, most of which were dominated by diatoms. Diatoms species which were frequent and abundant in the area include *Fragilaria* sp., *Rhopalodia* sp., *Navicula* sp., *Hantzschia* sp., and *Surirella* sp. which can be potential phytoremediators of copper in water. While some of species are indicators of organic and nutrient pollution, there is still low diversity of microalgae in the pond, which may be due to copper concentrations and high TSS in the water.

The riparian vegetation was composed of 19 genera from Division Ancerophyta and 3 genera from Division Pteridophyta. Among the angiosperm families observed, the most represented families were Poaceae (5 spp.), Compositae (4 spp.), Leguminosae (4 spp.), Convulvulaceae (4 spp.) and Cyperaceae (3 spp.). Identified plant species in the area have the potential to become phytoremediation agents. Among the identified grass species that are capable of dominating the site are: Bamboo (IV=0.40), followed by *Synedrella nodiflora* (IV=0.36), *Axonopus compressus* (IV=0.36), *Mimosa pudica* (IV=0.35), and the 5th in rank is Poaceae sp. 1. These identified plant species have the potential to be used for phytoremediation due to its high Importance Values and its capability to tolerate soils with high copper concentration.

Recommendation

The study revealed an assessment of the potential phytoremediator plant and microalgal species of the Ino-Capayang Mine-made. To further validate the efficiency of the species for phytoremediation, experimental studies on the dominant plant species are recommended to determine its phytoremediation strategy. Determining the total root and shoot copper concentration of the top dominating plant species in the selected sites is also recommended. Further chemical analysis in soil such as Soil Organic Matter content determination is also recommended.

Acknowledgement

The authors would like to thank the Office of the Vice Chancellor for Research and Extension (OVCRE) UPLB Basic Research Fund 2017 for providing financial support for the research. Also, to the local government unit (LGU) of Bgy. Mogpog, Marinduque for allowing and accompanying the researchers to the study site.

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