Mitigating heavy metal contamination in natural springs through traditional ecological knowledge on plants: pathways toward sustainable mining practices and resource management

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Abstract. The local communities, particularly belonging to mineral-rich areas such as Marinduque, face challenges from heavy metal contamination. This study documents the traditional knowledge of the community in the utilization of plants for managing natural spring. Data were collected from ten key informants through interviews and guided walks. For comparative water analysis, samples were collected from the natural springs with and without the identified vegetation. The water samples were subjected to AAS analysis for Cu^{+2}, Zn^{+2}, and Pb^{+2}. Eleven of the identified herbs were grown in a medium with known concentrations of Cu^{+2}, $Pb^{+,2}$ and Zn^{+2} in the laboratory for one week and analysed for accumulated heavy metals. The study identified 56 plant species, represented by 33 families. Species *Dracontomelon, Dillenia, Nauclea* and *Duabanga,* together with the *Ficus,* are most preferred by the old folks in cleaning natural springs. The water samples from vegetated springs showed permissible to negligible amounts of heavy metals as compared to those with no plants. The ferns showed high potentials in accumulating heavy metals. These findings show the value of traditional knowledge in the mitigation process and its relevance in the sustainable resource management in mining-affected landscapes.

1 Introduction

Water is one of the basic needs of life. It covers almost the surface of the Earth, but only 3% of it is freshwater, and less than 1% is readily accessible for human use [1]. It is now becoming precious because, as the Earth's population is increasing, less than 0.007% of all the water on Earth is available to drink [1]. Today's growing population, pollution, and industrialization limit the availability of freshwater to humankind.

In the Philippines, the country depends on its freshwater supply from rainfall, surface water resources, and groundwater resources for domestic use and drinking supply [2].

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These three sources are interconnected to each other, because as the rainwater seeps into the ground, some is stored in the permeable layers underground that form the aquifers, and some is absorbed by the trees and vegetation, which in the end are discharged into the rivers and natural springs as a freshwater supply.

The surface springs that are welling out from natural springs of the aquifers and the forest vegetation are the viable freshwater resources that form the headwaters of brooks, creeks, rivers, and lakes [3]. But through this natural process of recharging, storing, and discharging water from rain to aquifers, vegetation, natural springs, creeks, rivers, and lakes, chemistry modifies the chemical and biological composition of the freshwater. Rocks, sediments, vegetation, population, and industrialization influence the chemical and biological contents of the freshwater [4]. Thus, for heavily mineralized areas, the presence of heavy metals in the freshwater supply is a problem, especially in areas where mining has occurred and is continuously operating.

Most of the Philippine islands are parts of the island arc areas and the Philippine mobile belt areas, which are considered mineral-rich areas [5, 6, 7, 8]. The island province of Marinduque is one of these geologically mineral-rich islands with copper, silver, gold, and iron in association with other heavy metals, such as lead, manganese, and zinc [9]. Therefore, it is presumed that the freshwater supply of some of the households in these areas has been affected by minerals ever since the mining operations in the province.
In a province where 55% of the population is dependent on deep and shallow wells and natural springs for their water supply [10], especially those in the far-flung areas, the population is considered at risk.

But in the initial study made, regarding the old folks' traditional knowledge of protecting the environment, a number of them mentioned the use of plants in improving the quality of the water that they are fetching in the natural springs and wells for domestic water supply [11]. Thus, it is presumed that these plants are used by the old folks in protecting and preserving their water supply from heavy metal contamination. Central to this is the life experiences and daily encounters of the old folks with nature [12], like the protection of water resources that is transferred from generation to generation and now forms the traditional or indigenous ecological knowledge of the community. It is considered an alternative way of improving the lives of the rural poor, while simultaneously offering insight to the broader global community in fostering traditional ecological knowledge [13]. As Escobar said, "the remaking of development must start by examining local constructions, to the extent that they are the life and history of the people, that is, the conditions for and of change" [14, p. 98].

As such, this study tapped the traditional knowledge of the old folks in the use of natural plants in managing the water supply. The study specifically aims to identify and classify the plants thriving around the natural springs, compare the amount of heavy metals present in water samples from vegetated and non-vegetated natural springs and measure the amount of heavy metals sequestered by the most abundant plants.

2 Methodologies

2.1 Study area

Interviews with the local old folks, guided walk for plant identification, and grab-sampling of spring water were conducted in Barangay Bayute, Boac, Marinduque. The barangay lies in the interior part of the province of Marinduque, where the headwaters of the Boac River originate. Geologically, the area belongs to the Boac River Iron-belt, characterized by metamorphic rocks with minor intrusions of igneous rocks.

2.2 Research design

This study is a combination of exploratory qualitative research and experimental quantitative research. The traditional knowledge of the five participants, aged 70 to 84, was gathered through focus group discussions in one of the participants' houses in Bayute, Boac, Marinduque.

The experimental design was done using eight of the identified plant species, such as the ferns *Pteris vittata, Pityrogramma calomelanos, and Dicranopteris linearis; the herbs Desmodium heterophyllum, Amaranthus viridis, and Scoparia dulcis; and grasses Cyperus diffusus and Scirpus grossus.* Their young seedlings were acclimatized and grown in the laboratory using soil samples from Marcopper minesite with pre-determined heavy metals of 453.2 ppm Cu+2, 11 ppm Pb+,2 and 238.5 ppm Zn+2). Another group of the same plants was grown in plain garden soil with detectable to permissible amounts of heavy metals, such as 2.47 ppm Cu+2, 0.09 ppm Pb+2, and 1.01 ppm Zn+2.

They were grown in 16 plastic pots with the same amount of soil (300 g each) and placed in a shallow plastic basin. Each pot was filled with 150 mL of distilled water and then planted with three similar plant species as replicates. The whole pot with the plants was covered with a transparent plastic bag to avoid transpiration and to acclimate the plants for two weeks.

2.3 Sampling procedure

Grab samples of water were taken at the same station for analyses of heavy metal contents from two adjacent natural springs, one of which was vegetated with identified plants as protected by the community people themselves, and the other was almost barren of vegetation. The two springs are 82.4 meters apart. Samples of water were also gathered from the nearby Bayute Creek, which flows from a nearby forest, and water from a deep well.

The samples were acidified with concentrated HNO3 and stored in cleaned polyethylene bottles packed in an icebox at a temperature of 4°C or lower. Trace metal analysis of the samples was performed using AES-ICP Inductively Coupled Plasma Spectrometry at Intertek Testing Services in Manila, Philippines.

The laboratory-grown plants (with three replications each, their aerial parts and the roots) were harvested after two weeks, cleaned with distilled water, dried, and ashed prior to analysis for the heavy metals content using the same spectrometric method at Intertek Testing Services.

2.4 Data collection and analysis

The plant samples collected during the guided walk with the old folk were tabulated and identified taxonomically with the assistance of the College botanist and forester. The plant descriptions were also counterchecked using the works of different authors.

The spectrometric results of the water samples for Cu+2, Pb+2, and Zn+2 was compared using analysis of variance (ANOVA) and Duncan Multiple Range Test (DMRT) at 5% level of significance. Likewise, the spectrometric results of the harvested plants were tabulated and analyzed using ANOVA at 5% level of significance. These were done to find out the differences in the heavy metal contents of the water samples and the plant samples.

3 Results and discussion

3.1 Traditional use of plants in protecting natural springs

The guided walk conducted with the participants in Barangay Bayute revealed 56 plant species that are used by the community people in protecting the quality of their water supply from natural springs.

They said that these plants, when around the natural springs, make the water clear, 'sweet' in taste, and free from contaminants, like heavy metals, thus potable for drinking purposes. They learned from their forebears that these should not be cut or weeded out, especially the trees and the shrubs, because the spring will be dried up, and if not, will not be suitable for drinking purposes.

Based on importance, the trees Dracontomelon, Dillenia, Nauclea, Duabanga, and the Ficus species preserve the continuous supply of the springs even during the long dry season, because they pump the water underground. They said that the waters emerging from the roots of Homonoia and Petersianthus have curative effects against liver and blood diseases. The rest of the trees and the shrubs are giving that almost 'cold' and 'sweet' effect to the water. The zingibers are thought to be helpful in driving away the small animals, pests, and insects that breed within and around the natural springs, and they also filter off the dirt and microorganisms released by the decomposing leaves of other vegetation near and around the springs. The ferns and the grasses are believed to be water purifiers. They filter and absorb the minerals released by the rocks that are believed to be detrimental to health.

3.2 Taxonomical identification and classification of the plants

The study revealed 56 plant species, represented by 33 botanical families; 21 species are trees and shrubs, 21 are herbs, 12 are ferns, and two are grasses. Most are Moraceae (7), Euphorbiaceae (4), Araceae, Hypoxidaceae, Thelypteridaceae, Urticaceae, and Zingiberaceae (3 species each), Cyperaceae, Marantaceae, and Pteridaceae (2 species each). The rest of the families are represented singly with species. This shows that the plants used by people are not confined to one family or a few species alone but are considered diverse. The old folks said that the more diverse and thicker the vegetation surrounding the natural springs, the better the quality of the water for drinking purposes.

3.3 Concentration of metallic ions in the natural springs, creek, and deep well

The amounts of heavy metals present in a natural spring vegetated with the studied plants range from undetectable (0 ppm Pb^{+2}) to permissible (0.01 ppm Cu^{+2} to 0.03 ppm Zn^{+2}. This can be attributed to the heavy metal sequestering properties of the said plants.

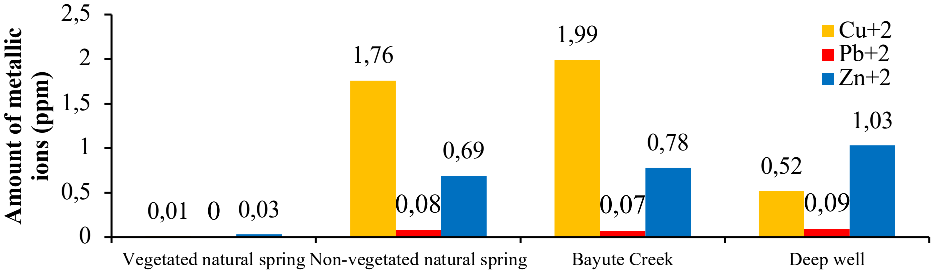

Fig. 1. Comparison of heavy metals present in the water samples from different sources in the area.

The sample from Bayute Creek showed the highest amount of Cu^{+2} (2.43 ppm), which is much closer to the reading obtained from a non-vegetable spring (2.01 ppm). This can be due to the rock samples that are scattered in the area from where the water is flowing.

In terms of Zn^{+2} content, the highest readings are obtained from the deep well (1.03 ppm), followed by Bayute Creek and the non-vegetated spring (0.78 and 0.69 ppm, respectively).

Statistically, the amounts of Cu^{+2} present in Bayute Creek, and the non-vegetated spring are not significantly different from one another at 5% level of significance, meaning that they have almost the same levels of copper ions present. This is also true in the amounts of Zn^{+2} ions present in the deep well, Bayute Creek, and non-vegetated samples. The amount of Pb^{+2} ions in the three samples is also statistically not different from one another.

In terms of the metallic ions present in the samples, the water from vegetated natural spring passed the national standard for drinking water—that is, 1.0 ppm Cu^{+2}, 5.0 ppm $Zn^{+,2}$, and 0.01 ppm Pb^{+2}. The Pb^{+2} present in the samples from the deep well, non-vegetated spring, and the creek are above the maximum limit of 0.01 ppm, same as the case of Cu^{+2} present in the non-vegetated spring and the creek. The Zn^{+2} content of the water from the four samples is all within the national standard.

With the above results, it is presumed that the identified plants that have been traditionally used by the immediate community improve the quality of the drinking water that they use in their homes.

3.4 Amounts of Heavy Metals Sequestered by the Test Plants

3.4.1 Copper ion (Cu^{+2})

In Fig. 2, among the eight tested plants in the laboratory, the fern *P. vittata* shows the highest amount of sequestered Cu^{+2} (14.23 ppm), followed by *A. viridis* (12.5 ppm), D. *heterophyllum* (11.14 ppm), *P. calomalones* (10.12 ppm), and *S. dulcis* (9.06 ppm). These are considered copper hyperaccumulating plants because they can sequester large amounts of the metallic ions in a few days (14 days).

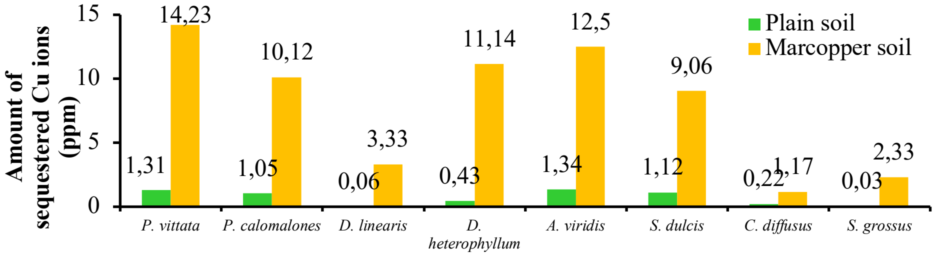

Fig. 2. Amount of sequestered Cu^{+2} by the plants in the soil samples.

The species that show moderate amounts of sequestered Cu^{+2} are *G. linearis* (3.33 ppm), S. grossus (2.33 ppm), and C. diffusus (1.17 ppm). Likewise, the plants also worked in few amounts of Cu^{+2} present in the plain garden soil. It was found out that the plants perform better in sequestering the metallic ions in plain garden soil with appreciable amounts of Cu+2 as compared to the metal-contaminated soil of Marcopper soil. A viridis accumulated 54.25% in plain soil, followed by *P. vittata* (53.036%) and *S. dulcis* (45.344%), and *P. calomalones* (42.51%) as compared to 2.758% by *A. viridis*, 3.139% by *P. vittata* and 2.458% by D*, heterophyllum* in Marcopper soil. This may be due to the difficulties of the plants to adjust to a soil with higher amounts of Cu^{+2}, like the Marcopper soil.

Statistically, there is no significant difference in the ability of the plants to sequester Cu^{+2} in the two soil samples, despite the significant differences between the Cu^{+2} contents of the soil samples. This means all the plant samples can sequester the Cu^{+2} present in the soil and therefore can prevent the contamination of the water from the natural springs.

3.4.2 Lead ion (Pb^{+2})

In Fig. 3, *D. heterophyllum*, a common herb, showed the highest amount of sequestered Pb^{+2} (5.47 ppm), followed by *A. viridis* (3.78 ppm), *S. dulcis* (1.98 ppm), and *P. vittata* (0.92 ppm).

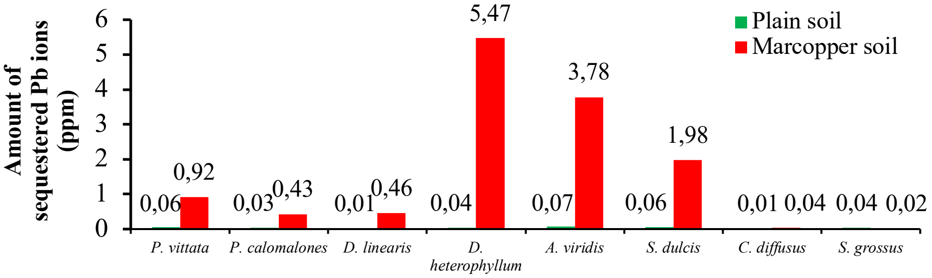

Fig. 3. Amount of sequestered Pb^{+2} by the plants in the soil samples.

Minimal amounts of Pb^{+2} is sequestered by the plants in the plain garden soil, as it is related to the small amounts of the said ion present in the soil. But in terms of percentage in sequestering the ions, the plants perform better in the plain garden soil (e.g. 77.778% by *A. viridis*, 66.667% by both *P. vittata* and *S. dulcis*) as compared to performance in Marcopper soil (e.g. 49.727% by D. *heterophyllum*, 34.364% by *A. viridis*, and 18.000% by *S. dulcis*).

Adjustment of the plants in highly mineralized soil is still considered a factor, but statistically, it can be noted that there are no significant differences in the performance of the plants in sequestering Pb^{+2}, despite the significant differences in the amount of Pb^{+2} present in the two soil samples.

3.4.3 Zinc ion (Zn^{+2})

In terms of sequestered Zn^{+2}, *A. viridis* accumulated 10.19 ppm, followed by *D. heterophyllum* (7.21 ppm), *S. dulcis* (5.14 ppm), and *P. calomalones* (4.03 ppm).

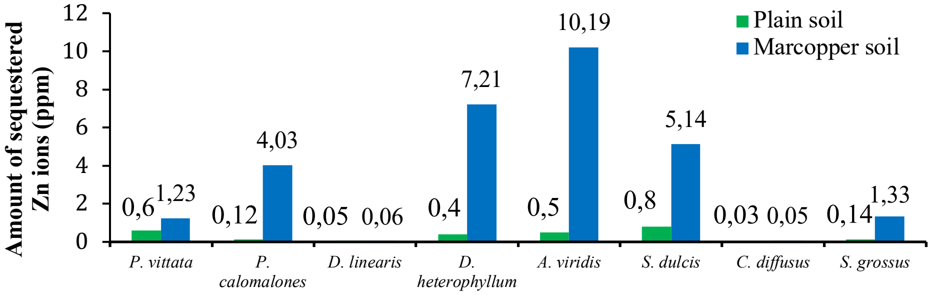

Fig. 4. Amount of sequestered Zn^{+2} by the plants in the soil samples.

Their ability to accumulate the ion in plain garden soil is higher than that in Marcopper soil; it is also true with these plants' performance in sequestering Cu^{+2} and Pb^{+2} in the plain garden soil. There are no significant differences in the plant samples tested in sequestering the ion, despite the significant differences in the concentration of Zn^{+2} in the two soil samples. This explains that the plants can sequester Zn^{+2} in both soil samples, although the sequestering activity is faster in plain garden soil.

4 Conclusion and recommendations

Traditional knowledge is really tied to nature. As our forebears learned how nature purifies itself and passed this knowledge to us, the more we learn and understand nature, life, and development like the natural springs that emanate from the forests and aquifers, which served as a source of drinking water to our forebears long before water treatment and purification were discovered.

It is concluded, therefore, that the claims of the old folks are valid that the studied plants not only help protect the environment and the water table of the land, but also help in sequestering the heavy metals that are carried by the water from rocks to rocks in surface waters and in the aquifers of underground waters. They improve the quality of the water by giving an "icy cold-sweet effect" aftertaste and presume that the active chemicals present in the plants have also curative value for several diseases.

Therefore, it is recommended that protecting these plants and their natural vegetation around water streams, such as in headwaters and springs, is crucial for maintaining the quality of water in creeks, brooks, and rivers for human, animal, and plant use.

Further, it is recommended that similar studies be conducted in other areas to identify more plant species that have those "water purifying effects", like sequestering heavy metals and other chemicals that are contaminating them—this is more environmentally friendly and a sustainable process.

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