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Environmental Biomonitoring of Terrestrial Ecosystems in the Philippines: A Critical Assessment and Evaluation

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ABSTRACT

Environmental, biological monitoring becomes an important approach to assess the extent of environmental pollution in the current status of the ecosystem's quality. Hence, this review paper aims to identify the most suitable biomarkers for environmental biomonitoring and determine the different bioremediation approaches. This different bioremediation approaches in the terrestrial ecosystem across Luzon, Visayas, and Mindanao need to be developed and promulgated. As found in the review, heavy metals like mercury, lead, chromium, cadmium, copper, zinc, magnesium, potassium, iron, manganese, and nickel are among the reported pollutants in terrestrial ecosystems including agricultural pesticides that contribute to soil pollution. Through pollutants assessment in the terrestrial ecosystem, bioindicators to human hair, lichens, and biomarker in chromosomal damage indicate genotoxicity at the chromosomal level. This apparent occurrence in environmental pollutants is associated with the degradation of environmental quality affecting biological species in the terrestrial ecosystem that requires remediation approaches to restore the air and soil quality. These phytoremediation approaches have shown evidence in the studies conducted in the Philippines' mine tailings to identify potential tropical are phytoremediators for phytoremediation. Furthermore, immobilization techniques, soil washing, and phytostabilization approach are applicable in the country. Finally, the available literature on environmental biomonitoring of the

terrestrial ecosystems in the Philippines, which focused more on biomonitoring studies and bioassessments, is still a pressing need.

KEYWORDS

Environmental biomonitoring; terrestrial ecosystems, heavy metals; bioaccumulation; biomarkers; remediation approaches, critical assessment, Philippines

INTRODUCTION

The Philippines, environmentally diverse natural resources are considered as one of the major exporters of metallic minerals. Yet recently, it is a dumpsite of foreign garbage (Mogato, 2019) because of damaging environmental activities like mining, garbage site dumping, and landfilling. All of these have contributed to the accumulations of heavy metals in soils that are fatal, dangerous, and toxic to humans, animals, and even plants.

One prevalent environmental activity in the country is mining that serves as sources of income or livelihood to numerous local people in their communities from the 1980's up to present (Cortes-Maramba et al., 2017) in Luzon and Mindanao provinces, but seldom in the Visayas where most of the small and large scales mining of gold and nickel are located. According to the Mines and Geosciences Bureau (2016), around 40 metallics and 62 non-metallic mines in the Philippines face controversial environmental issues and concerns for the past few years.

In Luzon (Mountain Province and Palawan) and Mindanao (Davao Provinces, Caraga, and SOCSRARGEN) have practiced large scale mining operations using innovative advanced mining types of machinery in the extraction and exploitation of metallic mineral deposits. In contrast, the ordinary and small scale mining has employed traditional and rudimentary mining techniques that are often environmentally hazardous among people and other terrestrial living organisms in the soil (Hinton et al., 2018). In this existing scenario, the extraction method of mercury (Hg) is relatively easy to do it but, it is potentially hazardous that can cause extreme environmental contamination due to incorrect handling of environmental waste management issues on heavy metals (Israel & Asirot, 2015; Odumo et al., 2014). As mentioned, mercury (Hg) is considered as the most toxic chemicals indeed found in the contaminated environment biota even at very low and little concentrations (Göthberg & Greger, 2016) and its harmful effects on the soil (Harris-Hellal et al., 2009; Müller et al., 2010). In humans, for example, mercury (Hg) could induce harmful and fatal effects on the immune system, reproduction, internal organs, and central nervous system (Dietz et al., 2018).

Furthermore, substandard mining activities are aggravated by the absence of proper ecological bio-monitoring in the affected areas that can lead to cautious and accidental waste disposal (van Straaten, 2017). Despite its economic impact, this remains an extremely controversial issue and concern due to its occurrences on environmental deterioration and degradation amongst organisms exposed to it (Cortes-Maramba et al., 2006). The increase of heavy metals on the soil in the terrestrial environment (Getaneh & Alemayehu, 2016) is certainly deposited in the rocky soil that could release in the terrestrial environment either by artificial activities of people or by natural weathering in nature.

This scenario could give organisms an environmental threat due to their increased potential to bio-accumulate and interfere with numerous biological, environmental processes (Heikens et al., 2015). So, when the soil is exposed to chemicals with heavy metals, there is a tendency for this to be stored and accumulated within the living organs of organisms. These contaminants are inevitable and raise major concern to all. In due time, it will bio-accumulate within humans, mammals, and plants that can eventually compromise the organisms. Although small amounts may give positive effects, excess volumes may cause heavy metal toxicity that will lead living organisms to various problems. For this reason, many recent studies revealed elevated content of mercury (Hg) levels in living organisms (Cortes-Maramba et al., 2017), and the harmful effects of mercury (Hg) on terrestrial organisms in the country is still insufficient and lacking.

As contamination of heavy metals continues, dumpsites and landfills are another major problem for environmental concerns due to its toxins released to the soil. For instance, highly urbanized cities like Metro Manila in Luzon, Cebu in the Visayas, and Davao in Mindanao has a big bulk of wastes thrown in landfills that consist of dangerous metal-containing household wastes, factory / industrial, and hospital/laboratory (solid and liquid) wastes. Based on health reports, heavy metals usually the content of combustible solid waste materials have shown that cadmium (Cd) and chromium (Cr) are present in dumpsite and landfill wastes (Riber et al., 2015). For instance, cadmium (Cd) enters the environment biota through some activities like improper disposal of solid waste in the surroundings, where heavy metal is toxic and has long and short biological effects on living organisms (Sankaran & Ebbs 2017). For chromium (Cr), that is an essential element in trace amounts from the soil (Prasad & de Oliveira Freitas, 2016). Still, the hexavalent form of chromium (Cr) is relatively toxic and poisonous (Shanker et al., 2017). With this, the composition of solid waste materials deposition on the living cell is found 30% of the total volume of heavy metals including cadmium (Cd) and chromium (Cr) in wastes from the dumpsite and landfill are in an available reactive form (Flyhammar et al., 2017).

Presently, the extent of the biomarker in the terrestrial ecosystem responses in the sensitivity of organisms is an initial cautionary alteration in organisms to evaluate and monitor bio-environmental integrity and assess changes in the terrestrial environment of organisms (Pascoe; Blanchet; Linder, 2018). With this, the use and procedure of the biomarker approach in the lab experiments of contaminated terrestrial environments have increased for many years, particularly in the Philippines, where the terrestrial environments are massively engaged in environmental activities like in Metro Manila, Cebu City, and Davao City. This triggers the fact that biomarkers are a very important tool for environmental bio-monitoring chemical exposure detection in living organisms. Its effect assessment is useful decision-making of environmental management service activities and protection to the ecosystem and protection of habitat implementation on remediation procedures in the Philippines. The possibility of heavy metal contamination of cadmium (Cd), chromium (Cr), mercury (Hg), Lead (Pb), and zinc (Zn) in the mining areas, dumpsites, and landfills (Carmona, Cavite, Philippines) are expected but undetermined.

As such, soil degradation in the environment poses severe environmental problems that need to be resolved and determined. As an effect, heavy metals such as lead (Pb) tend to persist in the upper layers of soil and metabolized or absorbed in tissues. Thus, the high magnetization of heavy metals for certain organic materials and its excessive amount may cause serious and severe organ problems. So, the heavy metals could be of great concern to organisms because they can react with chemicals which are essential for biological processes and lab activity (Agrahari, Richa, Swati, Rai, & Singh, 2016). For instance, the plants absorb the heavy metal (Pb) through their roots. The heavy metals tend to concentrate mainly on leaves and in the outer part of the plant roots. So, when organisms, including humans, eat the contaminated plants, a fraction of lead (Pb) is entering inside the body organs like liver, kidney, and bones. Thus, the lead (Pb) contamination in living organisms affects a wide range of sub-lethal effects, and a higher-level could cause biological defects and death (Pain, 2016). More so, it is time for the health professionals and government agencies of the country to increase concern for assessing and evaluating the protection and identifying consequences of the contamination intake by the living organisms (Mupo et al., 2015).

In this scenario, terrestrial biological organisms will be beneficial in detecting heavy metals because of their great interest in exploring the organisms inhabiting sensitive organs where these heavy metals are deposited into the body (Lotfy et al., 2013).

OBJECTIVES OF THE STUDY

This study aims to identify the most suitable biomarkers for environmental biomonitoring and to determine the different approaches for bioremediation in the terrestrial ecosystem across Luzon, Visayas, and Mindanao that needs to be developed and promulgated.

METHODOLOGY

Research articles with qualitative and quantitative designs were generated from the website engines, specifically in Google Scholar, written from 2010 to 2019. These years gapped were chosen because few and updated studies of terrestrial biomonitoring were published as well as conducted in the Luzon, Visayas, and Mindanao. The searching studies pool was using different keywords such as meta-analysis, research synthesis, literature synthesis, biomonitoring, genotoxicity, and chromosomal damage. The citations from the studies published were identified if any potential meta-analysis is used and synthesize. With this, multiple research articles were analyzed and synthesized.

Mainly, here are the inclusion criteria established in this analysis: (a) heavy metals like mercury, lead, chromium, cadmium, copper, zinc, magnesium, potassium, iron, manganese and nickel as reported pollutants in terrestrial ecosystems, (b) agricultural pesticides that contribute to soil pollution, and (c) phytoremediation approaches as conducted in the mine tailings of the Philippines to identify potential tropical phytoremediators for phytoremediation.

RESULTS AND DISCUSSION

Types and Sources of Pollutants

Pollutants in the terrestrial environment are found to be heavy metals that occur in the soil and in the plant body, airborne heavy metals, and pesticides that come from various sources. Different kinds of these pollutants are present in the three islands of the Philippines. Studies revealed that pollutants in the terrestrial ecosystem are common to the three islands are chromium (Cr) and cadmium (Cd). Other pollutants such as copper (Cu), zinc (Zn), lead (Pb), and mercury (Hg) are present both in Luzon and Mindanao islands whereas; magnesium (Mg), potassium (K), iron (Fe), manganese (Mn), and nickel (Ni) are only present in Luzon island.

In Luzon, studies on environmental biomonitoring in the terrestrial ecosystem (Ragragio et al., 2010; Juson et al., 2016; Navarrete et al., 2017; Solidum, 2014; Cortez & Ching, 2014; Pfeiffer et al., 1990; & Ona et al., 2006) revealed that the most prominent heavy metals which are found in the soil and vegetation of Luzon are lead (Pb), copper (Cu), and zinc (Zn). Other metals include cadmium (Cd), chromium (Cr), nickel (Ni), and mercury (Hg). These pollutants come from various sources such as mining activities, industrial plants, vehicular emissions, small factories, anthropogenic activities, land-use change, urban wastes, and e-waste such as computers, batteries, appliances, and other related waste products.

Other pollutants are airborne heavy metals from e-wastes such as cadmium (Cd), copper (Cu), chromium (Cr), lead (Pb), and nickel (Ni), and essential minerals like zinc (Zn), magnesium (Mg), potassium (K), iron (Fe), and manganese (Mn) are found in landfills in Metro Manila (Alam et al., 2017). The same heavy metals enumerated above, for instance, cadmium (Cd), nickel (Ni), and lead (Pb), are also found in the nickel mining site in Mindoro Island (Eufemio et al., 2016).

Aside from heavy metals, pesticides are also reported as pollutants in the terrestrial ecosystem. The three major types of pesticides commonly used by farmers in Benguet province according to chemical composition are pyrethroids, organophosphates, and carbamates (Lu, 2009; Lu, 2010). The pyrethroids used include cypermethrin, cyfluthrin, deltamethrin, cyphenothrin, fenvalerate, and fluvalinate. Organophosphates such as malathion, parathion, diazinon, fenthion, dichlorvos, chlorpyrifos, and ethion were also used as well as dithane a carbamate.

Also, both soils and crops have pesticidal residues. The most common pesticide residue in crops is chlorpyrifos while in soils are endosulfan sulfate, profenofos, chlorothalonil, T endo-sulfan, chlorpyrifos, cypermerthrin, and cyhalothrin (Lu, 2010).

In the Visayas, the plants in the landfills of Cebu City are found to have cadmium (Cd) and chromium (Cr) heavy metals (Nazareno et al., 2015).

In Mindanao, heavy metals include mercury (Hg), cadmium (Cd), copper (Cu), zinc (Zn), and lead (Pb). These heavy metals come from gold mining

(Appleton et al. 2006; Martinez et al. 2018; Maramba et 0al., 2006). Airborne heavy metals such as mercury (Hg) and methylmercury are also found in gold processing and refining plants (Akagi et al., 2000).

Biomarkers and Classification

WHO (1993) defines a biomarker as almost any measurement reflecting an interaction between a biological system and a potential hazard, which may be chemical, physical, or biological. The measured response may be functional and physiological, biochemical at the cellular level, or molecular interaction.

Biomarkers are classified into three categories: (1) biomarker of exposure indicates the presence of previous exposure to the substance (2) biomarker of effect suggests the presence and magnitude of a biological response to exposure (3) and biomarker of susceptibility indicates an elevated sensitivity to the impact of a chemical (Gupta, 2014).

In Luzon, most of the biomarkers used are classified as biomarkers of exposure. Specifically, human scalp hair samples are used (Alam et al., 2018 & Macawile et al., 2013) to assess human beings' exposure to heavy metals. Alam et al. (2018) investigations reveal that there is a higher concentration of copper and lead in the hair samples of those who are engaged in e-waste recycling activities than the control group. As reported, there is an increased concentration of lead in children studying in public schools than in private schools (Macawile et al., 2013). Plants can also be used as a biomarker of exposure. The roots, leaves, and grains of Zea mays (corn) were used to measure the presence of heavy metals (Cd, Cu, Pb, and Zn) in dumpsite soil in Manila (Cortez et al., 2014). A. sessilis and E. indica, common plants in Park and Wildlife Areas in Quezon City) were used to assess the presence of Chromium in landfill areas (Navarette et al., 2017).

In the Visayas, biomarkers of exposure and biomarker of effect utilizing plants were investigated (Nazareno et al., 2015). These include Cyperus odoratus, Cenchrus echinatus, Vernonia cineraea, Terminalia catappa, and Cynodon dactyl. Results revealed that these plants vary in their behavior towards the presence of Cr and Cd. C. odoratus displays the possibility for uptake and internal transfer of Cd; C. dactylon for internal transfer of Cr; and T. cattapa for the uptake of Cr.

In Mindanao, the study of a biomarker of effect, particularly genotoxicity using micronucleus test was done by Recoleto et al. (2017). The micronucleus test is a famous cytogenetic procedure frequently utilized to evaluate the genotoxic effect instigated by ecological stressors. The existence of micronuclei indicates chromatin rupture created by clastogens or spindle impairment, brought about by toxic compounds (Heddle et al., 1983; Carrano & Natarajan, 1988). Micronuclei emerge when cells are not able to integrate whole or fragment chromosomes in the daughter nuclei during cell division. Instead, these are combined in small supplementary nuclei, where they persist throughout the cell (Viarengo et al., 2007). In the study conducted in Northern Mindanao, a buccal micronucleus test was used to inspect the damage in the genetic material caused by exhaust exposure from vehicles. Female street sellers exposed to the exhaust from vehicles have a notably higher incidence of micronucleated cells than females, which are minimally or not exposed (Recoleto et al., 2017). There is no parallel study found in Luzon and Visayas settings that focus on using the micronucleus test to examine exposure to vehicular exhaust.

Organisms Used for Terrestrial Environmental Monitoring

Studies reveal that humans, plants, and lichens can be used to assess the presence of pollutants in Philippine's terrestrial environment.

Humans

Humans have the possibility of being exposed to lead (Pb) environmentally and occupationally. This may happen if the particles of lead produced from burning resources that contain lead are inhaled during the shedding of leaded paint, smelting, recycling and consuming leaded gasoline and aviation fuel. Likewise, exposure may also occur through the ingestion of dust, water, and food contaminated with lead. Additional sources of lead contaminants from loosely regulated medicines and cosmetics (World Health Organization, 2018). Biomonitoring of humans' exposure to heavy metals such as Pb is an important health care concern since it has detrimental effects, especially to children.

One of the biological specimens that can be collected easily and inexpensively is the hair. Lead can be expelled through the hair. Because of this, many recommended it to become a way of analyzing Pb exposure, especially in developing countries where high-end laboratory facilities and materials are limited (Schumacher et al., 1991). Though, there is an extensive call for the review of the use of hair analysis in human biomonitoring because of some scientific matters that need to be addressed before it becomes an effective biomonitoring tool (Agency for Toxic Substances and Disease Registry, 1999).

One of the insistent ecological issues nowadays is the airborne lead as an effect of growing numbers of vehicles as part of urbanization. Many organisms, not just humans, tend to be continuously exposed to airborne lead. The intensifying harmful problem of air pollution happening, not just in Manila but also to the other provinces of Luzon, such as in Cavite, is causing lifelong and costly problems in human health.

In a study of hair lead bio-monitoring among school children in the province of Cavite, Philippines who designed to investigate the status of trace lead in pupils and determine if the socio-demographic profile, Body Mass Index (BMI), means of transportation significantly impact the existence of airborne hair lead absorption in them. To do this, concentrations of hair lead traces amongst school children living in rural and urban places in the Cavite province (Israel & Asirot, 2015).

As a result, the traces of lead concentrations are in the hair of those children attending classes in public schools that are relatively higher than children in private schools. Also, students who live in rural places are lower hair lead traces concentrations than those living in urban settings where hair lead concentrations are high. The study found that there is a significant difference in hair lead concentration between school children residing in urban and rural places and those studying in private and public schools in Bacoor and Alfonso, Cavite. The school children are constantly exposed to airborne lead, especially in areas where there are many vehicles (Macawile et al., 2012).

At present, there is no parallel study found in Visayas and Mindanao that focus on hair as a medium for biomarkers of lead and other heavy metals (Gupta et al., 2000).

Plants

Plants can also be used as a biomarker of exposure. *Zea mays* (corn) used to measure the presence of heavy metals such as Cd, Cu, Pb, and Zn in dumpsite soil in Manila (Cortez et al., 2014). *A. sessilis* and *E. indica,* common plants in Park and Wildlife Areas in Quezon City) are used to assess the presence of Chromium in landfill areas (Navarette et al., 2017).

Lichens

Lichens refer to the symbiotic relationship between algae and fungi. They have particular requirements for their habitat. In the study of Phlyctis argena Spreng, flot lichen is biomonitoring of airborne heavy metals near a nickel mining site in Mindoro Island, Philippines, Phlyctis argena, or white paint lichen is collected and used to analyze the presence of cadmium, nickel, and lead. The performance of P. argena as an effective biomonitoring tool is also assessed. Samples are collected near a nickel mining area and along a roadside in Barangay Villa Cerveza, Municipality of Victoria in the Island of Mindoro. Heavy metals in white paint lichens were analyzed using Flame Atomic Absorption Spectrometer. As a result, among cadmium (Cd), nickel (Ni) and lead (Pb), nickel was the most plentiful metal in the two (2) sampling places.

The study concluded that Phlyctis argena (white paint lichen) is useful as a bioindicator of airborne heavy metals such as cadmium, nickel, and lead. However, the bioaccumulation levels of these heavy metals depend on several parameters, such as season and climatological circumstances (frequency of rainfall occurrence, temperature, wind speed, and wind direction) (Eufemio et al., 2016).

Many existing literatures show that lichens are good bioindicators of pollutants such as heavy metals. In detecting airborne heavy metals, it is said that lichen species such as white paint lichen have a necessary characteristic of being a reliable bioindicator and an effective tool for biomonitoring. It is because of their capability to accumulate heavy metal and chemical pollutants in the atmosphere in their tissues without the organism dying because of hostile effects on its growth or survival (Zverina et al., 2014; Beeby, 2001; Sarret et al., 1998; Nash, 1989).

Lichen species depend on their nourishment on atmospheric particles due to their plain anatomy and the absence of a fully developed root structure. Consequently, atmospheric pollutants or airborne heavy metals easily bioaccumulate on its tissues (Bargagli et al., 2002). The absence of the waxy, outside cuticle, enables the absorption and retention of atmospheric particles (Sloof, 1995; Nash, 1996). Thus, in a long period, the metal ions present in the atmosphere and its rudimentary composition reflects on the lichens (Adamo et al., 2003). Furthermore, lichen species distribution is widespread in many places. These characteristics of lichens make them an effective bioindicator, and reliable biomonitoring means.

Remediation of Heavy Metals

Phytoremediation studies in the Philippines have shown some potential tropical plant species as phytoremediators. Such plants possess a unique, remarkable metabolic and absorption capability that enables them to decrease or remove heavy metal contamination in the soil, thereby decreasing human exposure to heavy metals and other toxic pollutants. The study of Paz- Alberto and Sigua (2012) on potential phytoremediation species in mine tailings of Benguet province showed some tropical Philippine plant species as phytoremediators. Vetiveria zizanioides L. (Vitever grass) is a potential phytoremediation species for lead phytoextraction, absorbing a high amount of lead in lead-contaminated soil. Amaranthus spinosus (Spiny amaranth), Eleusine indica (Wiregrass), and Portulaca oleracea (Common purslane) are potential for absorbing a high amount of copper. Amaranthus spinosus (Spiny amaranth), Achyrantes aspera (Chaff-flower), Portulaca oleracea (Common purslane), and Alternanthera sessilis (Dwarf copperleaf) are reported to absorb a high amount of lead. Eleusine indica (Wiregrass) and Amaranthus spinosus (Spiny amaranth) absorb a high amount of zinc. Crassocephalum crepidiodes (Fireweed), Portulaca oleracea (Common purslane), Alternanthera sessilis (Dwarf copperleaf), and Cyperus alternifolius (Umbrella sedge) absorb a high amount of cadmium. Amaranthus spinosus (Spiny amaranth) and Blumea sp. absorb a high amount of nickel. Paz-Alberto & Sigua (2007) reported mustard, tomato, and Vetiveria zizanioides L. (Vitever grass) as potential phytoremediators for ethidium bromide, a mutagenic agent commonly used in the molecular biology laboratory for Agarose Gel Electrophoresis.

Generally, the country must regulate and make remediation in soil strategies for reducing metal bio-availability equated with possible reduced risk for long term solution (Martin & Ruby, 2004) so that in the scenario of heavy metals' contaminating the soils, the chemical form of these contaminants in the soil will intensely impact in the selection of the proper remediation treatment method. With this, various technologies exist nowadays for the soil remediation of heavy metal in the polluted soil environment (Gupta et al., 2000). Some of the most applicable bioremediations in the country are the immobilization techniques, soil washing, and chemical extractants for soil washing, phytoremediation, and photostabilization.

Immobilization techniques

This technique employs practical approaches in the remediation of contaminated soils of heavy metal in the area of concern. This scientific technique is probably used and applied in the areas with highly contaminated soil to eradicate heavy metal from its origin. Its storage is linked with high ecological risk because its alterations of organic and inorganic materials have hastened the decrease of soil toxicity to the affected ground/area. Its prime role in this manner is to immobilize the ground where the alter of soil metals' origin is more geochemically unchanging through precipitation, sorption, and complexation methods/processes (Hashimoto, 2009).

Recent studies have shown possible low-cost industrial/manufacturing chemical residues (Boisson et al., 2015; Lombi, 2002; Anoduadi, 2009) to restrain heavy metals in the polluted/contaminated terrestrial environment due to the bulk of soil environment and the limits of present methodical techniques where the halt mechanisms are not yet simplified by concern field, which contains precipitation processes, chemical absorption technique, precipitation method, organic ligands materialization complexes, and the reaction of redox (Wang, 2009). In this technique, most immobilization technologies perform in situ/ex-situ.

Soil washing

In this technique, there is a quantity of heavy metals have been declined in the mined soil (Dermonth et al., 2008). As conferred in this evaluation, this technique could employ physical and chemical processes to remove heavy metal toxins from soils. In the process of the soil washing method, the soil particles in the site with bulk metal contamination will be removed from the soil portion. With this, metal pollutants will be vanished from the soil particles by aqueous chemical substances and retrieved from a solution on the dense substrate, and a mixture of chemicals (compound) (Dermonth et al., 2008). In many situations, the detached soil impurities then drive to harmful waste in landfills. So, in extracting the bulk of impurity from the terrestrial environment, a big portion is retained in the soil that could be usually recycled in the area being remediated, or the user of the new area as fill, and secure proper disposal of somewhat inexpensively as non-hazardous waste materials in the site.

So, soil washing is mainly and commonly used in the so-called soil remediation method since it totally removes the metal contaminants from the soil and henceforth warrants the quick clean-up of a terrestrial contaminated site (Wood et al., 2015). With specific and appropriate soil criteria, it reduces long-term accountability, with effective and lucrative soil solution, and it may yield recyclable material (GOC, 2016). For its disadvantages, the metal contaminants could be moved to different sites, or the concerned agencies must strictly monitor and evaluate the threat of diffusing chemically contaminated soil. Thus, soil excavation is a relative option when involved huge volumes of soil need to be removed, or proper toxic disposal of waste is required.

Chemical extractants for soil washing

In the various characteristic of heavy metals in the terrestrial environment, extracting solutions of hazardous metals from the soil is an optimal concern of the many to remove them in the soil washing technique. Many chemicals can be applied for soil washing techniques, including cyclodextrins, chelating agents, and organic acids (USEPA, 2015). These methods/techniques of soil washing extractants are created and developed based on the type of soil contaminant at a specific area/site. Recent findings have mentioned that the extraction of toxins by washing solutions varies significantly in various soil types because acidic chemicals degrade soil crystallinity structure at a lengthy time frame. In this regard, when damaging washes are less, the organic acids and chelating components or agents are frequently recommended as substitutes for the conventional use of acid (Yu et al., 2014).

The usual organic acids, including of this technique are formic, aconitic, oxalic, acetic, malonic, itric, fumaric, and succinic acids are usual and natural products of exudated roots and microbial secretions residue decomposition in the terrestrial environment (Naidu et al., 2016). For metal dissolution of carbon-based acids is possible to become a mobile metal portion existing in the soil biota (Labanowski, 2008). Chelating agents of carbon-based acids could extricate the interchangeable reducible portions of metals by chemical extractant procedures (Dermonth, 2008). In chelating agent mixture for activating heavy metals, it is evaluated that the remaining uncertainties are the optimal option for this application. So, in the quantification and identification of co-existing metal in the organisms of soil (before and after), treatment is important to design the efficacy of this method (Kirpichtchikova, 2006). Presently, the changes in heavy metals in the uptake in a sandy loam soil before and after washing with chelating agent organic acids showed citric acid. EDTA seemed to bid better possibilities for remediating the permeable soil structure (Wuana, 2010).

Phytoremediation

In this technique, the use of related microbiota, vegetation, and agronomic methods to remove environmental soil contaminants are a friendly and harmless way (Cunningham et al., 2015). The knowledge of this technique in metal bio-accumulating plants in the contaminated/affected sites to remove dangerous metals compounds was introduced before. Still, its idea has been applied to wastewater discharges (Henry et al., 2000). So, the medium could degrade organic impurities or eliminate and stabilize heavy metal impurities. With this, the techniques /methods applied in phytoremediation metal pollutants are somewhat dissimilar from other methods/techniques in the remediated areas with organic contaminants. Because of the new technology application, phytoremediation is still typically in its testing stages. Though it has been confirmed conclusively in some places of different contaminants, phytoremediation is a powerful method in removing soil contaminants. It is efficient and applicable to a traditionally remedial method as a vital phase of the remedial soil process.

Its advantages compared to conventional remediation show more economically practical with using similar tools. This phytoremediation technique is less disrupting to the soil environment without involving new plant populations to recolonize the area, with no need of disposal areas, so acceptable public because of its applicability to conventional methods, does not involve excavation of contaminated media to eradicate the threat in the spreading of hazardous chemicals.

Phytostabilization

In the technique of phytostabilization, the prime concern is the use of plants to halt the sediment in soil (USAPE, 2015), where toxin in the soil will be absorbed by plant roots (rhizosphere). It believes that this reduces the mobility of preventing soil impurities migration from the groundwater to reduce bio-availability of the impurity hence avoiding its spread in the food web. When phytostabilization is in plants, it can reduce the volume of H2O penetrating through soil ground that may cause the formation of hazardous soil as a result, and avoid soil corrosion and can circulation of toxic metal in the other sites (Raskin & Ensley, 2000). This technique may occur in the process of absorption or metal reduction. This is very beneficial because of the clean-up of heavy metals (Jadia & Fulekar, 2009). This may use to re-establish a plant environment on bared areas because of its metal contamination. When the environment of tolerant organisms has been established, the possibility of wearing away is reduced. So, in this regard, the phytostabilization is very important because the disposal of toxic material is not required with very good protection of surface soil.

CONCLUSIONS

Based on the results of this review paper, findings show that the concentrations of heavy metals (Hg, Cd, Cr, Cu, Pb, Mg, Fe, Zn) in terrestrial ecosystem varies in the different parts of the country. Mercury (Hg) is the most hazardous element in the sites where mining lies neither terrestrial nor water ecosystem. The contamination in soil is hazardous and severe compared to other heavy metals. These ecological pollutants are found to be heavy metals that occur in the soil and in the plant body, airborne heavy metals, and pesticides that come from various sources. These pollutants are present in the Philippines' three islands in Luzon, Visayas, and Mindanao, where most metallic mines are actively operational. As mentioned in the findings, pesticides are also reported as pollutants in the terrestrial ecosystem in Benguet, Luzon, and crop pesticidal residues. For plants in Cebu, landfills found heavy metals of cadmium (Cd) and chromium (Cr). In Mindanao, most heavy metals include mercury (Hg), cadmium (Cd), copper (Cu), zinc (Zn), and lead (Pb). These heavy metals come from gold mining, including airborne heavy metals like mercury (Hg) and methylmercury found in gold processing and refining plants.

With the complexity of pollutants present in the Philippines, the choice of appropriate specific biomarkers for terrestrial biomonitoring varies in different regions. Hence, identifying the single most suitable biomarker for the same pollutant that would apply to all regions still needs further investigations even though the most commonly used biomarker would be far from ideal. Still, the combinations of several biomarkers for a particular pollutant may give complementary data.

Lastly, the role of the phytoremediation strategy of advanced technology (immobilization techniques, soil washing, and chemical extractants for soil washing, phytoremediation), photostabilization (plants), and phytoremediation species absorb a high amount heavy metal. Thus, bioaccumulation of heavy metals by agents plays a vital role in the elimination of contaminants from the soil because they possess unique remarkable metabolic (species) and absorption capabilities that enable them to decrease or remove heavy metal contamination. In conclusion, the country must regulate and make remediation in soil strategies for reducing metal bio-availability equated with possible reduced risk for long term solutions and improve knowledge in the environmental contamination in a global vision.

RECOMMENDATIONS

In this light, the following recommendations are offered for consideration. More research studies will be conducted on environmental biomonitoring in Luzon, Visayas, and Mindanao to identify potential revolutionary developments for mining to lessen the environmental impacts and to provide substantial benefits to both the mining industry and the public. On biomining, the use of biological agents to extract metals, waste less mining technologies, and remediation techniques or strategies, may give top priority to address environmental-related issues and concerns.

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