Phytoremediation as a Sustainable Way for Land Rehabilitation of Heavy Metal Contamination

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Abstract. Land contamination from heavy metals leads to a decrease in soil functions. Chemical contamination on agriculture land will cause negative impacts especially affecting human health. The factor that causes heavy metals to be included in the group of pollutants is the nature of heavy metals to be non-degradable. Several physicochemical techniques have been utilized to remove the pollutants from the contaminated environment. However, such techniques require high costs, intensive labor, irreversible change of the nature of the soil which cannot be recovered and other contribution towards pollution. One of the methods of toxicity reduction or applicable heavy metal mobility through in situ or ex situ as well as being environment-friendly is phytoremediation. Phytoremediation technology includes phytostabilization, phytostimulation, phytotransformation, phytofiltration, and phytoextraction. This paper aims to study phytoremediation formulate the sustainable indicators, namely environmental, social and economic aspects. Phytoremediation is one of the sustainable ways to recover contaminated lands by offering the lowest cost compared to other methods. Healthy and fertile agriculture land is the key to food security so that by utilizing phytoremediation it may recover the polluted land with low fertility through sustainability aspects.

1. Introduction
Land contamination from heavy metals are one of the dangerous forms of contamination for living organisms. Heavy metal-contaminated lands will cause a decrease of soil function. This may give an adverse effect especially towards human health and ecosystem, land productivity as well as social and economic welfare [1]. Based on such things, there needs to be a form of human intervention through the existing technology in order to overcome the pollution. Several ways may be used, one of them is with physicochemical technique. One of the forms of contamination control with physicochemical technique is by giving chemical substance to the contaminated land and could also be done by replacing the contaminated land through the removal of land [2]. Removal of land means adding a significant number of clean soil to cover the contaminated soil surface. In addition to the high costs, this way is also deemed to remove the original nature of the soil that cannot be recovered. Conventional remediation technique is deemed to be incompatible to be conducted especially in widespread area [3].

One of the alternatives to overcome heavy metal-contaminated lands which is environmental friendly with affordable cost, namely phytoremediation. Phytoremediation is a technology utilizing specific plants to remove the pollutants from the soil and reduce the toxic effects from the contaminants in the
surrounding environment [4]. Phytoremediation technology could be implemented to remove contaminants from the contaminated soil with affordable cost, effective and environmental friendly [5]. Phytoremediation is the use of plants associated with microorganisms to remove pollutants from contaminated soils and waters. Phytoremediation has the potential to be implemented on several types of substance including severe environment pollutants and could recover soil functions [6], [7]. Phytoremediation could include soil fertility allowing it to follow up the growth of plants with economic added value [8]. However, the use of this technology could not be fully implemented by farmers with contaminated agriculture lands. The lack of knowledge by the farmers is assumed to cause the lack of such implementation in heavy metal-contaminated lands. The importance of the farmer’s knowledge towards the utilization of phytoremediation is also considered to be the key to success for contaminated land rehabilitation. Based on such things, this paper will study the phytoremediation technology of the heavy metal contaminated soil in a sustainable matter.

2. Materials and Methods
This research utilizes literature study method about phytoremediation technology as way of heavy metal-contaminated lands. The data used in this paper comprises of secondary data from previous researches. The source of research data utilized namely regarding phytoremediation technology as the solution to heavy metal-contaminated lands in a sustainable manner. The research utilized in this literature study is namely a research conducted in the last ten years.

3. Result and Discussion

3.1 Result
Potential danger of heavy metal towards the environment could be determined from the total heavy metal concentration on the area [1]. The accumulation of heavy metal on the agriculture land is caused by the industrialization and the agricultural activity such as fertilizers, pesticides and irrigation [2]. Heavy metal contamination could give an effect which is carcinogenic and mutagenic towards the living organisms [3].

| No | Source of pollutants | Type of heavy metals | Effects on humans | References |
|----|----------------------|----------------------|-------------------|------------|
| 1  | Air, food, water, soil, dust, biosolids, metal mining | Lead (Pb) | Damage to the kidney, production of Cardiovascular system (CVD) | [4,5] |
| 2  | Biosolids and manure, air | Cadmium (Cd) | Lung cancer, liver cancer, bone damage | [3,6] |
| 3  | Pesticides, food (sea fish) | Mercury (Hg) | Damage to the fetus and baby’s brains | [7,8] |
| 4  | Biosolids, irrigation, food, water, air | Arsenic (As) | Cardiovascular, skin, digestion, respiratory, neurological, endocrinological, cancer | [9] |
| 5  | Fertilizers, pesticides, water, food, biosolids | Copper (Cu) | Nausea, vomit, stomachache, diarrhea | [3,8] |
| 6  | Fertilizers, pesticides, food, industrial waste, dust, biosolids, metal mining and milling | Zinc (Zn) | Epigastric pain, diarrhea, increasing risk of prostate cancer, respiratory problems, lethargy, microcytosis, neutropenia | [8,10,11] |
Phytoremediation Mechanism

Phytoremediation mechanism consists of phytoextraction, phytofiltration, phytostabilization, phytovolatilization and phytodegradation. Phytoextraction is an absorption of pollutants by the plant roots and accumulate to the parts of the roots, stems and leaves. Phytofiltration is the utilization of plant roots to absorb, precipitate, accumulate heavy metals from the waste stream. Phytovolatilization occurs when the plant absorbs the heavy metals and releases it through the leaves to the air and occasionally the heavy metals experience degradation first before being released through the leaves. Phytodegradation is the metabolism of the heavy metals in the plant tissue by enzymes such as dehalogenase, reductase and oxygenase [16].

| No | Plant species | Family       | Metal (Accumulation) | Duration of treatment | Translocation Factor | References |
|----|---------------|--------------|----------------------|-----------------------|----------------------|------------|
| 1  | Sunflower     | Asteraceae   | Pb Shoot Root Seed   | After 126 days        | TF > 1               | [17]       |
| 2  | Flax          | Linaceae     | Pb Shoot Capsule Seed| 155 days (harvesting stage) | Pb, TF > 1 (shoot and capsule), Pb, TF < 1 (seed) Cd, TF < 1 Zn, TF > 1 (capsule and seed) Zn, TF < 1 (shoots) | [18]       |
| 3  | Solanum nigrum L. | Solanaceae | Cu, Zn Pb Pb Cd Mn Hg Leaves Root Shoot | 7 months Cu, TF = 0.62 Zn, TF = 0.30 Pb, TF = 0.58 Cd, TF = 1.47 Mn, TF = 0.39 Hg, TF = 0.33 | [
| 4  | Vetiver       | Poaceae      | Pb Cr Ni Co Root Shoot | 1 year Pb, TF = 0.5 Cr, TF = 1.1 Ni, TF = 0.6 Co, TF = 0.6 | [20]       |
| 5  | Erodium glaucophyllum L. | Geraniaceae | Pb Cd Zn Fe Mn Cu Root Shoot | 2 months Pb, TF > 1 Cd, TF = 1 Zn, TF > 1 Fe, TF > 1 Mn, TF < 1 Cu, TF < 1 | [21]       |
3.2 Discussion

Sustainable development is a form of economic growth that meets the current necessity and desire without compromising the fulfilment of future necessities in which the concept consists of three aspects, namely environmental, social and economic [22–24]. Those three aspects are interrelated and inseparable from one another. This paper discusses the use of phytoremediation reviewed from the sustainable indicators, namely environmental, social and economic aspects. Sustainable agriculture is a harmonious and balanced agricultural system in accordance with environmental governance. The importance of sustainable agriculture theory based on the awareness will maintain environmental health and preservation that has become a world trend which is internationally developed through global regulations requiring agricultural products to be safe to be consumed, environmental-friendly and with high nutrients [25].

Sustainable agriculture thrives to support farmers to implement sustainable agricultural practices in the farmer’s agricultural land [26]. One of the examples, namely ‘sustainable intensification’ as an alternative which is more environmental-friendly without utilizing additional lands or causing yield losses [27]. Sustainable agricultural system is a growth system from traditional agriculture with an objective to meet the maximum targets that have been planned, overcome global economic problems and maximize the fast and instant necessities. Based on its managements, sustainable agricultural system that is environmental-friendly performed through the use of natural resources in an optimal, sustainable and profitable manner as well as be utilized sustainably for the benefit of the present and future generations.

Based on the sustainable agriculture theory, phythoremediation is one of the sustainable ways to recover contaminated lands. Phytoremediation could increase the soil fertility that could be follow up the plant growth with economic value added [28]. Healthy and fertile agricultural land is the key to food security thus by using phythoremediation is expected to be able to recover contaminated lands with low fertility rate. Indonesia is one of the countries that has agreed to the implementation goals of Sustainable Development committed to support the implementation of SDGs. One of the principles of SDGs, namely integration carried out in an integrated and interrelated manner on the dimensions of environment, social and economy. The research utilized by the researcher is one of the efforts to achieve sustainable development goals. Subject to Sustainable Development Goals 2030, on the goal number three, namely “Good Health and Well-Being” especially with the target to alleviate mortality rate and diseases caused by hazardous chemicals and also pollution and air, water and soil contamination. Moreover, the indication of this objective, namely mortality rate caused by unsafe water, unsafe sanitation and lack of hygiene.

Chemical contaminations especially on water and soil in agricultural land will cause adverse effect especially on human health. The polluted agricultural land becomes a serious a public health concern. The health impact due to heavy metals, namely physiology effects, effects on the skin, effects on respiration, effects on the kidney, effects on the liver, carcinogenic, growth and reproduction. Based on such things, there needs to be recovery efforts on the heavy metal contaminated agricultural land to achieve the third objective. Phytoremediation as a sustainable way is studied from three main aspects, namely, natural, social and economic aspects.

The environmental aspects on this research, namely the land contamination by heavy metals caused the decrease of soil function leading to the disruption to the surrounding environment as well as towards humans. Heavy metals are part of pollutant groups due its non-degradable nature and be easily absorbed. Based on such things, there needs to be land improvement efforts, one of the methods of toxicity decrease or the applicative heavy metal mobility as well as being environmental-friendly is phytoremediation. All plants are capable to absorb metals in various amounts, but several plants accumulate certain metal elements with high level of concentration. The result in Table 2 shows that
each type of plant can absorb heavy metals respectively. Translocation factor shows the ability of plants to translocate metals from roots through shoots and leaves of plants. The plants can be used as bio accumulators if the translocation factors higher than one.

Based on the economic aspects, the utilization of phytoremediation to absorb heavy metals is deemed to be efficient as it does not require expensive costs. According to Mahar et al. [28], the purpose of phytoremediation to be studied from the economic aspects is the sustainable land management that could raise the soil fertility so as to enable plant growth with economic added values. In addition to phytoremediation, there are a number of ways to remove pollutants from the contaminated environment, one of which is by physicochemical methods [29]. However, with such ways, it is required in a significant amount depending on the contaminated area thus potentially involving expensive costs. The conventional remediation technique is deemed to be incompatible to be performed in a widespread area [30]. However, according to Zehra et al. [17] the utilization of phytoremediation on an agricultural land that is not balanced with economic income is not feasible for farmers. Plants that become phytoremediator agents must also give additional benefits for the economic life of farmers. Based on such purposes, the researcher believes that phytoremediation is an environmental-friendly technology with relatively cheap costs. The research outcome from Mwegoha [31] shows that the use of phytoremediation is 60-80% cheaper than the physicochemical techniques.

Apart from the environmental and economic aspects, the social aspects are also an important case of how the farmers are able to apply phytoremediation on their own agricultural lands. Based on such things, this becomes important for the farmer’s knowledge on the choice of plant types to optimally reduce heavy metals. The farmer’s knowledge on phytoremediation is still very limited and has not been widely implemented. Based on such things, there needs to be a study on the farmer’s knowledge so that the farmers are able to utilize this technology in accordance with necessary steps. One of the ways that could be used to increase the farmer’s knowledge is by convening agricultural extension. Agricultural extension is an activity to disseminate information with the view of the farmers to be well-informed, capable and be able to overcome agricultural problems to improve welfare. As opposed to the other techniques, the use phytoremediation depends on the location of the contaminated land. Based on such things, therefore this becomes impractical if field trials of the phytoremediation were conducted on every region. The land recovery efforts with conventional techniques are more feasible compared to the phytoremediation technology. The result of the physicochemical process is more predictable and controllable than the physiological parameter [32]. In addition, the conventional technique is easier to be applied in the field compared to the phytoremediation that also requires longer time. Based on such things, there needs to be a development on phytoremediation regarding the environmental and commercial matters. This is to ensure that the phytoremediation could become a solution to the heavy metal-contaminated lands.

4. Conclusion
Land contamination by heavy metals could be alleviated with phytoremediation technology. The advantages of phytoremediation from other technologies are being environmental-friendly with affordable cost compared to other methods. Moreover, the use of appropriate plant not only removes soil pollutants but also could be utilized as the farmer’s income. The farmer’s knowledge on phytoremediation needs to be further studied. The choice of appropriate plants as phytoremediation agent on the polluted land area becomes the key to success in this phytoremediation technology.

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