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Removal of Pesticides Using Aquatic Plants in Water Resources: A Review

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Abstract. According to the Food and Agriculture Organization of United Nation (FAO), there is a demand of increasing 70 % of food production to sustain 2.3 billion people by the year of 2050. This shows the need of rapid growth of agriculture applications to improve the food production worldwide. It's an undeniable truth that pesticides induced major role in the economic production. Notwithstanding the beneficial effects of pesticides, the negative impacts on human health, environment quality have well documented worldwide and raise the concerns to the health hazard globally. Pesticides need to be closely regulated for quality control monitoring on fruits, vegetables and water resources for safety purposes. European Regulation 396/2005 and amendments were established on the amount of maximum quantities of pesticide residues permitted in products of animal or vegetable for human or animal consumption. Phytoremediation technology using aquatic plants acts as cost effective alternative over conventional technologies to remove harmful heavy metals, organic and inorganic pollutants from various water bodies. To best of our knowledge, there is little or no data are available on the effectiveness of aquatic plants for the phytoremediation of pesticides. Therefore, in this review paper, the main focus is to study the effectiveness of aquatic plant factors in removal of pesticides from water sources and to provide insight for the future development.

1. Introduction

According to the Food and Agriculture Organization of United Nation (FAO), there is a demand of increasing 70 % of food production to sustain 2.3 billion people by the year of 2050[1]. These shows the urge of rapid growth of agriculture applications are the possible option to improve the food production worldwide. It's an undeniable truth that pesticides induced major role in the economic production of wide ranges of vegetable, fruit, cereal, forage, fibre and oil crops which now constitute a large part of successful agricultural industry in many countries [1,2]. Crop loss reduction, help to increases the revenue income of farmers from the additional marketable yield and reduces the cost of crop production per unit output are the important keys that drive farmers to support pesticides usage on their agriculture field [2]. Notwithstanding the beneficial effects of pesticides, the negative impacts on human health, environment quality have well documented worldwide and raise the concerns to the health hazard globally [3]. In addition, European Regulation 396/2005 and amendments were established on the amount of maximum quantities of pesticide residues permitted in products of animal or vegetable for human or animal consumption. As this to ensure the pesticide residues in foodstuffs do not constitute an unacceptable risk for consumer and animal health. Currently, maximum residue limits (MRLs) in force for the following foodstuffs are established in Directives 76/895/EEC (fruit and vegetables), 86/362/EEC (cereals), 86/363/EEC (foodstuffs of animal origin), 90/642/EEC (products of vegetable origin and honey) and amendments [4].



Pesticides are divided into many classes, of which the most important are organochlorine and organophosphorous compounds. Organochlorine pesticides are known to resist biodegradation and therefore they can be concentrated through food chains and produce a significant magnification of the original concentration at the end of the chain [3,4]. The general progression of pesticide development has moved from highly toxic, persistent and bio-accumulating pesticides such as DDT, to pesticides that degrade rapidly in the environment and are less toxic to non-target organisms. The developed countries have banned many of the older pesticides due to potential toxic effect to man and or their impact on ecosystems, in favor of more pesticide formulations [5]. In developing countries, organochlorine pesticides still remain as cheapest to produce and, for some purposes, remain highly effective. Developing countries maintain that they cannot afford, for reason of cost or efficacy, to ban certain older pesticides. The dilemma of cost and efficacy, versus ecological impacts, including long range transport, and access to modern pesticides formulations at low cost remains a contentious global issue [5,6].

Pesticides need to be closely regulated for quality control monitoring on fruits and vegetables for safety purposes [6]. Biological control such as phytoremediation also known as plant assisted clean up exploits the ability of plants to remove, degrade, assimilate, metabolize, or render harmless both inorganic and organic contaminants. It is being promoted as more cost effective over conventional technologies for the remediation of polluted environment. Aquatic plants are well known for the removal of harmful pollutants from water resources. However, little or no data are available on the effectiveness of aquatic plants for the phytoremediation of pesticides. In this review paper, the main focus is to study the effectiveness of aquatic plants factors in removal of pesticides from water sources and to provide insight for the future development.

2. Aquatic Phytoremediation Technology Applications

Phytoremediation is a cost-effective and eco-friendly technology that has the ability to remove environment pollutants such as an organic, inorganic compounds and heavy metals by using specific plants or certain plant associated bacteria strains from water resources [7,8]. Also, able to remove many pollutants from shallow depth contaminated water to hydrologic control of ground water within short period of time [9]. Four mechanisms are involved in phytoremediation of organic pollutants: direct uptake and accumulation of contaminants and subsequent metabolism in plant tissues, transpiration of volatile organic hydrocarbons through the leaves, release of exudates that stimulate microbial activity and biochemical transformations around the root system and enhancement of mineralization at the root–soil interface that is attributed to mycorrhizal fungi and microbial consortia associated with the root surface [10].

Aquatic plants such as *Eichhornia crassipes*, *Lemna minor* and *Elodea canadensis* has been used in water treatment due to its photosynthetic activity and growth rate of plants easy to harvest and high absorption rate of pollutants [11].

Eichhornia crassipes known as water hyacinth is a free-floating aquatic macrophyte that rapidly grow to high depth (over 60kg/m²) in an open pond, irrigations and other water bodies cause the clogging of water bodies and triggers unfavorable environment effect, human health and affects the economic development as well [11,12]. Despite, *Eichhornia crassipes* shoot covers the surface of water bodies prevent the entry of sunlight impacts the algae growth and also aquatic organisms and this disturbs the balance of ecosystem. The common *Eichhornia crassipes* species has long pendant roots, rhizomes, stolon and it can grow in the range of 40 cm to 100 cm height. It has the ability to float due to the stem and leave contain air-filled tissue that provides substantial buoyancy and also able to grow in drastic condition such as moist sediments for several months [12]. According to Xia and Ma, 2006 [13], a phytodegradation experiment was conducted using *Eichhornia crassipes* to remove malathion, ethion from aqueous solution and also from polluted water. It was known that 56% of 10 ppm of malathion in 250 mL was degraded by (approx. 11g of weight) *Eichhornia crassipes*. Meanwhile the accumulated ethion in live *Eichhornia crassipes* plant decreased by 55-91% in shoots and 74-81% in roots after the plant growing one week in ethion free culture solutions. This shows the

Eichhornia crassipes uptakes on pesticides and its phytodegradation can be used as a potential, economical and alternative biological method to remove pesticides from the water bodies.

Lemna minor known as duck weed aquatic macrophyte that withstands cold weather (1.7°C to 35°C) and grows rapidly within a week under optimum pH 6 [14]. Also, it decontaminates heavy metal and organic pollutants such as pesticides by rhizofiltration [15]. Cost effective, long storage capacity and minimal usage of chemicals are the other potential benefits from this plant [16]. According to Dosnon-Olette et al., 2010 [17], a study was conducted using two types of duckweed species to test the efficiency of removing fungicide dimethomorph from agricultural waste water. From the result obtained, duckweed able to remove dimethomorph as long as the concentration does not become too toxic and inhibit depuration mechanisms. The maximal removal of 41 and 26 $\mu\text{g g}^{-1}$ fresh weight of dimethomorph (at 600 $\mu\text{g L}^{-1}$ of dimethomorph and an initial density of 0.10 g E-flask $^{-1}$) by *Lemna minor* and *Spirodela polyrhiza*, respectively. *Lemna minor* sensitivity towards dimethomorph was correlated with their ability to remove it from water. An increase of removal (in $\mu\text{g L}^{-1}$) was correlated with the increase of growth rate inhibition ($r^2 > 0.86$).

Aquatic plants have great potential to function as on-site biosinks and biofilters of aquatic pollutants because of their abundance and limited mobility [18]. They have been successfully used to sequester selected heavy metals and nutrients through their root systems and by uptake through their plant bodies [19]. *Elodea canadensis* is a free floating, rapid growth and fast cultivate macrophyte aquatic plant. This plant is a native to North America and considered as weed due to its fast growing at drastic conditions. This species has been used commonly in phytoremediation technology to treat organic pollutants such as pesticides. Olette et al., 2008 [19] carried research using *Elodea canadensis* to remove three types of pesticides such as copper sulphate (fungicide), flazasulfuron (herbicide) and dimethomorph (fungicide). It was known that the toxicity of the pesticides were same for this aquatic plant and occurred in descending order such as flazasulfuron > copper sulphate > dimethomorph. The maximal removal rates for copper sulphate in *Elodea Canadensis* was 16.5 % within three days, dimethomorph was 5.5% within two days and 12% within 4 days for dimethomorph.

Chemical and physical properties of pesticide compounds and interaction of environment factors play vital role for the removal efficiency in aquatic plants. Different absorption, volatilization and translocation rates of pesticides causes different removal rate in *Eichhornia crassipes*, *Lemna minor* and *Elodea canadensis*. High removal rate of pesticides occurs when pesticide mobility proportional to surface adsorption on part of plant [20].

3. Future Trends

There are many studies has been conducted widely in removal of heavy metals from various water resources. Yet, there were less study been carried out on removal of pesticides from water sources using aquatic plants and also limited in details of the four mechanisms in phytoremediation using aquatic plants. More researches should focus on the pesticide removal from water bodies using aquatic plants as wide application of pesticide usage by the year 2050 will damage human health and pollute the environment as well.

4. Conclusion

Large scale application of pesticides to crops in agricultural field contributes to the presence of toxic contaminants in the water reservoirs, streams and rivers. This triggers negative impacts on human health as well as aquatic organisms. Phytoremediation technology known as plant assisted cleanup exploits the ability of plants to remove, degrade, assimilate, metabolize, or render harmless both inorganic and organic contaminants and prove to be cost effective over conventional technologies for the remediation of polluted environment such as pesticides [21]. Aquatic plants such as *Eichhornia crassipes*, *Lemna minor* and *Elodea canadensis* has been used in water treatment due to its photosynthetic activity and growth rate of plants easy to harvest and high absorption rate of pollutants. The studies of the effectiveness of aquatic plant factors in removal of pesticides from water sources were discussed.

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