Phytoremediation Might be a tool for Depletion of Heavy metals in Malwa Region, the focal Point of cancer cases in Punjab: A Review study

Dr. Samriti [1], Dr. Reena Chauhan [2]

[1] *Assistant Professor, Department of Chemistry, Baba Farid College, Bathinda, Punjab(India)*

[2]*Research Associate, Department of Entomology, College of Agriculture,*
CCSHAU, Hisar, Haryana (India)

ABSTRACT

Ground water & waste water of Malwa region in Punjab contain U, Pb, Cd, Al, As, Ba, Mn, Hg, Cr and Sr. Here, soil contain Ni, Hg, Se, U, As, Pb and Cd and even various samples of humans contain U, Fe, Al, Ba, Mn, Pb and Ba which turned out to be the major causes of cancer in Malwa region of Punjab. Among the three regions of Punjab (i.e. Majha, Malwa and Doaba), the prevalence of cancer is highest in Malwa (108.9 per lakh) region, particularly in cotton belt of Malwa region, as the use of pesticides is more on cotton crop as compared to the other crops grown in the state. Due to this, the cotton belt of Punjab is labelled as 'Cancer Belt of Punjab'. Several methods already used to clean up the environment from these kinds of contaminants, but most of them are costly and difficult to get optimum results. Currently, Phytoremediation has been offered as a cost-effective and non-invasive alternative to the conventional engineering-based remediation methods. This review gives details about heavy metals, their toxicity mechanisms and some recommended plants which are commonly used in phytoremediation to reduce the contaminant are also reported.

Keywords: Cancer, Heavy metals, Malwa Region, Phytoremediation

I.INTRODUCTION

The state of Punjab located in North West India, bordering Pakistan, extends from $29^0$32´ to $32^0$32´ north and $73^0$55´ to $76^0$50´ east. It is surrounded by the Indian states of Jammu and Kashmir in the north; the hilly state of Himachal Pradesh in the east; and the states Haryana and Rajasthan in the south.'South of river Sutlej' the Malwa region, commonly known as the 'cotton belt' of Punjab comprises of eight districts namely, Sangrur, Barnala, Moga, Firozpur, Faridkot, Muktsar, Bathinda and Mansa [1 & 2]. Punjab's lethal pesticide legacy can be traced to the Green Revolution of the 1960s and 70s, when high-yielding varieties of cotton were introduced in the region's relatively arid Malwa belt. Initially the move was successful as yields and prices were good. But farmers soon discovered that the cotton was highly susceptible to pests, and ended up spending huge amounts on pesticides. As the pests, such as pink bollworm and aphids became increasingly resistant to chemical spraying, farmers reacted by laying on even more, sometimes mixing two or more products against all scientific evidence. The region virtually became a chemical laboratory [3]. According to the State Council for Science and

Technology's State of Environment Report (2007), Malwa belt consumes 75% of the pesticides used in Punjab [4 & 2]. The saying 'excess of everything is bad' implies to the use of fertilizers and pesticides which turned out to be the cause of countless serious health hazards in general but cancer in particular among farmers and agricultural labour. It is also estimated that 99 per cent of the fatal poisonings take place in developing countries [5]. The cancer mortality was analyzed in the 15 villages of malwa region and the result shows the greater mortality in females than males [6]. The usage of banned and restricted pesticides in malwa region is increasing mental retardation and reproductive disorder [2]. The average cost of cancer treatment is high i.e. Rs.2.75 lakh is big burden on poor victims and the government support is untimely and insufficient [7].

1.1 Cancer at World Level:

As per the data published by WHO, Cancer has doubled its grip over the world in the last 20 years and struck deep roots in India, from 800,000 lives in 2001 to 3.3 million in 2014. It is also reported that 70 per cent of the cancer deaths are taking place in developing countries where India ranked fifth [8]. As per WHO report 2003, the global cancer rate may increase to 15million by 2020. In developed countries, about 50 per cent of cancer patients pass away due to this fatal disease, while in developing countries, 80 per cent of cancer victims already have late-stage incurable tumours when they are diagnosed [9].

1.2 Cancer in Punjab:

Punjab, once known for its prosperous agriculture and hard-working peasantry, has now infamously got the label of cancer capital of India. Punjab with 90 cancer patients for every 1 lakh populace crosses the national average of 80 per lakh [10, 11]. Malwa region in Punjab is the biggest victim of this disease. Amongst the various districts of Malwa region, cotton belt or south-western Punjab is worst affected by it. In this region, the disease of cancer has become such an alarming issue of concern that the historically known cotton belt has bagged the synonym cancer belt for it. According to Dr. Pritpal Singh (Baba Farid Centre for Special Children, Faridkot), "We can say that Punjab is dying now. There is no doubt. Punjab is the food basket of India. Now, we can say it is the disease basket" [12].

II. REASONS FOR HEAVY METALS IN ENVIRONMENT OF MALWA REGION

Various industries e.g. Guru Nanak Dev Thermal Power Plant (GNDTPP), Milk plant (MP), National Fertilizer Limited (NFL), Ambuja Cement Factory (ACF), Paint Stores (PS), Dyes Shops (DS) and refineries are here in Malwa region. These industries consume large quantity of water. Waste water discharged from these industries into natural water bodies; contaminate ground water, surface water and the soil of nearby fields. Environmental Protection Agencies (EPA) like World Health organization (WHO) and Bureau of Indian Standard (BIS) set the permissible limits for the discharge of waste water into natural water bodies [13]. So, all of these unhealthy practices in Malwa region lead this region vulnerable to many heavy metals in water, soil and food.

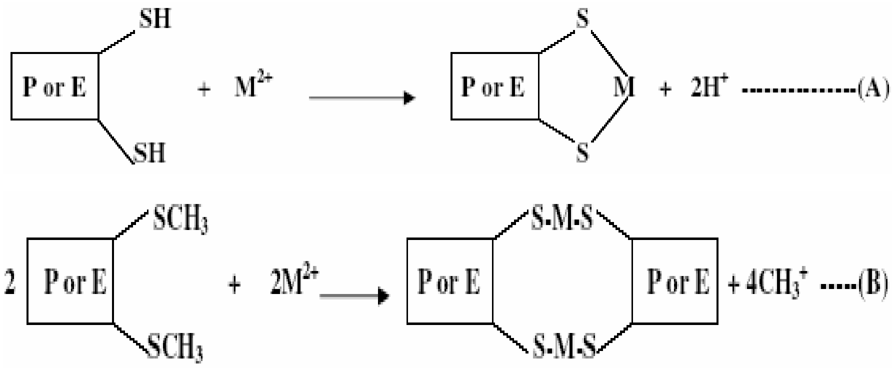
2.1 What are Heavy Metals

Heavy metals are generally referred to as those metals which possess a specific density of more than 5 g/cm^3 and adversely affect the environment and living organisms [14]. These metals are quintessential to maintain various biochemical and physiological functions in living organisms when in very low concentrations; however they become noxious when they exceed certain threshold concentrations. Although it is acknowledged that heavy metals have many adverse health effects and last for a long period of time, heavy metal exposure continues and is increasing in many parts of the world. Heavy metals are significant environmental pollutants and their toxicity is a problem of increasing significance for ecological, evolutionary, nutritional and environmental reasons (15 & 16).The contamination chain of heavy metals almost always follows a cyclic order: industry, atmosphere, soil, water, foods and human. Although toxicity and the resulting threat to human health of any contaminant are, of course, a function of concentration, it is well-known that chronic exposure to heavy metals and metalloids at relatively low levels can cause adverse effects [17, 18, 19, 20, 21 & 22].

2.2 Toxic effects of heavy metals

These metals become toxic when they are not metabolized by the body, and thus, they accumulate in the body tissues. They may enter the human body through various modes like air, water, food, or absorption through the skin when they come in contact of humans in agriculture and in manufacturing, pharmaceutical, industrial, or residential settings. Industrial exposure accounts for a common route of exposure for adults. Ingestion is the most common route of exposure in case of children. They may develop toxicity from the normal hand to mouth activity in those individuals who come in contact with contaminated soil or by actually eating objects that are not food (dirt or paint chips). The less common routes of exposure are during a radiological procedure, from inappropriate dosing or monitoring during intravenous (parenteral) nutrition, from a broken thermometer, from a suicide, or homicide attempt [23].

When ingested, in the acid medium of the stomach, they are converted to their stable oxidation states (Zn^{2+}, Pb^{2+}, Cd^{2+}, As^{2+}, As^{3+}, Hg^{2+} and Ag^{+}) and combined with the body's biomolecules such as proteins and enzymes to form strong and stable chemical bonds. The equations given below show their reactions during bond formation with the sulphydryl groups (-SH) of cysteine and sulphur atoms of methionine (-SCH_3) as reported by [24]



Where (A) = Intramolecular bonding, (B) = Intermolecular bonding, P = Protein, E = Enzyme and M = Metal

The hydrogen atoms or the metal groups present in the above reaction are displaced by the poisoning metal, and the enzyme is thus inhibited from functioning, whereas, the protein metal compound acts as a substrate and reacts with a metabolic enzyme. The scheme shown below (equation C) and enzymes (E) reacts with substrates (S) in either the lock and key mechanism, or the induced-fit pattern. In both the cases, a substrate fits into an enzyme in a highly specific fashion due to the enzyme chirality's to form an enzyme-substrate complex (E-S*) [25] as given below:

$E + S \rightarrow E\text{-}S \rightarrow E - S^* \rightarrow E - P \rightarrow E + P$ ----- **(C)**

(E = Enzyme, S = Substrate, P = Product and * = Activated Complex)

While at the E-S, E-S* and E-P states, an enzyme cannot accommodate any other substrate until it is freed. Sometimes, the enzymes for an entire sequence coexist together in one multi-enzyme complex consisting of three or four enzymes. The product from one enzyme reacts with a second enzyme in a chain process, with the last enzyme yielding the final product as follows:

$A \longrightarrow B \longrightarrow C \longrightarrow D \longrightarrow F$

The final product (F) goes back to react with the first enzyme, thereby inhibiting further reaction since it is not the starting material for the process. Hence, the enzyme E1 becomes incapable of accommodating any other substrate until F leaves and F can only leave if the body utilizes it. If the body cannot utilize, the product formed from the heavy metal- protein substrate- there will be a permanent blockage of the enzyme E1, which then cannot initiate any other bio-reaction of its function. Therefore, the metal remains embedded in the tissue and results in bio-dysfunctions of various gravities [26].

III. DISCUSSIONS

Phytoremediation techniques have been briefly depicted in many literatures or articles. The generic term "phytoremediation" consists of the Greek prefix phyto (plant), attached to the Latin rootremedium(to correct or remove an evil) [36 & 37]. Some definitions on phytoremediation that have been described by several researchers are listed in Table1. Generally, according to the above researchers, phytoremediation is defined as an emerging technology using selected plants to clean up the contaminated environment from hazardous contaminant to improve the environment quality. Fig. 1, depicts the uptake mechanisms of both organics and inorganics contaminants through phytoremediation technology. For organics, it involves phytostabilization, rhizodegradation, rhizofiltration, phytodegradation, and phytovolatilization. These mechanisms related to organic contaminant property are not able to be absorbed into the plant tissue. For inorganics, mechanisms which can be involved are phytostabilization, rhizofiltration, phytoaccumulation and phytovolatilization.

Table 1: Definition of phytoremediation.

No.	Researchers	Definition of phytoremediation
1	[38]	The use of plants to improve degraded environments
2	[39]	The use of plants, including trees and grasses, to remove, destroy or sequester hazardous contaminants from media such as air, water, and soil
3	[40]	The use of plants to remediate toxic chemicals found in contaminated soil, sludge, sediment, ground water, surface water, and wastewater
4	[41]	An emerging technology using specially selected and engineered metal accumulating plants for environmental cleanup
5	[42]	The use of vascular plants to remove pollutants from the environment or to render them harmless
6	[43]	The engineered use of green plant to remove, contain, or render harmless such environmental contaminants as heavy metals, trace elements, organic compounds, and radioactive compounds in soil or water. This definition includes all plant-influenced biological, chemical, and physical processes that aid in the uptake, sequestration, degradation, and metabolism of contaminants, either by plants or by the free-living organisms that constitute the plant rhizosphere
7	[37]	Phytoremediation is the name given to a set of technologies that use different plants as a containment, destruction, or an extraction technique. Phytoremediation is an emerging technology that uses various plants to degrade, extract, contain, or immobilize contaminants from soil and water
8	[44]	Phytoremediation in general implies the use of plants (in combination with their associated microorganisms) to remove, degrade, or stabilize contaminants Organiccontaminants

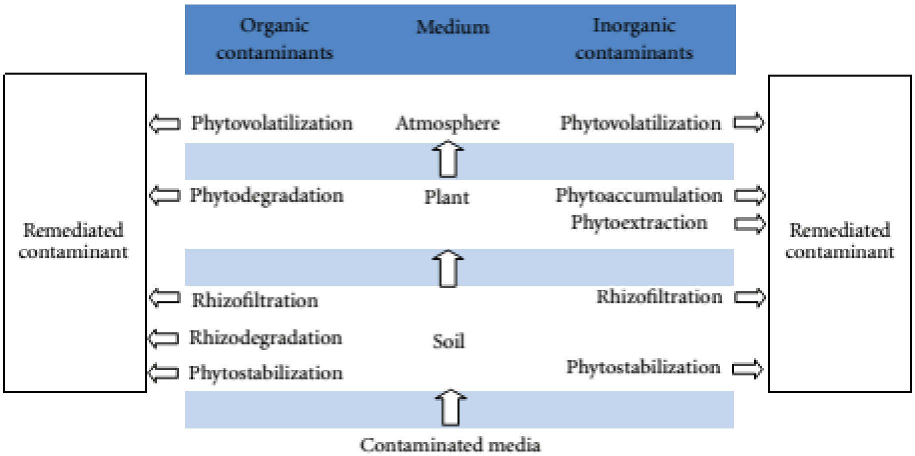


Figure1: Uptake mechanisms on phytoremediation technology. Source: [45].

Based on Fig. 1, some certain essential processes involved in phytoremediation technology [37 & 39] are phytostabilization and phytoextraction for inorganic contaminants, and phytotransformation/phytodegradation, rhizofiltration, and rhizodegradation for organic contaminants. The root plants exudates to stabilize, demobilize and bind the contaminants in the soil matrix, thereby reducing their bioavailability. These all are called as phytostabilization process. Certain plant species have used to immobilize contaminants in the soil and ground water through absorption and accumulation by roots, adsorption onto roots, or precipitation within the root zone. This process is for organics and metals contaminants in soils, sediments, and sludges medium [37 & 39]. Specific plant species can absorb and hyperaccumulate metal contaminants and/or excess nutrients in harvestable root and shoot tissue, from the growth substrate through phytoextraction process. This is for metals, metalloids, radionuclides, nonmetals, and organics contaminants in soils, sediments, and sludges medium [37 & 39]. Phytovolatilization process is the plants ability to absorb and subsequently volatilize the contaminant into the atmosphere. This process is for metal contaminants in groundwater, soils, sediments, and sludges medium. Since phytotransformation/phytodegradation process is the breakdown of contaminants taken up by plants through metabolic processes within the plant or the breakdown of contaminants externally to the plant through the effect of compounds produced by the plants. This process is for complex organic molecules that are degraded into simpler molecule contaminants in soils, sediments, sludges, and groundwater medium [37 & 39]. Plant roots take up metal contaminants and/or excess nutrients from growth substrates through rhizofiltration (=root) process, the adsorption, or, precipitation onto plant roots or absorption into the roots of contaminants that are in solution surrounding the root zone. This process is for metals, excess nutrients, and radionuclide contaminants in groundwater, surface water, and wastewater medium [37 & 39]. The breakdown of contaminants in the soil through microbial activity that is enhanced by the presence of the root zone is called rhizodegradation. This process uses microorganisms to consume and digest organic substances for nutrition and energy. Natural substances released by the plant roots, sugars, alcohols, and acids, contain organic carbon that provides food for soil microorganisms and establish a dense root mass that takes up large quantities of water. This process is for organic substance contaminants in soil medium (37 & 39). Sidhu et al.2017 [a] revealed

Coronopus didymus satisfies the conditions required for hyperaccumulator plants and may be practically employed to alleviate Cd from contaminated soils [46]. Sidhu at al. 2017 [b] also accumulated Pb from contaminated soils via *C. didymus* and it can be used either alone or with some other eco-friendly amendments viz EDDS and Ammonium Molybdate for soil remediation purposes [47]. Mohant 2016 pointed out that postharvest strategies are essential with pre harvest approaches for developing a sustainable phytoremediation technology [48]. In spite of benefits phytoremediation technique contributes huge quantities of contaminated materials to the environment and creates further pollution problems. Post-harvest management of these byproducts through advanced techniques like composting and compaction, combustion and gasification, phytomining and pyrolysis is essential. A lot of contaminated biomass is produced during phytoremediation processes, which uses high biomass weeds. So it needs proper disposal and management to restrict the passage of contaminants into the food chain. The high biomass plant selected for phytoremediation should be non-edible, disease resistant and tolerant plants, which can provide renewable energy. Post-harvest management of phytoremediation technique is an alternative for biomass to biofuel conversion. This enhances the practicability of phytoremediation technology. Rani et al. 2016 suggested amelioration of ground soil with specific quantity of 20 % tannery sludge can tremendously enhance the plant growth in pot experiment and tannery sludge can act as a substitute of synthetic fertilizer [49]. Majority of the metals was accumulated in root part (BCF>1) and meager translocation (TF <1) in aerial part, concluded *Ricinus communis* and *Brassica juncea* could be suitable plant species to be grown in heavy metal rich tannery sludge treated soil, vis-à-vis for phytostabilization of heavy metals. Virk 2016 used LED Fluorimeter to measure the uranium content of the ground water samples of Bathinda District of South Punjab and uranium content exceeds the safe limit of 60 ppb in groundwater proposed by AERB, India [50]. Ghosh 2015 confirmed that coal FA amendments are genotoxic. Metal estimation and genotoxicity study revealed that grass, *Vetiveria zizanioides* (L.) Nash is capable of remediating FA by stabilizing the metals in the root [51]. Apart from phytostabilization of the metals in the roots, reduction of genotoxicity renders *vetiver* an excellent candidate for remediation and restoration of FA dumpsites. Kumar and Maiti 2015 phytoremediated Chromite-Asbestos metalloid and metal contaminated mine waste by using two aromatic grasses, Cymbopogon citrates and Chrysopogon zizanioides by applying different proportions of amendments (chicken manure, farmyard manure and garden soil) [52]. Application of manures resulted significant improvements of mine waste characteristics and plant growth, reduction in the availability of total extractable toxic metals (Cr, Ni) and increase in Mn, Zn and Cu concentration in the substrate. Pandey 2015 proposed “assisted phytoremediation of Fly ash (FA) disposal sites" through naturally grown potential plants for fast green capping development in view of FA dumps’ management [53]. Thus, the assisted phytoremediation of FA dumps through naturally colonized plants with multipurpose species will provide economic benefits and other ecosystem services such as increasing FA disposal areas and mitigating carbon-dioxide released nearby coal-based thermal power stations. Finally it should be considered as adaptive FA management. Mani 2012 suggested that *Helianthus. annuus L* fulfils the necessary condition for efficiently increasing species bioaccumulation after soil treatment with humic acid in Cr-polluted sewage-irrigated soils through soil- plant rhizospheric processes [54].

IV. CONCLUSION

Conventional techniques for reclamation of such soils are expensive and environmental non friendly. Phytoremediation an emerging group of technologies utilizing green plants to clean up the environment from contaminants and has been offered as a cost-effective and non-invasive alternative to the conventional engineering-based remediation methods. There are different versions of phytoremediation viz. phytoimmobilization, phytostabilization, rhizofilteration, phytovolatilization and phytoextraction, the latter being most widely accepted for remediation of soils contaminated with toxic heavy metals [55, 56, 57 & 58]. Identification of candidates for removal of heavy metals by phytoremediation is still at its preliminary stage.

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