Impacts of Heavy Metal Pollution on Agricultural Production and Response Strategies

Qingyang Luo[1,*]

[1]High School Attached to Shandong Normal University, Jinan, Shandong, 250014, China
*Corresponding author: jyluo@umich.edu

Abstract:

Agriculture is one of human beings' most essential productive activities, and it is closely linked to human sustenance. Due to the ignorance of environmental production, production waste treatment in industries, and the lack of government regulation, the heavy metal pollution problem in agriculture has gradually become an important problem that needs to be solved urgently. Heavy metal pollution in agricultural land is a widespread problem that can contaminate downstream water systems, reduce crop yields, and threaten human safety. This paper examines the main sources of heavy metal pollutants and their impacts on agriculture and proposes related treatment measures for the public. Firstly, in part, by analyzing the sources of heavy metal pollutants, researchers find out that the pollutants are usually categorized into factory emissions, municipal waste pollution, and the use of pesticides. Secondly, the paper focuses on illustrating the impacts on agriculture. Mentioning the destruction of crop growth and health hazards posed on humans. Finally, the treatment measure is divided into the aspects of present technologies (including Laser-induced breakdown spectroscopy (LIBS) and Phytoremediation), treatments for governments, and measures for farmers. In the future, to ensure people's health, human beings should put more effort into solving heavy metal pollution, caring for agricultural safety, and protecting the environment. The paper will contribute to recalling society's awareness of environmental protection, offering new aspects of viewing heavy metal pollution, and providing practical methods of solving the agricultural pollution problem.

Keywords: Agriculture; heavy metal pollution; solution; environmental protection.

1. Introduction

As the world's population grows, agricultural production is increasingly valued by more and more people and organizations. How to break through land resource limitations and grow enough food to feed most people around the world has become an important issue for the United Nations (U.N.) and many governments. Land resources are so scarce, but a large number of land areas that originally could be cultivated by humans are continuously contaminated by heavy metal pollutants due to the lack of regulation. Since heavy metals can lead to severe diseases in human beings and reduce agricultural yields dramatically, plentiful high-quality land, therefore, becomes unavailable for cultivation. The condition damages the society's confidence in governments and each person's livelihood. Therefore, people and governments must act to deal with this pressing problem.

Studying heavy metal pollution problems related to agriculture yield offers a great platform for people to discuss and build awareness. It will contribute to not only the observation of agricultural production but also the improvement of people's consciousness of environmental protection and health concerns. This paper collects research published by other researchers and scholars working on solving the problem of heavy metal pollution. Assisted by the prior studies, this paper will summarize and reorganize the latest research and information and categorize the whole paper into three logical parts: reasons, impacts, and countermeasures. This will result in a more comprehensive and rigorous summary of the heavy metal pollution situation.

The main idea of this essay is to analyze the influences exerted on agriculture by heavy metal pollutants. Furthermore, the article will also attempt to form accessible solutions for the people, especially farmers, and the governments to deal with the problem. First, this paper introduces the common sources of heavy metal pollutants, which are divided into factory emissions, municipal solid refuse, and pesticides. Then, the impacts of heavy metal pollution on crop growth, agricultural yield, and the human body are discussed, with details and pieces of evidence listed in the article. Thirdly, the methods of dealing with the relevant problems that can be offered to

the individuals and the governments are proposed. Several novel techniques are also mentioned due to different subject knowledge used in addressing heavy metal pollution. Finally, the paper proposes the future expectations for agricultural yield and pollution-dealing action.

2. Sources of Heavy Metals

Worldwide, the development of the industry is quite rapidly, which also causes heavy metal pollution to increase yearly. Recently, it has been widely accepted that heavy metal pollution mainly comes from factory production, waste treatment, and pesticide usage. Heavy metal pollutants also slowly accumulate, becoming a serious problem for human life.

2.1 Factory Sewage and Exhaust Emissions

Due to the features of basic industry, the places where mining and smelting plants take place usually contain high concentrations of heavy metals. While the factories produce pure minerals, plentiful pollutants, gas or liquid, are released without disposal and contaminate the environment.

2.2 Municipal Household Waste

Though closely related to people's lives and considered safe in most cases, daily necessities contain a certain amount of heavy metals. For example, batteries and thermometers, which people use nearly daily, are filled with lead and mercury. Heavy metals can cause serious problems, such as diseases if they are not treated correctly. However, most people do not have the consciousness to do garage sorting. Suppose humans do not carefully separate these potentially harmful necessities from other common garbage. In that case, these daily stuff will be buried in landfills and slowly release poison chemicals into the soil. Although a person's landfill of a single battery or thermometer cannot impact the entire environment, the problem is magnified thousands of times by a huge population.

2.3 Pesticide Chemicals

Spraying pesticides is an indispensable part of crop cultivation, but the composition of the pesticide could be harmful, leading to pesticide pollution, a significant issue for people (Table 1). When a field is tilled repeatedly year after year, the cumulative amount of heavy metals and pesticide spread also rises and poses a potential threat to crops and soil. Since agriculture goes hand in hand with irrigation, this also raises the possibility of water pollution. Table 2 shows heavy metals in pesticides.

Table 1. The different pesticide toxicity classifications according to the World Health Organization (WHO) [1]

WHO Type	Toxicity Level	LD_{50} for the Rat(mg/kg Body Weight)		Examples
		Oral	Dermal	
Type Ia	Extremely hazardous	<5	<50	Parathion, Dieldrin
Type Ib	Highly hazardous	5–50	50–200	Eldrin, Dichlorvos
Type II	Moderately hazardous	50–2000	200–2000	DDT, Chlordane
Type III	Slightly hazardous	>2000	>2000	Malathion

Table 2. The heavy metals accumulated in soils after using different functional pesticides in vegetable fields [2]

Pesticide types	Cumulative amount/(mg/hm^2)						
	Cr	Cu	Zn	As	Cd	Hg	Pb
Herbicides	2.61	2.83	2.79	2.98	0.0064	1.72	1.06
Insecticide	112	41.7	28.6	22.3	0.11	4.21	10.8
Non Cu/Zn fungicides	50.7	22.0	63.0	5.93	0.052	1.23	7.78
Fungicides containing Cu	41.7	331633	640	3.92	0.13	1.41	8.65
Fungicides containing Zn	33.7	143	86292	2.94	6.65	0.54	7.56

3. Impacts Posed by Heavy Metals on

Agriculture

3.1 Crop Growth

The introduction of heavy metals will inevitably affect the growth of crops. Industry is growing rapidly, raising the possibility of untreated pollutants being intentionally discharged [3,4]. Therefore, in agricultural production, people are more likely to unconsciously use industrial wastewater for irrigation [3, 4]. Through biomagnification, this is likely to trigger the trophic cascade and ultimately affect the sustainability of agriculture [3, 4]. The seed is a relatively initial plant growth form, so the seed germination process is essential in forming plants' physiological processes. To improve survival chances, seeds have evolved certain sensory mechanisms. The seed can sense its surroundings and will only germinate and grow when the environment is conducive to growth. However, many seeds are still exposed to severe environmental factors after germination despite the protection of these mechanisms [5]. Heavy metals, such as Co, Cd, Cu, Ag, Pb, Zn, and Hg, have all been proven to have some negative impacts that people are not willing to see in the germination process of seeds. Photosynthesis is a significant physiological activity supporting plant growth. However, it is known that heavy metals can damage the process to a certain extent. The different photosynthetic apparatuses are easily attacked by toxic metals, which cause the plant foliage to be full of deposited heavy metals, the formation of photosynthetic pigments is greatly reduced, and so on [5]. In conclusion, heavy metals can affect plant life in various ways and result in abnormal development of crops.

3.2 Hazards to Humans

3.2.1 Heavy metal exposure

The heavy metals in soil may be exposed to humans in four ways. First, the human diet has a chance to consume heavy metals. The accumulation of heavy metals in the human body often comes from vegetables, fruits, and crops grown from contaminated soil; this process is often called biomagnification. Second, it is highly likely that humans will directly inhale soil particles containing heavy metals. Third, contaminated soil dust may be inhaled through the nose or mouth. The last is often called skin exposure, where the skin is directly exposed to contaminated soil particles [6]. Fig. 1 shows the aspects that heavy metal influences the human body.

3.2.2 Destruction to human beings

Admittedly, certain amounts of trace elements, such as iron, nickel, copper, and zinc, are inside the human body to help balance the organism system. Still, too many of them will be harmful to human beings [7]. It is reported that components and cellular organelles, such as nuclei, cell membranes, lysosomes, mitochondria, and enzymes, can be highly influenced by heavy metals. By proving that metal ions can react with nuclear proteins and DNA, researchers show that this can lead to carcinogenesis or cell cycle modulation, as well as apoptosis because of the destruction of DNA.
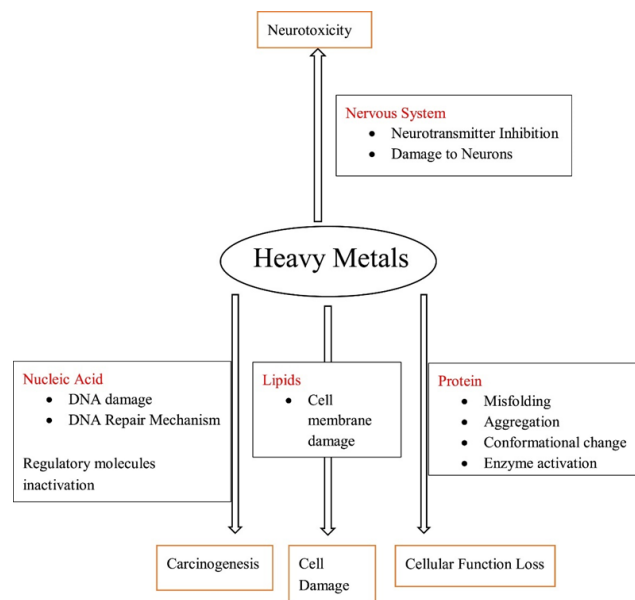

Fig. 1 Human exposure and source of heavy metals [7]

4. Measures to Mitigate the Harm of Heavy Metals

Heavy metal pollution has already become a severe issue that must be solved immediately. Although several treatments and techniques have already been invented to fight against pollution, they are not enough because contamination control requires multi-participation. Governments and farmers, who have a close relationship with crop production, should take action to improve the situation and bring people fresh food that is safe to eat.

4.1 Heavy metal treatment technology

To deal with heavy metal pollution and ensure public health, plenty of effective measures against heavy metals, which extensively use physical, chemical, and biological knowledge, have been proposed.

4.1.1 Instrument and principle of LIBS

Laser-induced breakdown spectroscopy (LIBS) is an elemental analysis technology based on atomic emission spectrometry [8]. The LIBS technique develops rapidly and is generally used in many domains, especially in the

soil heavy metal detection field. LIBS, as equipment with high efficiency, performs significantly well regarding detection speed and avoidance of secondary pollution. Furthermore, the LIBS can detect several different minerals simultaneously, which could help researchers save time for research.

4.1.2 Phytoremediation

Because the existing traditional heavy metal treatments are expensive and have low efficiency in low pollutant concentration cases, phytoremediation seems to be a better solution. The main idea of phytoremediation is to use certain plants with a high heavy metal accumulation capacity to absorb heavy metals to achieve the purpose of soil purification (Fig. 2). researchers continue to observe and develop plants with greater tolerance and adsorption capacity. Work to find better solutions for phytoremediation.
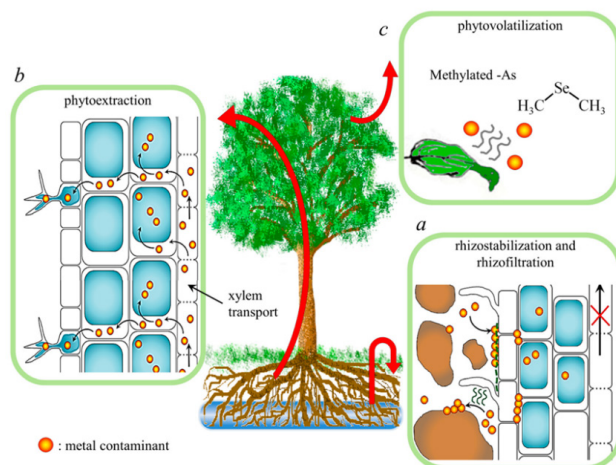

Fig. 2 Main processes of phytoremediation [9].

4.2 Government Solution

As a power organ that can play a decisive role, the government can contribute to controlling and preventing heavy metal pollution. For related industries like mining and smelting plants, policies should be issued to set emission standards for pollutants. For example, the government can set up a special department for heavy metal pollution to measure the emissions of factories and strengthen pollution supervision [10]. Then, based on the measurements, the government can collect fines from factories that exceed the measure standard to alarm them. Meanwhile, purifiers should become a necessity in the industry. Tax preference can be given to factories that actively install purifiers to promote the installation of purifiers. The government must set up to the plate for land resources that are already contaminated. They can organize manpower and technology to clear land. Simultaneously, farmers can

be offered some basic skills for cleaning up less polluted land. It is believed that these actions will play a positive role in managing heavy metal pollution.

4.3 Government Solution

Farmers are among those most concerned about soil pollution as people who possess farmlands and rely on agricultural production. Soil quality testing is an effective way to avoid crop contamination problems. For instance, the farmers can ask professional heavy metal testing companies to test the local soil and nearby water sources to receive agricultural safety insurance. Furthermore, farmers can use biological control methods rather than pesticides to reduce pest problems. Thus, the soil heavy metal pollution caused by the use of pesticides can be well-solved.

5. Conclusion

Agriculture is crucial to mankind's development since it is an important part of it. To realize the sustainable development of agriculture, human beings need to continuously improve agricultural production technology and pay enough attention to the environment. Heavy metal pollution is very harmful to agricultural production, leading to crop yield reduction and affecting human health since long-term consumption of heavy metal-contaminated agricultural products can pose a severe danger to human health. In this paper, heavy metal pollution sources and their impact on agriculture are discussed in depth. It is found that the dominant sources of heavy metal pollution include industrial emissions, excessive use of pesticides, and urban household waste. These pollutants accumulate in the environment and eventually cause serious harm to agriculture. To alleviate the impact of heavy metal pollution on agriculture, we must start from the source, strictly control pollutant emissions, strengthen environmental supervision, and improve public awareness of environmental protection. In addition, this paper analyzes the current status of heavy metal pollution in detail and puts forward practical measures to solve the existing problems. We should increase scientific research on environmental protection, promote green agricultural technology, improve relevant laws and regulations, and raise public awareness of environmental protection to ensure the sustainable development of agricultural production.

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