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Effect of heavy metals in metal plating plant waste sludge on tea plant primary development

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Heavy metals, some of the elements that damage nature, are known to have macroscopical, microscopical, and physiological effects on plants' vegetative organs. All living creatures that continue to live active lives in nature are impacted by this unfavorable circumstance, including the generative and vegetative organs of plants. Without understanding the consequences, people have been using heavy metals for ages in a variety of applications, including jewelry, weaponry, water pipes, etc. Coal that contained heavy metals started to be burned as a result of industrialization, and because our world is exposed to more and more industrial areas and traffic every day, the amount of heavy metal pollution combined with many other pollutants has increased to extremely high levels.

In addition to building up in living things, these compounds can persist in ecosystems for extended periods of time at hazardous amounts and move up the food chain. It is widely accepted that humans are the primary source of heavy metals' expansion and ecological harm when taking into account their dispersion in nature. Heavy metal concentrations are high in the environment due to ongoing pollution and usage-related factors. This concentration has a detrimental effect on natural plants and produces highly hazardous compounds for human health. This study used data from the greenhouse study on the tea plant to evaluate the sludge released for waste disposal in the metal coating facility in fertilizer production. Significant statistical results were obtained in terms of agricultural chemistry, and the topic of evaluation within the framework of the circular economy was discussed.

Keywords: tea plant, heavy metal, toxic effect, boron fertilizer, compound fertilizer

INTRODUCTION

People have always been fascinated by the natural world and the things that happen there. The development of organs like roots, stalks, and leaves by seeds that sprout in specific soil circumstances was one of the major topics that early humans were interested in because plant life has always been essential to human survival as a source of food, raw materials, and energy. Through their roots, plants may readily absorb the materials they require to grow and finish their physiological phases from the earth. In the same form as they are present in plants, these chemicals can also be found in soil. Many people think that these compounds that are present in plants are imported [1]. In plant nutrition, each nutritional component plays a distinct purpose and needs to be delivered to the plant in a balanced way. As they absorb nutrients, plants—which are extremely important to agriculture—face a variety of external factors. These adverse impacts are a major factor in reducing the plant's vitality. "Plant nutrient elements" are the components that plants require in order to survive. When plant tissues are analyzed, practically every element present in nature can be detected. Despite the fact that plants are selective in their nutrient ion intake, some heavy metals that can passively enter the plant body are absorbed by the plants and added to the food chain as the percentage of nutrients in a usable form in the growing environment rises. They may therefore be harmful to plants, as well as to people and animals that consume plants because plants absorb elements from their surroundings, whether or not they are essential to them, even in trace amounts. Nonetheless, all plants require 16 of these elements—C, H, 0, N, P, K, S, Ca, Mg, Fe, Zn, Mn, Cu, B, CI, and Mo—as vital nutrients. The remaining six elements—Co, AI, Na, Si, Ni, and V—are helpful but only deemed essential for specific plants or processes [2]. The number of heavy metals and several other contaminants in the environment is increased by both fast industrialization and exposure to growing traffic density. Numerous negative effects result from this circumstance, including the loss of products in plants that are unable to move [3]. Environmental pollution is seen as one of the most significant issues brought about in nature by urbanization and industrialization [4]. Fungicides and wood preservatives that contain metals have been said to damage soil and plants.

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These products are commonly employed by mining, metal and chemical companies, and gases and dusts are released by major industrial complexes [5]. For plants that grow in this kind of soil, heavy metal pollution in particular presents a serious risk. In order to boost production, extensive research is being conducted on soils containing this kind of heavy metal pollution using various reclamation techniques [6].

The productivity of soil and plants is negatively impacted by the amount of different gases and particles in the atmosphere, air pollution, and waste from manufacturing chimneys. All living creatures are now at risk from air and heavy metal pollution, which began as a result of industrial development and has been becoming worse since the second part of the 20th century. Since plants are the main producers in ecosystems, they are far more at risk. Numerous studies have found that these metals have a major impact on plants' vegetative organs. However, according to Kapitonova (2002), metal contamination impacts both the generative and vegetative organs [7].

"A metal with a relatively high density and which is toxic or poisonous even at low concentrations" is the definition of a heavy metal, which is typically encountered when environmental issues arise. In actuality, metals with a density greater than 5 g/cm^3 in terms of physical characteristics are classified as heavy metals. This category comprises over 60 metals, such as lead, cadmium, chromium, iron, cobalt, copper, nickel, mercury, and zinc. Because of their nature, these elements are typically found on Earth in stable compounds like carbonates, silicates, and sulfates, or bonded in silicates [8]. High amounts of some heavy metals can harm humans, animals that eat plants, and plants themselves. If soil contains 10–100 mg/kg of chromium, nickel, and lead, and less than 1 mg/kg of cadmium, these elements are regarded as typical. As environmental contaminants, cadmium and lead pose major health risks to both humans and animals. While nickel may be carcinogenic to the same group of organisms, chromium is an important microelement that is harmful to mammals and other animals at high doses. Nonetheless, it is now acknowledged that nickel is a necessary nutrient for higher plants. When extractable heavy metal concentrations in soils exceed 1 mg/kg for Cd, 10 mg/kg for cobalt, 0.1 mg/kg for copper, 10 mg/kg for selenium, 0.5-1 mg/kg for vanadium, and 100 mg/kg for nickel, toxic effects may ensue [9]. Cd, Pb, and Hg are said to be the most hazardous heavy metals [10]. Some metals are actual components of global ecosystems, and they are found in nature. Life depends on metals like zinc and copper. The system of enzymes that controls plant metabolism depends on zinc. Nevertheless, it is unknown if other metals, such lead and mercury, have any practical biological purpose [11]. Except for mercury and lead, which are toxic and unnecessary elements, copper and zinc are micronutrients required for the majority of enzyme activities and are part of molecules that play a crucial role in photosynthetic electron transport, even though they are toxic at high concentrations [12].

EXPERIMENTAL

ICP-OES ion chromatography analysis

In the study, HORIBA France SAS brand Ultima Expert LT Model ICP OES device was used for heavy metal content analysis of damaged tea leaves in the greenhouse. The 25.5.10 fertilizer used during the study was produced under laboratory conditions and the relevant composition was prepared by using the chemical compounds shown in Table 1.

Table 1. 25.5.10 compound fertilizer chemical composition

Chemical composition	Chemical formula	CAS number	Amount (%)
Diammonium phosphate	$(NH_4)_2HPO_4$	7783-28-0	9,3
Urea	CH_4N_2O	57-13-6	49,4
Potassium chloride	KCl	7447-40-7	15,2
Volcanic ash-perlite	SiO_2	93763-70-3	24,5
Wet mud/ dry mud/ dry phosphate/ wet phosphate/ dry carbonate/ wet carbonate	-/-/PO_4/CO_3	-	1

During the preparation of 25.5.10 fertilizer, the contribution of “wet mud/ dry mud/ dry phosphate/ wet phosphate/ dry carbonate/ wet carbonate” was 1%.

RESULTS AND DISCUSSION:

For the 25.5.10 compound fertilizer, which is the most produced and has the highest sales potential fertilizer for the tea plant as a waste material in the electrolytic metal coating industry, 6 different chemical compositions were studied depending on the trace element content of the raw material source. The toxic effect of the 25.5.10 fertilizer of these 6 different chemical compositions on the tea plant, especially on the leaves, during its development is shown in Figures 1-6. In this respect, the toxic effect of the waste material number 1 in Figure 1 during the development of the plant is seen as a brown-yellow color effect.

The aluminum and boron contents, in the concentrations specified in Table 1, were obtained by adding 1% to the 25.5.10 fertilizer of wet sludge, as shown in Figure 1. As can be seen in Figure 1, in a greenhouse application for 1 month, at 35 °C and 65% humidity, the metal concentration was as follows: brown and yellow spots formed from the outside to the inside of the leaf.

Figure 1. Effect of 25.5.10 fertilizer with wet sludge additive on tea leaves

Figure 2. Effect of dry sludge added 25.5.10 fertilizer on tea leaves

Figure 3. Effect of wet carbonate added 25.5.10 fertilizer on tea leaves

On the other hand, when waste number 2, expressed as dry sludge, was added to 25.5.10 fertilizer at 1%, a result like in Figure 2 was obtained. As seen in Figure 2, brown and yellow areas are more than 25.5.10 fertilizer with wet sludge content. The reason for this is that in the ICP OES analysis, especially Al and B content is higher than wet sludge content.

However, the heavy metal analysis of wet carbonate sludge released as a result of the phosphatization process as a metal industry waste is shown in Table 2. Based on this, in the greenhouse study conducted, as a result of the addition of a maximum of 5 g of 25.5.20 fertilizer per pot, brown and yellow color decreases were observed in tea leaves from the outside to the inside under the same greenhouse conditions (35 °C, 65% humidity) (Figure 3).

Unlike the wet carbonate-containing waste, dry carbonate contains approximately 20% moisture, however, a dramatic decrease in heavy metal concentrations is observed from the ICP-OES analysis results in Table 1. Based on this, in the results of the greenhouse study conducted, in the same amount of 25.5.10 fertilizer, a decrease in the rate of brown and yellow spots is observed compared to the images in Figures 1, 2 and 3, as seen in Figure 4.

Figure 4. Effect of dry carbonate added 25.5.10 fertilizer on tea leaves

Figure 5. Effect of 25.5.10 fertilizer with wet phosphate additive on tea leaves

Figure 6. Effect of dry phosphate added 25.5.10 fertilizer on tea leaves

Another material used in the fertilizer industry as metal industry waste is phosphate. Carbonate is evaluated in terms of moisture content according to the process in which it is produced and is called dry phosphate and wet phosphate. As can be seen from the ICP-OES results in Table 2, metal contents are close to each other, and as a result of the greenhouse study, the healthiest leaves were seen in the greenhouse study of 25.5.10 fertilizer to which this waste material was added in order to preserve its natural color (Figures 5, 6).

The effect of only 25.5.10 fertilizer on the development of tea plants in the greenhouse without the addition of the metal industrial waste, which is the subject of the study here, is shown in Figure 7. As shown in Figure 7, since 25.5.10 fertilizer does not contain any heavy metal content, it can be stated that there is no toxic effect, because no brown or yellow spots are observed on the tea leaves.

Figure 7. Effect of 25.5.10 fertilizer without any waste material additive on tea leaves

Table 2. Heavy metal ICP-OES content analysis of 6 different compositions added to 25.5.10 fertilizer as metal industry waste

		Al	B	Co	Cr	Cu	Fe	Mn	Ni	Pb	Zn	Ca	K	Mg	P	S	K_2O	P_2O_5	SO_3
Sample	No	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Wet mud	1	186596	207	477	6845.5	861.37	142364	15004	21772	230	218020	12.56	4.38	0.95	27.14	0.57	5.28	62.25	1.43
Dry mud	2	777334	1140	2166	33124	4545.6	438036	60365	91839	989.4	348800	58.85	24.85	4.28	118.45	2.84	29.94	271.68	7.1
Dry phosphate	6	2697.6	35	2.73	2983.4	217.92	584053	92377	81131	1292	318462	4.91	21.45	0.09	152.72	0.21	25.84	350.27	0.52
Wet phosphate	5	899.19	13.3	34.7	1055.9	71.11	368403	38226	29272	463.9	197378	1.63	7.14	0.03	65.54	0.09	8.61	150.33	0.21
Dry carbonate	4	120.56	104	2.73	5.14	26.21	364.93	6.4	941.66	2.49	11255	0.03	2.1	0	-0.07	17.5	2.53	-0.16	43.75
Wet carbonate	3	98.19	133	3.5	5.63	13.55	194.26	6.43	909.35	-0.52	10539	0.07	1.53	0.03	-0.15	23.22	1.84	-0.35	58.04

Heavy metals endanger the development of plants and animals, and also pose a hazard to human health in particular. Our environment is heavily polluted with heavy metals from industrial wastes that are growing daily as a result of growing industrialization and the acceleration of motor vehicle production. Agricultural areas also bear a portion of this pollution. European nations, which are especially concerned about the environment, have passed strict environmental laws and regulations and protected their soil and water resources, which are the most prized assets in agriculture. From an industrial standpoint, it is very pleasant that lead-containing gasoline production has ceased in recent years; yet, this is not thought to be adequate to reduce industrial waste. Enacting strict laws and regulations as soon as possible is crucial to protecting our water and soil resources from the dangers posed by heavy metal pollution.

The most harmful effects of heavy metals in soil include their ability to penetrate plant structures, their ability to mix with groundwater when they become mobile (as free ions), their ability to damage microorganisms, their ability to enter the food chain and indirectly harm other living things, their ability to cause plasma hardening in cells, swelling and shrinkage, protein precipitation, and a decrease in respiratory intensity and, consequently, oxygen consumption. The concentration of heavy metals, their form of presence (metal, ion, organic compound, etc.) species, duration of action, location, etc., all affect how poisonous they are. Agronomic practices like pH adjustments, organic matter and fertilizer management, proper plant selection, physical stabilization, strong acid washing, liming, phosphorus fertilizer application, washing with heavy metal chelators, and phytoremediation techniques can all help reduce the amount of heavy metals in soil.

As can be seen from the current results of this study, when the chemical compositions prepared in the form of wet sludge, dry sludge, wet phosphate,dry phosphate, wet carbonate and dry carbonate of the metal plating industry were compared with the 25.5.10 fertilizer which does not contain any of these additives, the toxic effect of this waste material was revealed by brown and yellow spots on the development of the tea plant which was the subject of the greenhouse study, as can be seen from the analysis results.

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