

# The Effect of Sewage Sludge on Heavy Metal Accumulation in Onion Plant (*Allium cepa* L.)

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**Abstract:** In a greenhouse experiment, the effect of applying sewage sludge to the soil on the dry matter content and heavy metal concentrations in onion plants (*Allium cepa* L.) was investigated. Under greenhouse conditions, treated sewage sludge was applied to pots at different levels, and onion plants were grown. In relation to sewage sludge applications, the levels of metals extractable with DTPA in the soil increased. The application of sludge had a statistically significant effect on the dry matter content of the leaves and bulbs, as well as on the Zn, Cu, Ni, Pb, and Cd contents in the leaves and bulbs. While the Zn, Cu, Ni, Pb, and Cd contents in the leaves and bulbs of the onion plant increased with sewage sludge applications, there was no significant change in Cr content. It was determined that Zn was the predominant metal accumulated in the leaves and bulbs. At high sludge application rates, the Zn and Pb concentration in the bulb tissue exceeded the reported limit values for the edible parts of vegetables. Sewage sludge applied to the soil positively affected plant growth and dry matter content at low levels; however, at high application rates (20 and 40 g/kg), it caused growth arrest and phytotoxicity.

**Keywords:** Sewage Sludge, Heavy Metals, Onion

## I. INTRODUCTION

Sewage sludge is the end product of municipal wastewater treatment and contains many pollutants remaining after wastewater treatment. Sewage sludge is a suspension of concentrated solids consisting primarily of organic matter and nutrient-rich organic particles; its consistency can vary between a slurry and a dry form depending on the treatment technique. The volume of sewage sludge is rapidly increasing today due to the growing population served by sewer systems, the spread of industrialization, and the commissioning of a greater number of wastewater treatment plants. The increasing volume of sewage sludge in cities, driven by population growth, coupled with the growing diversity of chemical substances within the sludge, is making the safe disposal of sludge increasingly challenging.

Since sewage sludge contains approximately 50–70% organic matter by dry weight and significant amounts of plant nutrients, it has been recognized in recent years as a notable and exceptional source of soil organic matter and organic fertilizer. It has been reported that the nutrient value of sewage sludge is similar to that of manure and organic compost and that it contains all the elements necessary for plant growth [1]. It has been reported that trace elements such as Zn and Cu are frequently deficient in soils that have been

cultivated for many years [2] and that the application of sewage sludge can help address these deficiencies [3]. It has been reported that when sewage sludge is applied at agronomic rates for N and P, it can sufficiently meet the plant's needs for most other essential nutrients (with the exception of potassium) [4].

Unlike commercial fertilizers, the nutrient content of sewage sludge is uncontrolled and can vary significantly depending on location and time. Therefore, applying sewage sludge to the soil in agronomic quantities to meet the requirement for one nutrient may result in excess or deficiency of other nutrients [5]. Additionally, depending on the characteristics of the wastewater entering the treatment system and the treatment process itself, the sludge exiting the system may contain high levels of salts, pH, heavy metals, and toxic substances. The fact that heavy metal accumulation is frequently observed in many soils where this material is applied is considered a limiting factor in the use of this rich organic matter source. However, the results of numerous studies indicate that soil contamination issues can be minimized when the necessary standards for the use of sewage sludge are followed. Nevertheless, it is believed that studies based on plant species responses are still necessary due to the varying effects of pollutants in sewage sludge on different plant species.

In this study, the effects of applying sewage sludge to soil on dry matter content and heavy metal concentrations in onion plants were investigated in a pot experiment conducted in a greenhouse.

## II. MATERIAL AND METHODS

In a greenhouse experiment, the effect of sewage sludge applied to the soil at varying rates on the Zn, Cu, Ni, Pb, Cd, and Cr contents in onion plants was investigated. The experiment was conducted in a plastic-covered greenhouse, and the onion plants were grown in plastic pots containing 15 kg of dry soil. In the experiment, a virgin soil sample known as "Red Mediterranean soil," taken from the Mediterranean soil group in the central district of Antalya, was used. The soil sample was collected from the 0–20 cm depth, sieved to 2 mm, and used in the experiment in an air-dry state. Some physical and chemical properties of the soil and the treated sludge used in the experiment are presented in Table 1. According to soil analyses, the experimental soil has a medium-to-heavy texture, a slightly alkaline reaction, low calcium carbonate content, low electrical conductivity, and a low organic matter content. The total Zn, Cu, Ni, Pb, and Cd contents of the experimental soil and sewage sludge are below

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the reported limit values for these materials, indicating that the soil is of clean quality.

TABLE I. ANALYTICAL CHARACTERISTICS AND CONTAMINANT LIMIT VALUES OF THE TEST SOIL AND SEWAGE SLUDGE

Ölçütler	Experimental soil		Heavy metal limit values in soil <sup>1</sup>	Sewage sludge	Heavy metal limit values in wastewater sludge <sup>1</sup>
Texture	Killi tın			-	
pH, (1:2 w/v)	7,68			7,55	
CaCO <sub>3</sub> , %	3,65			0,88	
E.C., µS/cm	288			3750	
Organic matter, %	1,85			62	
Zn, µg g <sup>-1</sup>	65 <sup>1</sup>	2,2 <sup>2</sup>	150-300	1875	2500-4000
Cu, µg g <sup>-1</sup>	22	0,5	50-140	64	1000-1750
Pb, µg g <sup>-1</sup>	26	1,8	50-300	348	750-1200
Ni, µg g <sup>-1</sup>	32	1,5	30-75	56	300-400
Cd, µg g <sup>-1</sup>	*	*	1-3	1,8	20-40
Cr, µg g <sup>-1</sup>	*	*	-	-	-

\*: Below the detection limit ( $< 0.001 \mu\text{g g}^{-1}$ ); 1: Total concentrations ( $\mu\text{g g}^{-1}$ , dry weight) [6]; 2: DTPA-extractable concentrations ( $\mu\text{g g}^{-1}$ , dry weight)

The sewage sludge used in the experiment was collected during the summer from the Antalya Metropolitan Municipality Wastewater Treatment Plant. After the fresh sewage sludge was collected, it was composted in the open for 3 months, air-dried, and sieved to 2 mm before being applied to the soil. The sewage sludge was applied to the respective pots at levels of 0, 10, 20, 40, and 80 g/kg based on absolute dry weight, mixed with the soil, and the total weight was adjusted to 15 kg. After the sewage sludge was incorporated into the soil, the mixture was left to incubate for two months under field conditions.

The experiment was designed as a randomized block design with five replications. In the experiment, 10 healthy onion (*Allium cepa* L.) seeds were sown in each pot, and the plants were subsequently thinned to leave 5 plants per pot. The soil in the pots was irrigated to field capacity, and the plants were grown under greenhouse conditions with regular phenological observations. The plants were harvested 90 days after germination by removing them from the pots. Leaf and bulb samples were collected for analysis, washed according to standard procedures, dried in an oven at 65°C, and their dry matter contents were determined. The plant samples were then ground and wet-ashed using aqua regia (1:3 HNO<sub>3</sub> /HCl) for metal analysis. At the end of the experiment, soil samples were collected from the pots, processed according to standard procedures, and extracted by using Diethylenetriaminepentaacetic acid (DTPA). In the wet-ashed plant samples and the DTPA-extracted soil samples, Zn, Cu, Ni, Pb, Cd, and Cr were determined by using ICP-MS.

A statistical Anova F test was applied to the results and treatment means were compared by the least significant difference test at  $P < 0.05$ .

### III. RESULTS AND DISCUSSION

In the experimental soil, the levels of metals extractable with DTPA from the applied sewage sludge increased with increasing application rates, with the exception of chromium. It was determined that Zn was the predominant metal among those extractable with DTPA (Table 2). These results indicate that the application of sewage sludge to soil not only increases the total metal content in the soil but also significantly increases the fraction of metals forms readily available to plants. On the other hand, it is also understood that the metals present in the sewage sludge are largely in a form readily available to plants. These findings indicate that in the use of sewage sludge, both the total metal concentrations in the sludge and the concentrations of metals beneficial to plants must be taken into account. The experimental results are consistent with other studies indicating that the accumulation of heavy metals increases in both plants and soil when sewage sludge is applied to the soil over many years [7, 8, 9].

TABLE II. EFFECT OF SEWAGE SLUDGE APPLIED TO SOIL ON THE DTPA-EXTRACTABLE METAL CONTENT IN THE EXPERIMENTAL SOIL AFTER INCUBATION

Treatments, g kg <sup>-1</sup>	Zn	Cu	Ni	Pb	Cd	Cr
	µg/kg					
0	2,18	0,51	1,48	1,77	<0,001	<0,001
10	13,42	0,57	1,66	6,71	0,022	<0,001
20	28,06	0,67	3,52	13,42	0,068	<0,001
40	42,70	0,70	6,78	20,74	0,104	<0,001
80	76,21	0,82	11,52	25,62	0,181	<0,001
Significancy	**	*	**	**	**	ns

\*\* :  $P < 0.01$ , \* :  $P < 0.05$ , ns: no significancy.

An increase in the dry matter content of onion plant leaves and roots was observed following the application of 10 and 20 g/kg of sewage sludge to the soil; however, a decrease in dry matter content was observed with applications of 40 and 80 g/kg (Figure 1). This indicates that at high application rates, sewage sludge with high salt and heavy metal content has a negative effect on the growth of the onion plant, which is extremely sensitive to salinity.

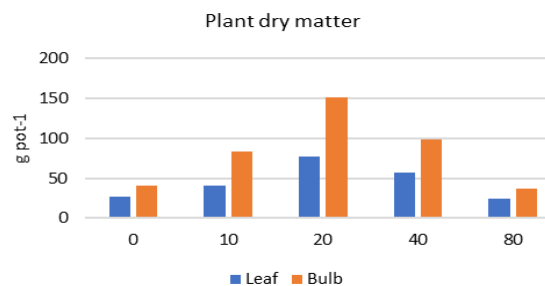


Fig. 1. Plant dry matter in treatments

Sewage sludge applications significantly ( $P > 0.05$ ) affected the levels of Zn, Cu, Pb, Ni, and Cd in the leaves, and heavy metal accumulation in the plant increased as the sludge application rate increased (Table 3). No significant change was observed only in Cr content. The similar trend in changes in metal content observed in leaf tissue following sludge applications was also observed in the bulb tissue of the onion plant. In numerous studies on onion plants, heavy metal

accumulation in leaves and roots has been documented in association with the application of sewage sludge to soil [10, 11].

TABLE III. EFFECT OF SEWAGE SLUDGE APPLIED TO SOIL ON DRY MATTER CONTENT AND METAL CONCENTRATIONS IN THE LEAVES AND BULBS OF ONION PLANTS

Plant tissue	Treatments, g kg <sup>-1</sup>	µg g <sup>-1</sup>					
		Zn	Cu	Ni	Pb	Cd	Cr
Leaf	0	28,60	6,93	1,65	2,20	<0,001	0,11
	10	35,20	12,10	4,29	12,32	0,06	0,13
	20	69,30	13,20	7,70	21,12	0,28	0,11
	40	134,20	16,50	9,79	31,57	0,98	0,12
	80	314,60	20,90	15,40	43,45	1,09	0,13
Bulb	0	29,04	5,54	1,41	1,85	<0,001	0,10
	10	48,40	7,04	3,34	13,38	0,06	0,11
	20	65,12	14,96	6,25	24,90	0,31	0,11
	40	118,80	16,72	7,48	31,59	0,58	0,09
	80	243,76	20,24	11,44	41,89	0,74	0,11
Significance		**	*	**	**	**	ns
Basal levels [12]		40	8	2	3	<0,50	-
Phytotoxic levels[13]		100-	20-	10-	30-	5-30	5-300

The normal basal levels of metal content detected in both tissues of the onion plant were exceeded in the sludge applications. Heavy metal content in the onion plant was found to be higher in the bulb tissues than in the leaves. Only the change in Cr content was at a very low level in both the leaves and the roots. The metal contents determined in the leaf and root tissues of the onion plant exceeded the phytotoxicity threshold values at 40 and 80 g/kg sludge applications. These findings indicate that the onion plant is highly sensitive to salt and metal contamination in its growing environment and are consistent with the results of most studies [14, 15].

#### IV. CONCLUSION

The findings of the study indicate that sewage sludge promotes growth in onion plants at low application rates, but high application rates cause growth retardation, dry matter loss, and phytotoxicity. High-level sludge applications significantly increased both DTPA-extractable metal contents in the soil and metal contents in the plants. Experimental findings regarding the agricultural use of sewage sludge generally indicate beneficial effects in terms of nutrient content and organic properties; however, the risks of heavy metal accumulation associated with long-term applications cannot be ignored. In addition, the sensitivity of plant species to salts and metals, which may be present in potentially high amounts in sewage sludge, is considered a critical factor that must be taken into account in sludge application. These risks must be considered, particularly in the cultivation of onion plants, a species that is extremely sensitive to salinity stress.

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