Phytoremediation of Lead-Contaminated Shooting Range Soils using Indian Mustard and Sunflower

Mohd Adnan[1], Sukhwinderpal Singh[2], Balihar Singh[3]

[1]*M.Tech (Environmental Science and Engineering), GNDEC Ludhiana, Punjab, India*
[2]*Assistant Professor, Dept. of Civil Engineering, Guru Nanak Dev Engineering College, Ludhiana, Punjab, India*
[3]*Assistant Professor, Dept. of Civil Engineering, Guru Nanak Dev Engineering College, Ludhiana, Punjab, India*

---***---

Abstract - *Lead in the soil is a common problem that hurts people and the environment. It gets into the soil from manufacturing, past lead use, and throwing things away that have lead in them. This is a big problem because lead can hurt the land and get into our water. We need to come up with good solutions to this problem. With phytoremediation, heavy metals like lead can be taken out of contaminated soil. It uses plants that can take in, move, and store heavy metals, which makes the earth cleaner. We looked at two plants, Indian mustard and sunflower, to see if they could remove lead from shooting ranges. Both plants did a good job, but Indian mustard did it better, cleaning up 67% of the lead while sunflower only cleaned up 54%. So, Indian mustard and sunflower are good choices for cleaning up lead at shooting ranges. They can get rid of lead and improve the dirt. By using plants' natural abilities, phytoremediation is a cheap and long-lasting way to deal with lead pollution, protect the environment, and help the land heal.*

***Key Words*: Lead pollution, Phytoremediation, Indian mustard, Sunflower, Shooting ranges**

1.INTRODUCTION

Our lives depend on the delicate balance of our environment, which includes the air we breathe, the water we drink, the land we live on, and the ecosystems that keep life going. Unfortunately, this balance is threatened by things that people do, such as industrial processes, mining, and not getting rid of lead-containing products properly. When heavy metals like lead are in the environment, they pose a major threat to both nature and human health. Heavy metals are naturally occurring substances that can hurt the environment and people's health if there are too many of them. Some of the elements in this group are lead, mercury, cadmium, arsenic, and chromium. The widespread release of these toxic substances into the environment, which is caused by both human activities and natural geological processes, has made people very worried about the bad effects they will have.

1.1 Lead and its acceptable limit in soil

Metals like lead have been used by people for a very long time. Pb stands for it, and its atomic number is 82. It's easy to bend lead, which is a soft, grey metal that doesn't rust. It has been used in many fields because of these qualities. But using lead has hurt the earth and people's health in very bad ways.

When lead gets into the ground, it can hurt both people and the environment. What the land is used for and the rules set by different countries or groups determine how much lead is allowed in the dirt. There was a lot of study that went into making these rules. The Environmental Protection Agency (EPA) in the US has set a lead limit of 400 parts per million (ppm) in dirt near homes. This means that people could get sick if they touch or eat things that grow in dirt that has more lead than this amount. There should be no more than 120 parts per million (ppm) of lead in the dirt in places where people garden or farm. Lead from the earth can get into plants, and then it could end up in the food we eat. When you think about how much lead is allowed in dirt, keep in mind that each country has its own rules. So, it's very important to follow the laws and rules that apply to a place when you're doing study or trying to clean up lead there.

1.2 Phytoremediation

Phytoremediation is the cleanup of contaminated soil, water, and air using plants and the microbial communities they are associated with. This method is natural, cheap, and safe for the earth. It uses the natural abilities of some plant species to absorb, change, or stabilise pollutants, which lowers their levels in the environment.

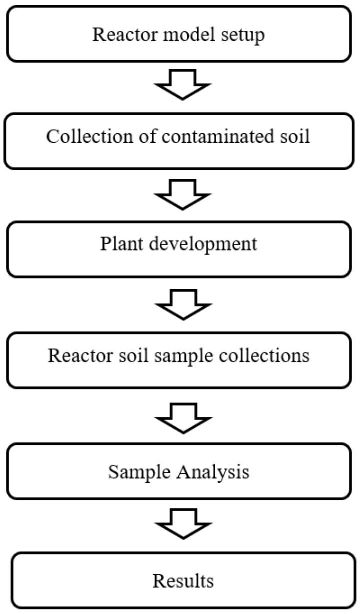
Phytoremediation can be used to get rid of heavy metals, organic pollution, radionuclides, and pesticides, among other things. Researchers have shown that phytoremediation could be a useful way to clean up lead pollution. Plants which are used for this research are Indian mustard and Sunflower.

1.3 Objective of this research

Pollution from lead in shooting range soils is a big problem for the environment and public health that could get worse. To deal with this problem, phytoremediation, a natural and environmentally friendly process, is becoming more popular, especially for harmful heavy metals like lead. In this study, the main goal is to find out how well Indian mustard and sunflower work as phytoremediation species to get rid of lead from shooting range soil.

2. Methodology

The flowchart shows the method used to examine the efficacy of Indian mustard and sunflower in lead phytoremediation in shooting range soil.



The following technique was used to achieve the research objectives:

1. Reactor Model Setup: A glass jar measuring 56 cm in length, 46 cm in width, and 28 cm in height was made to represent the shooting range's soil conditions. On one side of the pot, Indian mustard plants were grown, and on the other, sunflower plants were grown. The parts were clearly split up so that they could be separated and watched properly.

2. Collection of contaminated soil: Known sampling methods were used to get soil samples from a number of locations on the NCC shooting range site at Guru Nanak Dev Engineering College in Ludhiana. Samples of 30 kg of polluted soil were collected and put in clean containers with labels.

Fig 1: NCC shooting range site at Guru Nanak Dev Engineering College in Ludhiana

3. Plant Development: To grow plants, 10 cm apart Indian mustard (*Brassica juncea*) and sunflower (*Helianthus annuus*) seeds were put in glass containers. The seeds germinated normally, and the plants grew as planned. The pots were put in a well-lit area with enough sunlight, and the temperature was adjusted to make sure the seeds would germinate and grow well. Watering was done regularly with tap water that has been tested and found to be free of lead. This kept the soil at the right level of moisture for plant growth. Indian mustard grew best between 20°C and 25°C, and it did better in full sun than in some shade. It made sense to put Indian mustard in February and March because it grows best when it is cool. It was best for sunflower seeds to grow between 18°C and 24°C, and they needed to be in full sun. When put in February and March, just before spring, sunflowers did very well. Lead in the soil can hurt plants' health and growth in a number of ways. Too much lead can hurt plants by slowing their growth and making it harder for them to take in nutrients. It can also cause oxidative stress and death in the leaves, which can be seen as chlorosis and necrosis.

Fig 2: Reactor Model Setup

4. Reactor soil sample collection: Every five days for two months, soil samples were taken from the Indian mustard and sunflower parts of the glass container. To record differences in space, samples of each piece were taken more than once from different spots.

5. Sample analysis: The EPA 3050B method was used to get the soil samples ready for testing. To get the heavy metals out of the earth samples, strong nitric acid and hydrochloric acid were used as digesting reagents. The samples were heated in a device called a digestion unit, and digestion vessels were used to make the process go more smoothly. An AAS was used to test the digested soil samples. The AAS was calibrated with heavy metal analysis calibration standards that are widely used in business. The AAS readings were used to figure out how much lead was in the soil samples.

6. Results: The results from the AAS analysis showed the quantity of lead in the soil samples at different times. This gave important information about how well

phytoremediation with Indian mustard and sunflower worked. Throughout the study, careful records were kept of samples being taken and of plants growth. During the experiment, careful notes were taken on what was seen so that any changes in the plants and soil could be found.

2.1 EPA-3050B method

Atomic absorption spectroscopy has been used to determine the initial lead concentration using method epa-3050B acid digestion of sediments, sludge, and soils.

1. To achieve equal particle size, the materials were sieved with a USS #10 sieve. To avoid cross-contamination, all homogenization equipment was cleaned in accordance with the instructions.

Fig 3: Dry soil sample weighing 1 gm

2. Dry soil sample weighing 1 gm was added to a digestion vessel.

3. 2.5 mL of concentrated nitric acid (HNO3) and 10 mL of concentrated hydrochloric acid (HCl) were added to the sample in the digestion vessel. The sample was refluxed for 15 minutes on a heating source with the vessel covered with a watch glass or vapor recovery device.

Fig 4: Sample refluxed for 15 minutes

4. Whatman No. 41 filter paper was used to filter the digestate. In a volumetric flask measuring 100 mL, the filtrate was collected. The filter paper was washed once with 20 mL of hot reagent water and once with no more than 5 mL of hot (95°C) HCl while it was still inside the funnel. The same 100-mL volumetric flask was used to collect the washes.

5. The digesting vessel received the filter paper and residue back. The vessel was then filled with 5 mL of concentrated HCl and heated for 5°C at 95°C until the filter paper was dissolved. The vessel's cover and sides were cleaned with reagent water after being removed from the heating source. The filtrate was collected in the same 100-mL volumetric flask after the residue was filtered.

6. After allowing the filtrate to cool, it was diluted in the 100-mL volumetric flask to volume. Up to 10 mL of strong HCl was added to the flask to dissolve any precipitates that may have developed at the bottom. The solution was diluted to volume with reagent water after the precipitate had been dissolved.

Fig 5 : Final sample diluted in 100 ml volumetric flask

7. The digested and diluted soil sample solution was ready for further investigation with Flame Atomic Absorption Spectroscopy (FLAA).

3. Results and Discussion

The Guru Nanak Dev Engineering College's NCC shooting range soil contains lead at a value of 1579 ppm, which denotes a high degree of lead pollution.

Table -1: Concentration of Pb in soil before treatment (mg/kg)

Heavy metals	Concentration of heavy metals in soil (mg/kg)	Permissible limits (mg/kg)
Lead	1579	400

Table -2: Results for removal of Pb by Indian mustard

Time (Days)	Lead Concentration (mg/kg)	Lead Removal (%)
0	1579	-
5	1530	3.11
10	1454	7.93
15	1347	14.71
20	1238	21.61
25	1099	30.43
30	975	38.23
35	885	43.97
40	811	48.65
45	728	53.92
50	668	57.68
55	606	61.63
60	515	67.4

Table -3: Results for removal of Pb by Sunflower

Time (Days)	Lead Concentration (mg/kg)	Lead Removal (%)
0	1579	-
5	1535	2.76
10	1497	5.20
15	1396	11.61
20	1325	16.11
25	1253	20.62
30	1167	26.12
35	1062	32.75
40	992	37.17
45	904	42.74
50	852	46.07
55	781	50.56
60	722	54.3

3.1 Discussion on results of lead removal

The outcomes for the elimination of Pb by Indian mustard are shown in Table-2. The amount of lead in the soil gradually decreased as the number of days grew. The amount of lead removed from the soil likewise increased over time, demonstrating the efficiency of Indian mustard in doing so. The lead concentration was 1579 mg/kg on day 0 of the experiment, and there was no elimination. The lead elimination percentage was 67.4% after 60 days, although the lead concentration dropped to 5,15 mg/kg.

The outcomes for the elimination of Pb by sunflower are shown in Table-3. Like Indian mustard, the concentration of lead reduced, and the percentage of lead removal rose over time. Day 0 saw no elimination and a lead concentration of 1579 mg/kg. The lead levels dropped to 722 mg/kg after 60 days, yielding a lead elimination rate of 54.3%.

According to the findings, both Indian mustard and sunflower have the capacity to successfully remove lead from the soil. However, during the testing period, Indian mustard outperformed sunflower in terms of lead elimination. The unique traits and mechanisms of each plant species can be used to explain this variation in lead removal effectiveness. Indian mustard is renowned for its great resistance to heavy metals, including lead, as well as its capacity to ingest and store these pollutants in its tissues. Although effective at removing lead, sunflowers may have a marginally reduced efficiency because of their unique physiological and biochemical properties. The results of this study support the potential use of phytoremediation for the elimination of lead in shooting range environments utilizing Indian mustard and sunflower. Indian mustard might be a better choice for locations with higher lead contamination levels due to its higher lead removal percentage. To fully comprehend the underlying principles and enhance the phytoremediation procedure for optimal lead removal effectiveness, more research is nevertheless required.

Overall, the findings show how effective Indian mustard and sunflower are in phytoremediation methods, providing a long-term and environmentally safe solution to the problem of lead contamination in shooting range soils.

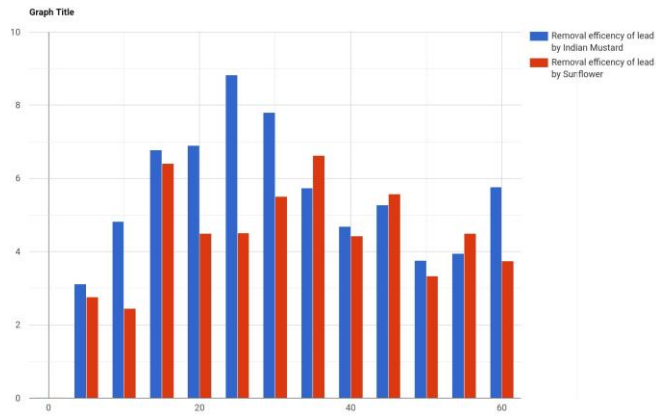


Fig 6: Bar graph showing removal efficiency between Indian mustard and Sunflower

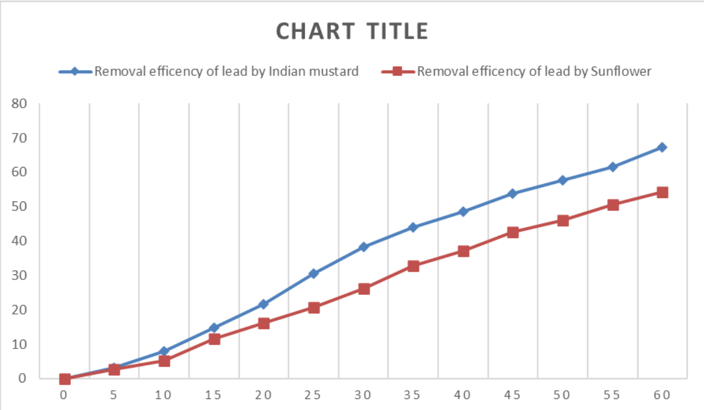


Fig 7: Line chart showing removal efficiency between Indian mustard and Sunflower

4. CONCLUSIONS

In the realm of phytoremediation research focused on tackling lead contamination in shooting range soils, both Indian mustard and sunflowers have emerged as promising candidates. The conclusive findings of this study highlight the effectiveness of both plant species in the removal of lead from polluted soil. Notably, Indian mustard exhibited a higher lead removal rate at 67.4%, outperforming sunflowers, which removed 54.3% of the lead. These results underscore the potential of Indian mustard and sunflower as valuable tools in the remediation of lead-contaminated soil, not only within shooting ranges but also in addressing similar pollution challenges in various other settings.

REFERENCES

[1] Alaboudi, K. A., Ahmed, B., & Brodie, G. (2018). Phytoremediation of Pb and Cd contaminated soils by using sunflower (Helianthus annuus) plant. Annals of agricultural sciences, 63(1), 123-127.

[2] Angelova, V. R., Perifanova-Nemska, M. N., Uzunova, G. P., Ivanov, K. I., & Lee, H. Q. (2016). Potential of sunflower (Helianthus annuus L.) for phytoremediation of soils contaminated with heavy metals. World J. Sci. Eng. Technol, 10(9), 1-8.

[3] Ashraf, S., Ali, Q., Zahir, Z. A., Ashraf, S., & Asghar, H. N. (2019). Phytoremediation: Environmentally sustainable way for reclamation of heavy metal polluted soils. Ecotoxicology and environmental safety, 174, 714-727.

[4] Bañuelos, G., Terry, N., LeDuc, D. L., Pilon-Smits, E. A., & Mackey, B. (2005). Field trial of transgenic Indian mustard plants shows enhanced phytoremediation of selenium-contaminated sediment. Environmental science & technology, 39(6), 1771-1777.

[5] Chandra, R., & Kumar, V. (2017). Phytoremediation: a green sustainable technology for industrial waste management. In Phytoremediation of environmental pollutants (pp. 1-42). CRC Press.

[6] Chen, M., Daroub, S. H., Ma, L. Q., Harris, W. G., & Cao, X. (2002). Characterization of lead in soils of a rifle/pistol shooting range in central Florida, USA. Soil and Sediment Contamination, 11(1), 1-17.

[7] Chrastný, V., Komárek, M., & Hájek, T. (2010). Lead contamination of an agricultural soil in the vicinity of a shooting range. Environmental Monitoring and Assessment, 162, 37-46.

[8] Dinake, P., Kelebemang, R., Sehube, N., Kamwi, O., & Laetsang, M. (2018). Quantitative assessment of environmental risk from lead pollution of shooting range soils. Chemical Speciation & Bioavailability, 30(1), 76-85.

[9] Goswami, S., & Das, S. (2015). A study on cadmium phytoremediation potential of Indian mustard, Brassica juncea. International journal of phytoremediation, 17(6), 583-588.

[10] Hosseini, S. S., Lakzian, A., Halajnia, A., & Razavi, B. S. (2021). Optimization of EDTA and citric acid for risk assessment in the remediation of lead contaminated soil. Rhizosphere, 17, 100277.

[11] Hou, D. (Ed.). (2019). Sustainable remediation of contaminated soil and groundwater: materials, processes, and assessment. Butterworth-Heinemann.

[12] Jadia, C. D., & Fulekar, M. H. (2008). Phytoremediation: The application of vermicompost to remove zinc, cadmium, copper, nickel and lead by sunflower plant. Environmental Engineering & Management Journal (EEMJ), 7(5).

[13] Jiao, F., Shi, X. R., Han, F. P., & Yuan, Z. Y. (2016). Increasing aridity, temperature, and soil pH induce soil CNP imbalance in grasslands. Scientific reports, 6(1), 19601.

[14] Liduino, V. S., Servulo, E. F., & Oliveira, F. J. (2018). Biosurfactant-assisted phytoremediation of multi-contaminated industrial soil using sunflower (Helianthus annuus L.). Journal of Evironmental Science and Health, Part A, 53(7), 609-616.

[15] Marques, A. P., Moreira, H., Franco, A. R., Rangel, A. O., & Castro, P. M. (2013). Inoculating Helianthus annuus (sunflower) grown in zinc and cadmium contaminated soils with plant growth promoting bacteria–Effects on phytoremediation strategies. Chemosphere, 92(1), 74-83.

[16] Meng, F., Jin, D., Guo, K., Larson, S. L., Ballard, J. H., Chen, L., ... & Han, F. X. (2018). Influences of U sources and forms on its bioaccumulation in Indian Mustard and Sunflower. Water, Air, & Soil Pollution, 229, 1-11.

[17] Mohammadzadeh, A., Tavakoli, M., Chaichi, M. R., & Motesharezadeh, B. (2014). Effects of nickel and PGPBs on growth indices and phytoremediation capability of sunflower (Helianthus annuus L.). Archives of Agronomy and Soil Science, 60(12), 1765-1778.

[18] Neina, D. (2019). The role of soil pH in plant nutrition and soil remediation. Applied and environmental soil science, 2019, 1-9.

[19] Nguyen, T. M. H., Bräunig, J., Thompson, K., Thompson, J., Kabiri, S., Navarro, D. A., ... & Mueller, J. F. (2020). Influences of chemical properties, soil properties, and solution pH on soil–water partitioning coefficients of per-and polyfluoroalkyl substances (PFASs). Environmental science & technology, 54(24), 15883-15892.

[20] Odoh, C. K., Zabbey, N., Sam, K., & Eze, C. N. (2019). Status, progress and challenges of phytoremediation-An African scenario. Journal of environmental management, 237, 365-378.

[21] Rantalainen, M. L., Torkkeli, M., Strömmer, R., & Setälä, H. (2006). Lead contamination of an old shooting range affecting the local ecosystem—a case study with a holistic approach. Science of the total environment, 369(1-3), 99-108.

[22] Rathore, S. S., Shekhawat, K., Dass, A., Kandpal, B. K., & Singh, V. K. (2019). Phytoremediation mechanism in Indian mustard (Brassica juncea) and its enhancement through agronomic interventions. Proceedings of the National Academy of Sciences, India Section B: Biological Sciences, 89, 419-427.

[23] Rehman, R. U., & Rashid, A. (2017). Biogas production: a sustainable approach for energy and global environment. Environmental Science and Pollution Research, 24(7), 6447-6458.

[24] Sanderson, P., Qi, F., Seshadri, B., Wijayawardena, A., & Naidu, R. (2018). Contamination, fate and management of metals in shooting range soils—a Review. Current Pollution Reports, 4, 175-187.

[25] Sehube, N., Kelebemang, R., Totolo, O., Laetsang, M., Kamwi, O., & Dinake, P. (2017). Lead pollution of shooting range soils. South African Journal of Chemistry, 70, 21-28.

[26] Shaheen, S. M., & Rinklebe, J. (2015). Phytoextraction of potentially toxic elements by Indian mustard, rapeseed, and sunflower from a contaminated riparian soil. Environmental geochemistry and health, 37, 953-967.

[27] Singh, R. P., & Agrawal, M. (2010). Variations in heavy metal accumulation, growth and yield of rice plants grown at different sewage sludge amendment rates. Ecological Engineering, 36(6), 969-972.

[28] U.S. Environmental Protection Agency. (2000). Guidance for Evaluating Land Disposal Restrictions on the Land Disposal of Used Oil Filters. EPA530-R-00-004.

[29] Witters, N., Mendelsohn, R. O., Van Slycken, S., Weyens, N., Schreurs, E., Meers, E., ... & Vangronsveld, J. (2012). Phytoremediation, a sustainable remediation technology? Conclusions from a case study. I: Energy production and carbon dioxide abatement. Biomass and bioenergy, 39, 454-469.

[30] Witters, N., Mendelsohn, R., Van Passel, S., Van Slycken, S., Weyens, N., Schreurs, E., ... & Vangronsveld, J. (2012). Phytoremediation, a sustainable remediation technology? II: Economic assessment of CO2 abatement through the use of phytoremediation crops for renewable energy production. Biomass and bioenergy, 39, 470-477.

[31] Xiang, L., Harindintwali, J. D., Wang, F., Redmile-Gordon, M., Chang, S. X., Fu, Y., ... & Xing, B. (2022). Integrating biochar, bacteria, and plants for sustainable remediation of soils contaminated with organic pollutants. Environmental Science & Technology, 56(23), 16546-16566.

[32] Zehra, A., Sahito, Z. A., Tong, W., Tang, L., Hamid, Y., Khan, M. B., ... & Yang, X. (2020). Assessment of sunflower germplasm for phytoremediation of lead-polluted soil and production of seed oil and seed meal for human and animal consumption. Journal of Environmental Sciences, 87, 24-38.

BIOGRAPHIES

MOHD ADNAN
M.Tech (Environmental Science and Engineering), GNDEC Ludhiana, Punjab, India

SUKHWINDERPAL SINGH
Assistant Professor, Dept. of Civil Engineering, Guru Nanak Dev Engineering College, Ludhiana, Punjab, India

BALIHAR SINGH
Assistant Professor, Dept. of Civil Engineering, Guru Nanak Dev Engineering College, Ludhiana, Punjab, India