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Examining Heavy Metal Pollution in Soil of Kottarakkara: Impact and Potential Solutions

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ABSTRACT: Worldwide, industrial operations, inappropriate waste management, and agricultural practices all contribute to the enormous environmental and public health problems associated with heavy metal pollution of soil. Lead, cadmium, arsenic, and mercury are examples of heavy metals that can linger in soil for years and have a negative impact on ecosystems and human populations due to bioaccumulation and biomagnification. The several remediation techniques used to lessen soil pollution by heavy metals are examined. These techniques include chemical treatments like soil stabilization and immobilization, physical techniques like soil cleaning, and biological techniques like phytoremediation and microbial remediation. In this study, soil replacement, soil stabilization and chemical fixation methods were analysed and stabilization methods were found as an effective method in reducing heavy metal contamination in the soil.

KEYWORDS: Heavy metal, soil replacement, soil stabilization, chemical fixation

I. INTRODUCTION

Heavy metals are a group of metallic elements that have high atomic weights and densities. These elements typically have toxic properties and can pose serious health risks to humans and the environment when present in high concentrations. Examples of heavy metals include lead, mercury, cadmium, arsenic, chromium, and nickel, among others. They are naturally occurring elements that can be found in rocks, soil, and water. However, human activities such as mining, industrial processes, and the use of certain products like pesticides and batteries can release heavy metals into the environment, leading to pollution. Heavy metals can accumulate in living organisms through various pathways, including ingestion, inhalation, and absorption through the skin. Once inside the body, they can disrupt biological processes, cause damage to organs and tissues, and even lead to chronic health conditions such as neurological disorders, kidney damage, and cancer.

Since the beginning of the Earth's history, these heavy metals have been discovered in their natural environments on its crust. Because of the staggering rise in the use of heavy metals, there is about to be an explosion of metallic substances in both the terrestrial environment and the aquatic environment. This is a consequence of the fact that the usage of heavy metals has dramatically increased. The mining of the metal, smelting, foundries, and other industries that are based on metal are the primary causes of heavy metal pollution. Leaching of metals from different sources such as landfills, waste dumps, excretion, livestock and chicken manure, runoffs, automobiles, and roadworks are also contributing factors. Human activity is the primary cause of pollution. The use of heavy metals in agricultural practices, such as the application of pesticides, insecticides, fertilizers, and a variety of other agricultural chemicals, has been the secondary source of heavy metal contamination. Heavy metal pollution may also be caused by natural processes, such as volcanic activity, corrosion of metals, evaporation of metals from soil and water, sediment re-suspension, soil erosion, and geological weathering

The soil is essential for living organisms, agricultural, construction etc. Heavy metal contamination in soil poses significant environmental, construction and health concerns due to their presence the toxicity and bio accumulation potential. The contaminated soil has poor compressive strength, shear strength and other properties. In project the chosen components, contaminated soil, cement (OPC), calcium carbonate (CaCO₃) and good quality soil. For estimating physical properties of the contaminated soil, weusing pH test, specific gravity test, Atterberg limit test, grain sieve



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analysis, water content test. Engineering property tests also estimated. In this project we determine heavy metal content in the soil and suitable remediation methods were discussed.

II. RELATED WORK

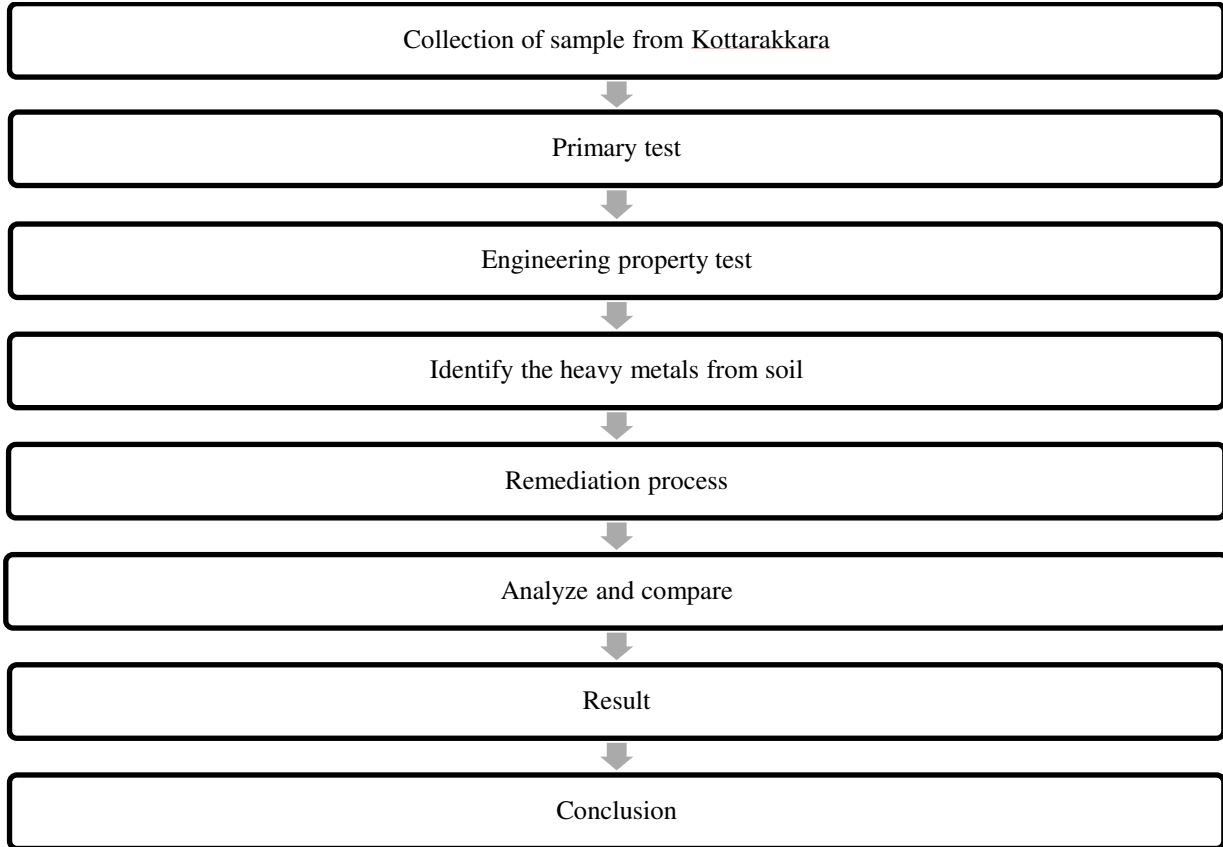
[1] Abdullahi.A, Lawal M.A, Salisu. A. M “Heavy metals in contaminated soil: source, accumulation, health risk and remediation process” (2021) This comprehensive review delves into the multifaceted aspects of heavy metals and their profound implications in contaminated soil ecosystems. It offers a meticulous exploration of the toxicity, bioaccumulation, biodegradation, mobility, and solubility of these elements, shedding light on the intricate dynamics at play. Heavy metals, such as lead, cadmium, mercury, and arsenic, are renowned for their toxicity. They disrupt biological processes in both flora and fauna, resulting in a spectrum of health maladies in humans, from neurological disorders to organ failure. [2] Rama Karn, Nishita Ojha, Sadiqa and Sonal Bhugra “A review on heavy metal contamination at mining sites and remedial techniques” (2021) The belief in the potential impact of this integrated processes review is well-founded. Such a comprehensive review, delving into the intricate web of interrelated factors in remediation, has the capacity to catalyse a robust research thrust within the scientific community. It has the power to inspire and shape future endeavours, fostering innovation and the development of novel remediation projects. This review's capacity to synthesize and present an integrated perspective on remediation processes is invaluable. It not only identifies existing gaps in knowledge but also provides a roadmap for exploring uncharted territory. Researchers and experts in the field are likely to be encouraged to investigate new, unexplored avenues and develop creative solutions based on the insights and suggestions within the review. The multidisciplinary nature of this review, which connects elements such as heavy metal toxicity, bioaccumulation, biodegradation, mobility, solubility, and their effects, makes it a potent catalyst for collaborative efforts. [3] Lianwen Liu, Wei Li, Weiping Song, Mingxin Guo “Remediation techniques for heavy Metal-contaminated soils: Principles and applicability” (2018) This paper serves as a vital resource by critically examining research on the detrimental impacts of heavy metal contamination in the vicinity of mining sites. It not only underscores the severity of the issue but also delves into an array of strategies and methods aimed at curtailing the spread of contamination and establishing safer environments for affected areas. The harmful effects of heavy metal contamination emanating from mining activities are multifaceted and encompass environmental, ecological, and public health concerns.



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III. METHODOLOGY



IV. SITE SELECTION

Ugrankunnu is a village in Kottarakkara municipality, this place is used as waste dumping area since 2000. In current situation this place is used as Material Collection Facility and Resource Recovery Facility for Kottarakkara municipality. All type of waste that is plastic waste, food waste, e waste, factory waste, etc...are dumped here. From E waste, plastic waste and factory waste are leads to heavy metal contamination. This heavy metal has toxic nature it affects constructions and others. This heavy metal also affects the physical and engineering properties of soil.

V. EXPERIMENTAL PROCEDURE

Soil property testing is essential for understanding the characteristics and behaviour of soil, which are crucial in various fields.Physical property tests on soil are essential for understanding its behaviour and suitability for various engineering and agricultural applications. These tests assess characteristics such as texture, structure, density, porosity, moisture content, and particle size distribution physical property tests on soil inform land use planning, construction design, agricultural practices, and environmental management, ensuring sustainable utilization of this vital resources.Engineering property tests on soil are conducted to evaluate its suitability and behaviour for construction and infrastructure projects. These tests provide crucial information regarding the soil's strength, compressibility, permeability, and other mechanical properties. engineering property tests on soil provide essential data for geotechnical engineers, civil engineers, and construction professionals to make informed decisions during the design, construction, and maintenance of infrastructure projects.The Table[1] shows the test result that conducted for getting the physical and engineering properties of the contaminated soil.



Table [1] Physical & Engineering properties of soil

PROPERTIES	OBSERVED VALUES
pH value	6
Specific gravity of the soil	2.35
Water content	6.1%
Liquid Limit, W_L	62%
Plastic limit, W_p	28.8%
Plasticity index, I_p	33.2%
Soil type	CH (Inorganic clay of high plasticity)
Uniformity coefficient	14.6
Coefficient of curvature	1.22
Unconfined Compressive Strength, Q_u	0.473 kg/cm ²
Shear Strength, C_u	0.236 kg/cm ²
Optimum Moisture Content (OMC)	15%
Maximum Dry Density (MDD)	1.758 Kg/m ³

VI. DETERMINATION OF HEAVY METALS

Soil is tested at Central Soil Analytical Laboratory Parottukonam, Thiruvananthapuram, for estimation of heavy metal using HCl Extraction in AAS (Atomic Absorption Spectroscopy) It's a technique used to determine the concentration of various elements in a sample of soil. This method relies on the absorption of specific wavelengths of light by atoms in the gaseous state. When a sample is atomized and then exposed to light of a particular wavelength corresponding to the element of interest, the amount of light absorbed is proportional to the concentration of that element in the sample. AAS is widely used in soil testing due to its sensitivity, accuracy, and ability to analyse multiple elements simultaneously. The Table [2] shows the test results of heavy metals in soil.

Table [2] Heavy metals in soil

Heavy metal	Observed value (PPM)	Permissible limit (PPM)
Lead (Pb)	462.16	200
Cadmium (Cd)	0.04	3

VII. HEAVY METALS REMEDIATION

Remediating heavy metal contamination in soil is a complex task requiring careful planning and execution. Various methods are employed, including physical techniques like soil washing and chemical methods like soil stabilization. Biological approaches such as phytoremediation, where plants absorb and accumulate metals, and microbial remediation, utilizing microorganisms to degrade contaminants, offer sustainable alternatives. However, the choice of method depends on factors like the type and extent of contamination, site conditions, and regulatory requirements. Effective remediation necessitates thorough site assessment, implementation of appropriate techniques, and continuous monitoring to ensure successful restoration of soil quality and environmental safety. For this project, three type of remediations were used, i.e. Soil Replacement, Solidification, Chemical Fixation.

- SOIL REPLACEMENT



Fig 1: Soil replacement

The system of soil replacement uses clean soil to completely or partially replace polluted metal soil. It is also referred to as the ‘dig and haul’ process. The key aim is to reduce the concentration of pollutants and increase the soil's natural potential, thus remediating the soil. This technique is very laborious, costly and only appropriate for smaller areas that are heavily polluted. Again, it is split into three types, namely soil substitution, soil spading and soil importing. Soil substitution is the process in which the polluted soil is removed and fresh soil is kept in its place. This approach is only

sufficient for smaller polluted areas of land. It should be remembered that it only moves polluted soil to a lower risk area from a higher risk area. The replaced soil will cause second contamination, so it needs to be carefully treated.

- CHEMICAL FIXATION



Fig 2: Chemical fixation

The technique of chemical fixation applies reagents or chemicals to the polluted soil that interacts with heavy metals and forms low toxic substances that are insoluble or hardly mobile. Such solid types of heavy metals could then not migrate to water, plants or any other environmental media, thereby completing the remediation process. This method is effective for soil with low contaminant concentrations. Conditioning agents used in the method include clay, metallic oxides and biomaterials, but these agents can affect the soil structure to some degree and can also have an adverse impact on the soil microbes.

- STABILIZATION/SOLIDIFICATION



Fig 3: Stabilization/solidification

Solidification is typically a process that involves a mixing of waste with binders to reduce the volume of contaminant leachability by means of physical and chemical characteristics to convert waste in the environment that goes to landfill or others possibly channels. Stabilization is attempts to reduce the solubility or chemical reactivity of



the waste by changing the physical and chemical properties. While, solidification attempt to convert the waste into easily handled solids with low hazardous level. These two processes are often discussed together since they have a similar purpose of improvement than containment of potential pollutants in treated wastes. The primary objective of this review is to investigate the materials used as a binder in Solidification method as well as the ability of these binders to remediate the contaminated soils especially by heavy metal. The Table [3] shows the test results of heavy metals in soil.

Table [3] Heavy metals in soil after remediation

Methods	Lead (Pb)	Cadmium (Cd)
Stabilization/ Solidification	197.32	0.15
Soil fixation	247.05	0.08
Soil replacement	268.38	0.010

VIII. COMPARISON OF RESULTS

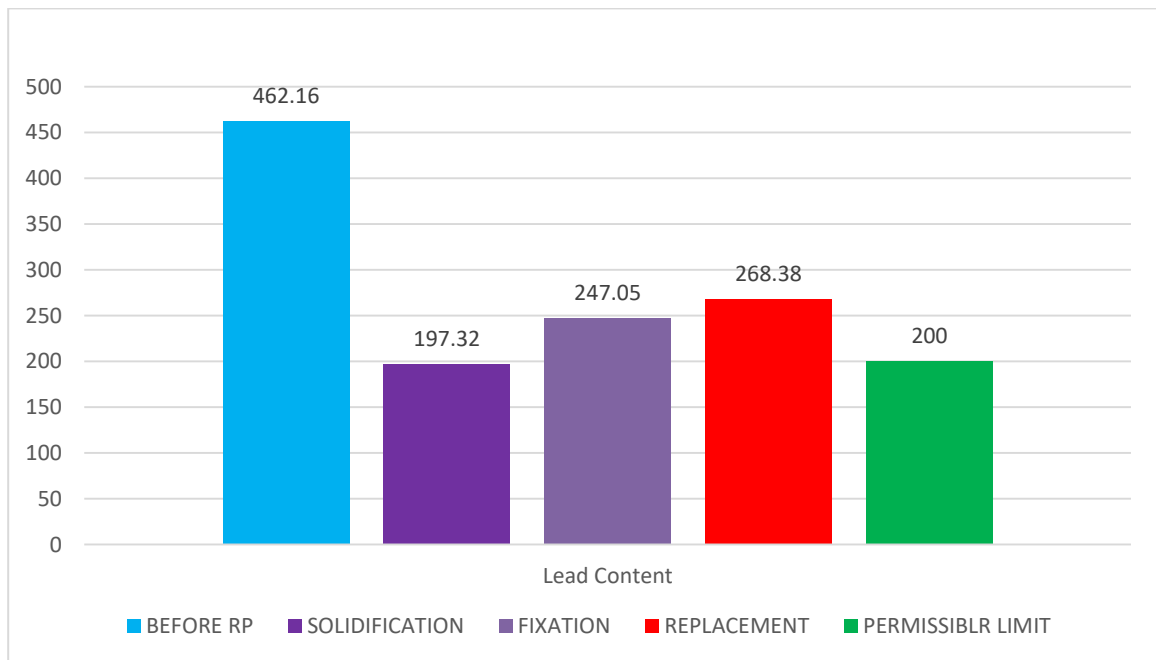


Fig 4: Comparison of results

From the study, Solidification/Stabilization method is more effective for the soil. It gives a maximum result and it is in permissible limit. Solidification is often preferred for Lead-contaminated soil remediation due to its effectiveness in immobilizing the lead, reducing its mobility and bioavailability.

IX. CONCLUSION

The soil is essential for living organisms, agricultural, construction etc. Heavy metal contamination in soil poses significant environmental, construction and health concerns due to their presence the toxicity and bio accumulation potential. The contaminated soil has poor compressive strength, shear strength and other properties. In project the



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- Heavy metal content in the soil is 462.16 PPM
- This Lead affects construction and also decreases the strength of soil
- Solidification/Stabilization method is the better remediation for the soil
- 57.30% of Lead (Pb) was removed from the soil by using Solidification method

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