Using The Lime with Nanosilicamaterials to Remidate The Lead and Cadmium Contaminated SoilAbstract

[1]Safaa Nader Jihad, [2]Assistant Prof. Dr. Khitam Abdulhussein Saeed
Environmental of Engineering Department, Mustansiriyah University, College of Engineering, Iraq
Water of Resources Engineering Department, Faculty of Civil Engineering Mustansiryah University, Iraq

Abstract:
Soil contamination by heavy metals significantly damages the environment, human health, plants and animals, which has become a burning issue recently. The presence of contaminated soils due to industrials and mining activities is a major concern in today' s heavily industrialized world. With the rapid development of society, more and more soils are polluted by heavy metals, which leads to a change in soil engineering properties. Several types of technology have long been in use to remedy the heavy metal-contaminated soil. Among them, solidification and stabilization has widely adopted. In engineering practice, engineers usually use additives to solidify and stabilize (s/s) heavy metal contaminated soils. Solidification and Stabilization is an economic and effective technology in the remediation of contaminated soil by heavy metals, as well as sludge and sediment. The main purpose of the study was to investigate the effect of (nanomaterial materials) on the remediation of contaminated soil by the (S/S) technique. The soil was polluted with (2000 mg/kg and 1000 mg/kg) of Lead and Cadmium respectively by using Lead and Cadmium nitrates. The Pb and Cd- impacted soil was remediation using rich silicon materials of (nano-silica) as an alternative cementitious material, and replaced with contaminated soil at (3, 5 and 7%) respectively with (5% and 10%) Lime. Nanosilica was prepared from plant extracts. The binder performance was analysed by using unconfined compressive strength (UCS) to the solidified soil at three curing times which were 7, 14 and 28 days. TCLP was also applied to investigate the treatment degree of solidified soil for the specimens within 28 days. The result of (UCS) indicated development in strength with curing day for all binders and proved that all mix ratios exceed the minimum Criteria of landfill disposal which is 340 kPa (0.34 N/mm^2). It also showed increases in strength with using nano-silica with a lime binder. The result of the leaching test for the stabilized soil after 28 day of curing, showed a reduction in lead and cadmium leaching rate for all binders, below the EPA lead leachability limit of 5 mg/l and cadmium 1 mg/l. The results showed that the sample SH2N5L10 after 28 days is the best percentage for decreasing the leaching rate of lead and cadmium, as it reached (1.4 mg /l and 0.012 mg/l) respectively with the highest compressive strength of 4852 Kpa.

Keywords: Soil Stabilization, solidification, Contaminated Soil, , Nano Silica, Lime, pozzolanic Materials, leachability and unconfined compressive strength.
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1. Introduction

Soil is a large reservoir of heavy metals that are released into the environment by human activities, These metals are naturally present in our environment and are rarely at toxic levels, especially in the components of the crust of Earth, as it contributes to other elements to the ecological balance of the planet (Migaszewski & Gałuszka, 2021). Heavy metals can enter the soil environment as a result of both pedogenic and anthropogenic processes. They occur naturally in the soil environment from the pedogenetic processes of weathering parent materials at levels that are regarded as trace (<1000 mg/kg) and have a limited impact on soil except for arsenic and selenium (Park et al., 2011). Heavy metals are essential nutrients for different biochemical and physiological functions, the essential nutrients include magnesium (Mg), cobalt (Co), nickel (Ni), iron (Fe), manganese (Mn), copper (Cu), chromium (Cr), selenium (Se), and zinc (Zn). However, they are considered both harmful and hazardous when their level in the environment surpasses the permissible borders (Alloway, 2013).Heavy metal contamination is a worrying problem for the following (Kabata-Pendias & Mukherjee.,2007):- The harmful effect of some of these elements on Living organisms, even if they are found in small concentrations, and some of them have carcinogenic effects, The multiplicity of these elements and the diversity of their sources in the environment. , and the ability of a large number of these elements to accumulate in the bodies of living organisms to a degree that sometimes leads to poisoning.

The remediation technology of solidification/stabilization (S/S) offers an effective means of treating the lead and cadmium-contaminated soil by considerably reducing the mobility and solubility of lead and cadmium in the sediments. Despite the cement is an effective binder in the stabilization process, cement production can lead to large emissions of carbon dioxide (Balachandra et al., 2021). As well as, the dumping of many industrial solid wastes used up much of our land but also caused environmental pollution, The process by which lead interferes with the strength and compressibility of traditional stabilizers is understood. Hence, there is an alternative technique for using pozzolanic waste materials containing silica and alumina which is responsible for cementitious formation (Kadhim et al.,2019a) . Some studies used nano-silica for stabilization of soil but there are a few studies related to stabilization/solidification of contaminated soil using nanomaterial techniques. It needs a general study, specifically with contaminated soil to show the behaviour of nano-silica with lime for remediation of contaminated soil. Several research works have been conducted on the use of pozzolanic waste like (fly ash, silica fume and rice husk ash) as mineral additives to improve the performance of concrete and soil (Aliyu and Karim, 2016). In this study, nano-silica with lime was used to remediation artificially contaminated soil with (2000 mg /l and 1000 mg/l) of cadmium. An evaluation of the treatment by compressive strength and the leachability of artificially contaminated soil.

2. Materials And Methods

Materials

Silty Clay Soil

One type of soil was selected in this study. It is a natural soil taken from the Al-Baitha region, south of Baghdad city, at depths from (0.75-1) m. A soil sample was taken from this area, as this area is close to the impact of the Dora power station, as well as the oil refinery. Natural soil was transported to the National Center for Construction Laboratories and Research and was tested. The soil sample was tested and analysed according to American Standard for Testing and Materials standards (ASTM- D422 - 2007). The physical properties and soil classification are shown in Table (1) while the chemical composition is illustrated in Table (2).

Table 1. Physical properties, and classification of the soil utilized in this study.

Physical Properties	Value
Particle size distribution Sand (%) Silt (%) Clay (%)	 5 45 51
L L (%) P L (%) P I (%)	55 30 25
Maximum dry density (g/cm3) Optimum moisture content (%)	1.579 19
Specific gravity	2.74
Soil classification USCS	Silty clay
Organic Matter	1.24%

PH	7.1
EC	0.8 ds/m
Total Soluble Salt (TSS)	2.1%
SO3	0.78%
CaCO3	21.3%

Table 2. Chemical Composition of Soil

Chemical Composition	Value (%)
Mgo	6.976
Al2o3	13.248
Sio2	43.664
So3	3.627
Cao	19.215
Fe2o3	8.820
Another element	4.45

Nano silica

Silica is known as pozzolanic material and has been used to stabilize and improve soil strength (Shahin et al., 2015).In recent years, Nanoparticles have attracted considerable scientific interest for many Geo-Environmental engineering applications. Nanosilica, a type of non-toxic and pollution-free non-metallic nanomaterial, is widely utilized because of its high mechanical strength, good chemical stability, high-temperature resistance, easy dispersion in solvents, and other unique characteristics (Ma et al., 2021).

Silica nanoparticles a fine white powder of less than 100 nm in average particle diameter, have a smooth touch and are odourless and tasteless. Nanosilica particales are widely used in high-tech applications owing to their many attractive properties such as excellent physicochemical, and mechanical properties. Nano-silica as a sole additive improved the soil strength and it acted as a strength enhancer for lime, cement, and fibre-treated soils. Also, nano-silica helps in reducing the hydraulic conductivity and compression index of the soil (Kannan and Sujatha, 2021).

A reduction in the size of nano-silica particles provides an exceptional surface area to volume ratio and changes in the surface energy, surface chemistry, and surface morphology of the particle, altering its basic properties and reactivity. Silica nanoparticles have been gradually researched and produced due to the unique features resulting from the size reduction, whereby enhances durability, strength, and versatility. SNP have much higher pozzolanic reactivity than that silica fume product that is commonly used as ultrafine pozzolanas for producing cementitious materials with advanced properties (Korpa et al., 2008).

The main advantages of nanoparticles addition for solidification processes are (Lian et al., 2019):-

- Silica is material not harmful to the environment.
- Improve the properties due to the effect of increasing surface area and reactivity through filling the Nanopores of the cement paste.
- Decrease leachable concentrations of contaminants.
- Silica materials with large surfaces have great adsorption ability.

in this study to prepare nano-silica by-products of the plant because it's not expensive, available, safe and environmentally friendly.

Preparing Soil Samples

In this study, all the soil samples were air-dried to keep their plasticity and compaction properties (Saeed et al.,2022). Then, ground into smaller sizes using a mechanical grinder and sieved through a 2mm sieve according to ASTM standards. Moreover, it should be preserved in clean plastic bags before soil analysing and contamination.

Soil Contamination by lead and cadmium Nitrates

The spiked soil was done by blending a specific amount of lead and cadmium nitrates (manufactured by the British Drug Hou House, BDH England) to reach (2000 mg/kg and 1000mg/l) lead and cadmium respectively as a polluted concentration. This concentration was prepared by adding (64 gm and 54.9 gm) of Pb and Cd nitrates to 3.8 litres of distilled water enough to spike 20 kg of soil with the required OMC which is 19%. The liquid was sprayed into the soil and then mixed by a mixer until being thoroughly homogenised. The contaminated soil with Pb and Cd kept in a close bucket and allow for physical and chemical behaviour of lead through the soil for seven days.

Preparation of UCS Samples

To study the effect of NanoSilica content as well as the effect of lime on the gain of mechanical strength, unconfined compressive strength should be done on each mix design sample through times of curing at 7,14 and 28 days. Initially, the binder (lime) was completely mixed with the contaminated soil on a glass plate, then the NS was mixed with the mixture. Table (3) shows the proportions of lime and nano-silica mixed with the contaminated soil. 19% the content of OMC was added to the mixture plus 2% percent for the evaporation loss process. This ratio was gradually spilt on the dry mixture and blended with a hand until complete the consistency of the mixture was for fifteen minutes. The mixture was statically compacted in three-layer inside cylindrical made from steel with a diameter of 38 mm and length of 76 mm. Immediately after moulding, the specimens were extracted manually as shown in plate (1)

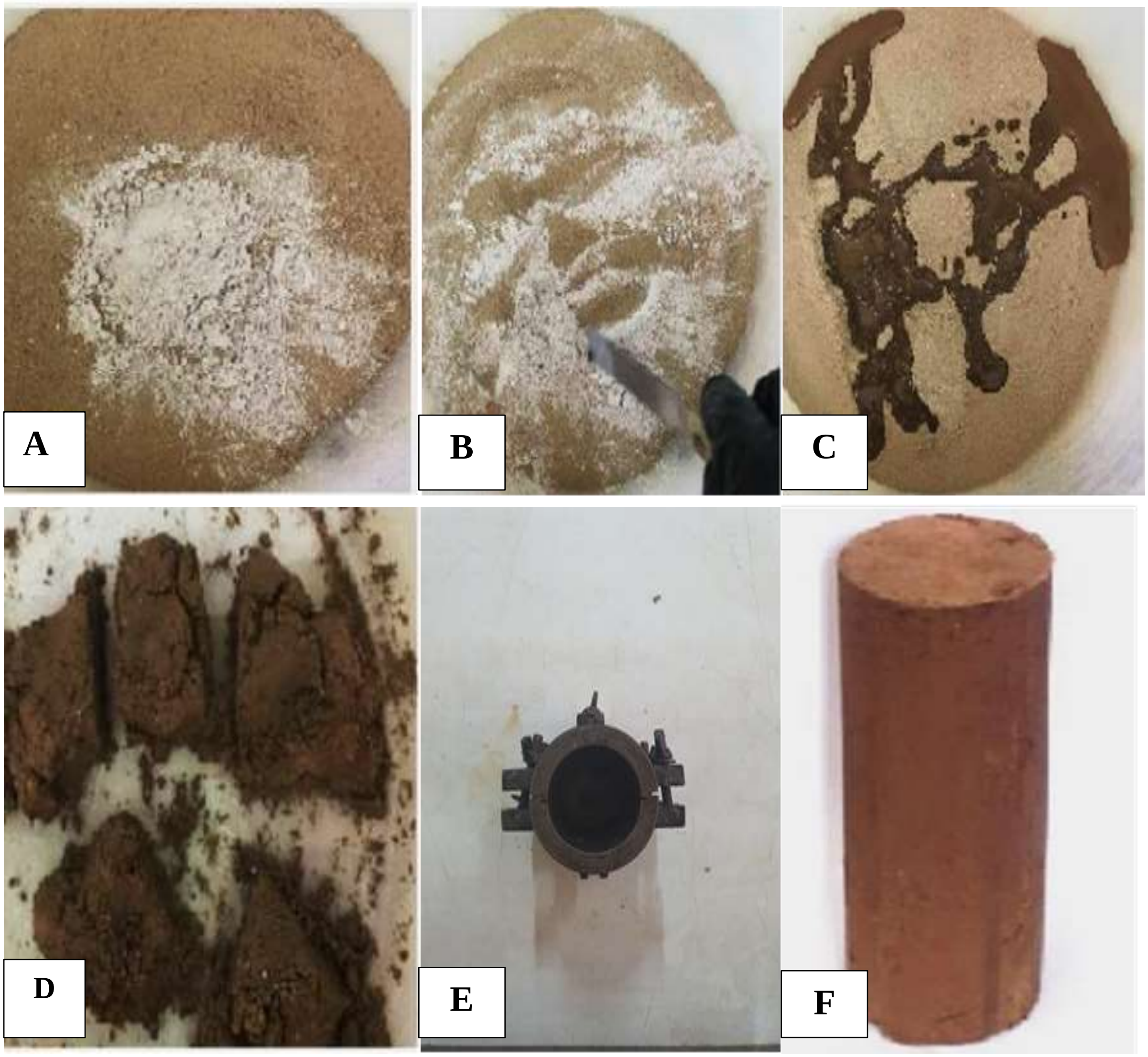

Plate (1) Steps of mixing Contaminated Soil With Lime And NanoSilica

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Samples were extracted manually, they were enveloped by plastic overlay and wax paper foil above it to avoid moisture loss during the time of casting as shown in the plate below (2).

Plate (2) aplastic container for storing samples during processing

The samples were then stored in a room at a controlled temperature of 23C (±2C) centigrade till reaching the destinated test for each time of curing, i.e., 7 days, 14 days, and 28 days. This resulted in an overall 24 cylindrical mould specimens.

Table (3) Mixing designs for fixing contaminated silty clay samples of heavy metal ions

No	Sample Name	Contaminated Soil in the mold (g)	Stabilizer Content Lime (g)		Nanosilica content (g)			Curing Time (Days)
			5%	10%	3%	5%	7%	
1	SH2L5	136	6.8	----	----	----	-----	7 , 14 , 28
2	SH2L10	136		13.6	----	----	-----	7 , 14 , 28
3	SH2N3L5	136	6.8	------	0.204	----	-----	7 , 14 , 28
4	SH2N5L5	136	6.8	------	-----	0.34	-----	7 , 14 , 28

5	SH2N7L5	136	6.8	------	-----	----	0.476	7 , 14 , 28
6	SH2N3L10	136	-----	13.6	0.408	----	-----	7 , 14 , 28
7	SH2N5L10	136	-----	13.6	-----	0.68		7 , 14 , 28
8	SH2N7L10	136	-----	13.6	-----	----	0.952	7 , 14 , 28

Not: (SH2) refers to soil-heavy metals mix,(N) refers to NanoSilica, and (L) refers to Lime.

Unconfined Compressive Strength

In order to evaluate the degree of improvement of soil stabilization, unconfined compressive strength (UCS) has been applied to measure the strength characteristic of stabilized samples. This test was an indication of the formation of cementitious materials. It should be noted regarding to context of contaminated soil, the unconfined compressive strength (UCS) test was performed as an indication if cured soil had the allowable value of landfill disposal strength which is 0.36 Mpa to avoid the compressive force. The compressive strength of the lime with different percentages of nano-silica was tested in a conventional method according to the BS 1924 standard: Part 2:1990. To enhance the credibility of the test conducted for each mix design, three samples should be applied for different curing times. the sample was extracted from the nylon film measured the diameter with a length of specimens and tested directly using a constant axial strain rate of 1.25 percent per min (Kadhim., 2019b) .

Leaching Characterization

The leaching test is considered a significant step in observing the chemical reactions that occurred within the contaminated soil during the stabilization process. The basis for this leaching characterization in the current study was to observe the changes in the concentration of Pb and Cd leaching from the stabilized specimens with 28 curing days by pozzolanic materials (NS), as well as the behaviour of lime concentration on the remediation degree. In this study, the leaching test was achieved according to EPA Method 1311 which is identified as the Toxicity characteristics leaching procedure test (TCLP). The cured samples after 28 curing days, were tested in the compressive strength, crushed and further grinded, and then passed through a No.40 Sieve (425μm). Five grams of the sieved sample were mixed with 100 ml of extraction fluid in the Baker of 500 ml. The acetic acid solution with pH 2.88, was chosen as a leaching fluid at a (solid/liquid) ratio of (1/20) by the weight of the sieved sample. This fluid was prepared by adding 5.67 ml of acetic acid to deionized water and completing the volume to 1 litre based on the TCLP procedure. After that, the mixture was transferred to the batch stirrer equipment for 24 hr and rotation speed of 80 rpm, At the end of mixing, all mixed solutions produced by the batch mixer test were filtered through 150mm diameter Chm No. F2142-150 Hardened Ashless Filter Papers. It should be mentioned that all funnels and conical flasks used in this process were of plain borosilicate glass construction. The filter papers were used to separate the aqueous phase, and all filtered solutions were stored in acid-washed Nalgene bottles and stored in a cold room at 4 ± 1C°. No samples were stored for longer than 48 hours before the chemical analysis. The extracted liquid was preserved for Pb and Cd analysis using Atomic Absorption, Shimadzu AA-7000 at the Ministry of Science and Technology / Department of Water and Soil Research.

3. Results And Discussion

Unconfined Compressive Strength (UCS)

The Effect of heavy metals content with lime on UCS of Stabilized

The UCS of the control sample for artificial soil contaminated with Pb^{+2} and Cd^{+2} (UCS=117Kpa) is in figure (1). This parameter was emphasized for comparison with respect to the presence of HM and improvement inhibition of lime stabilization. The Figure depicts the strengths (5% and 10%) ratios of lime-treated soil contaminated with heavy metals specimens contaminated with 2000 mg/kg from (Pb^{+2} and Cd^{+2}) at curing time (7, 14, and 28) days.

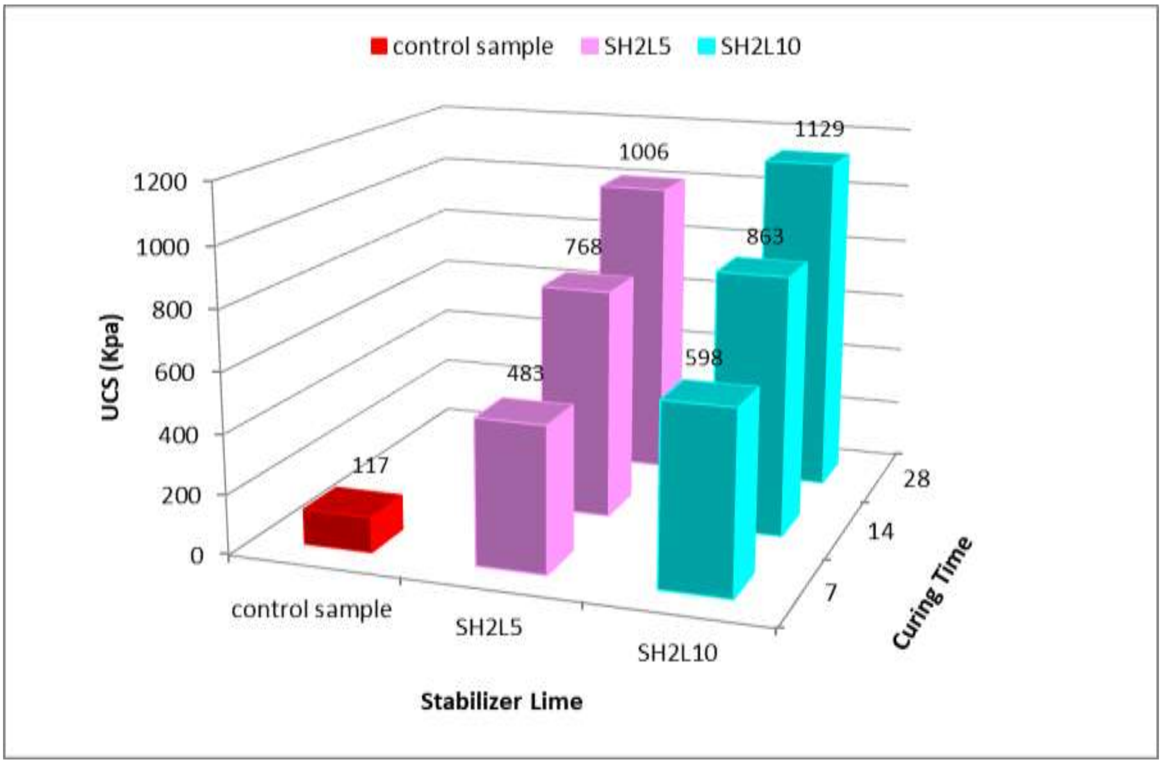

Figure (1) UCS results for Contaminated Soil Mixture with Lime

Maybe longer-term strength development depended more on interactions between the free stabilizer ions present in the pore water and the release of artificially contaminated clay-bound alumina and silica Which leads to the formation of stable cementitious products calcium silicate hydrates (CSH) and calcium aluminate hydrates (CAH). The pozzolanic products are obtained in the phase when they are added appropriate amounts of lime and water, the soil pH increases rapidly above 10.5, which allows the particles of artificially contaminated clay to break down (Sabzi, 2018). Silica and alumina are released and react with calcium lime to form calcium silicate-hydrate (CSH) and calcium aluminate-hydrates (CAH). Therefore, the pozzolanic reaction can continue with the presence of Si and AL in strongly alkaline conditions, and as long as enough residual calcium ions are present in the system, Which CSH and CAH have been identified as the main reaction activity for the good stabilization of the soil-lime.

As shown in the figure, it can notice increasing in the values of UCS is associated with Lime content. Also,it can seen increasing in compressive strength of contaminated soil with increasing Lime content for all samples. The UCS of samples with 5% Lime with HM only were (483,768,1006) Kpa respectively, while recorded (598,863,1129) Kpa at 10% lime at the same curing time and conditions. This reason for the increase in strength of the samples at all curing times is due to adding quantities of lime to the artificially contaminated soil,maybe the addition of a small amount of lime could further improve contaminated soil properties by increasing the pozzolanic activity (Kamaruddin et al., 2020).

These quantities of lime lead to the solubility of silica and alumina present in contaminated clay minerals being greatly increased at elevated pH levels, thus making them available for reaction with the ca+2 from Ca(OH)2 to form the cementitious hydrates, CAH and CSH. That formation of thus calcium aluminosilicate hydrates is mainly responsible for the high strength and heavy metal immobilization through surface sorption, inclusion and physical entrapment (Saeed et al., 2019).

The results proved that (SH210L) has a higher UCS value along all curing days and it was 10 times more than the control sample UCS of artificially contaminated soil after 28 curing days. While (SH25L) has a higher UCS value along all curing days and it was 10 times more than the control sample UCS of artificially contaminated soil after 28 curing days. This increase in strength with a longer curing period reflected the continuous hydration reaction during which the formation of C-S-H and C-A-H gels in lime). The Lime content plays a significant role in compressive strength. It was found that UCS increased when increased the Lime content from 5% to 10% percentage. It can also conclude that 10% of lime is suitable to stabilize the clay soil contaminated with heavy metals.

The effect of nano-silica on UCS of Stabilized Soil with lime

The percentage of NS applied to the lime mortar in the solidification process is another aspect that impacts the compressive strength results. By observing the strength of the mortar with different NS percentages, Figure (2) investigates the relationship between (3%,5%,7%) NS with 5% lime, while Figure (3) shows the relationship between (3%,5%,7%) NS with 10% lime.

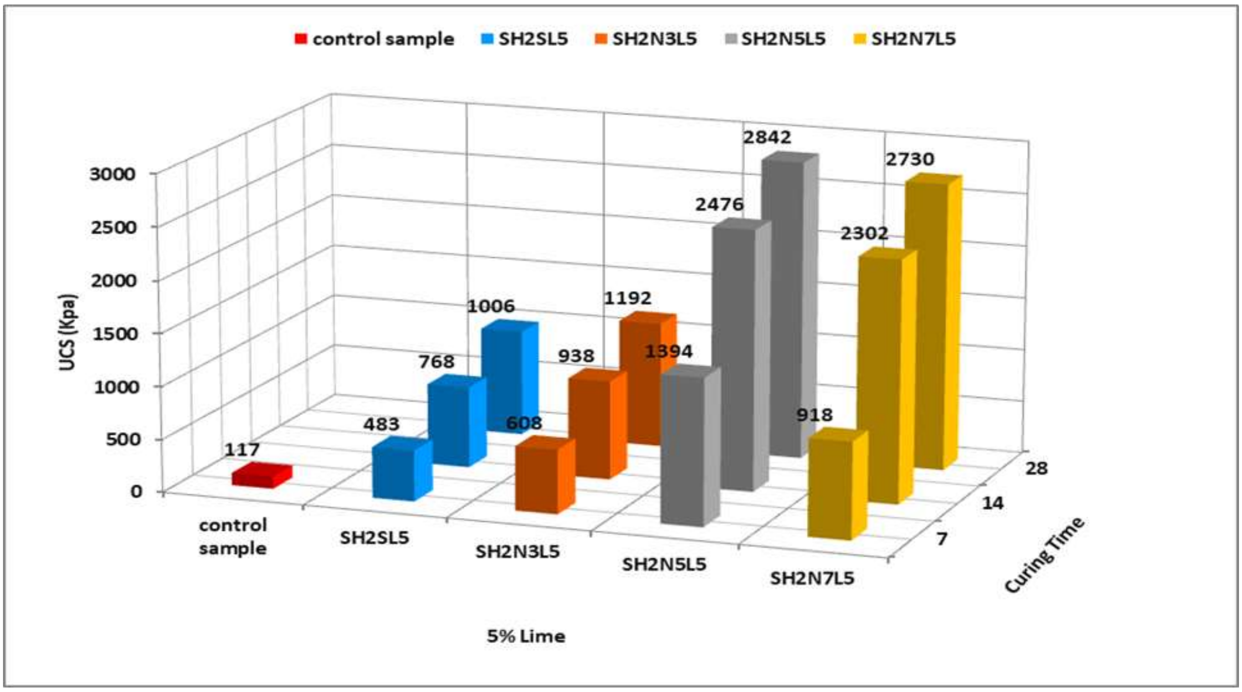

Figure (2) UCS results for Contaminated Soil Mixture NS with 5% Lime

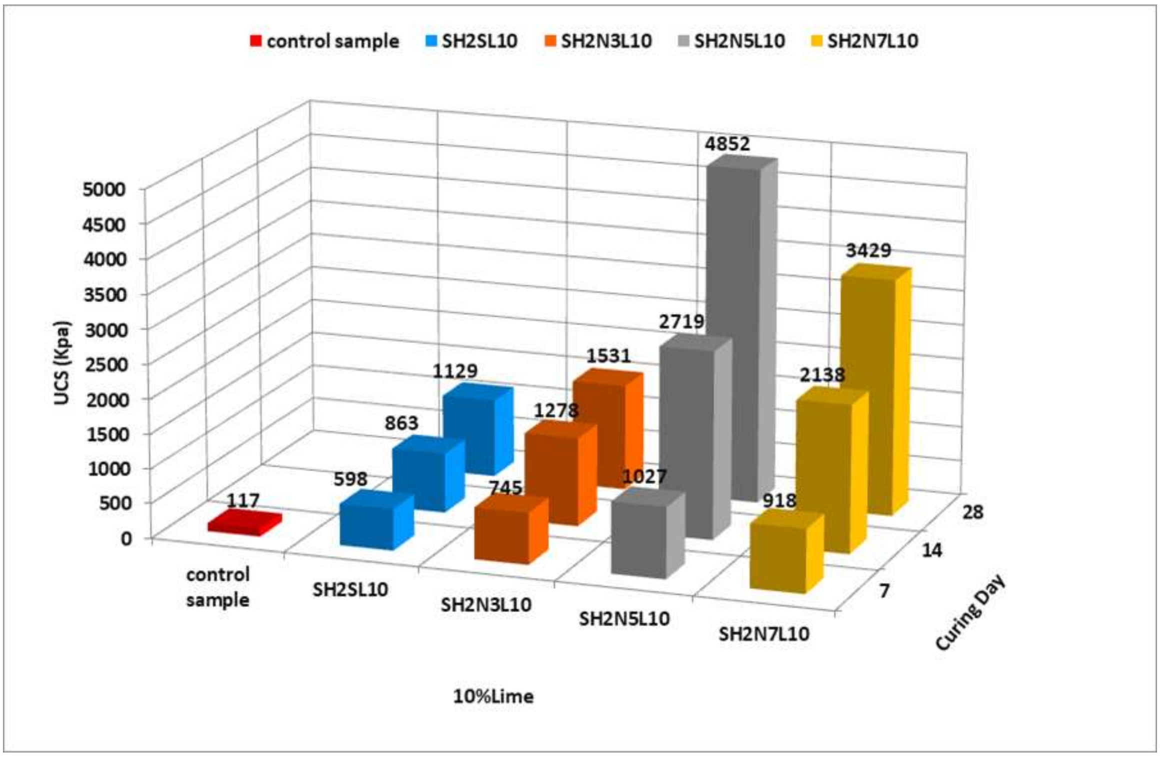

Figure (3) UCS results for Contaminated Soil Mixture NS with 10% Lime

Depending on the results, the UCS value has higher development with increasing curing time as well as with increasing Nanosilica content.

Through curing day 7 and 5% lime with NS, the strength was increased at (SH2N3L5), (SH2N7L5) and reached a maximum at (SH2N5L5). After the 14th and 28th of curing time.Similarly, with 10% Lime with NS, the UCS increased with increasing in Nano silica content and also with increasing in curing time. Maximum strength was attained with (SH2N5L10%) through (the 7th, 14th and 28th) of curing time. However, at 28 days both (3%, 5% and 7 %) NS modified samples showed approximately a similar improvement in strength. The addition of a stabilizer (Lime and NS) will result in a hydration reaction, pozzolanic reaction, and cation exchange on the surface of contaminated soil particles. Soil remediation with NS and Ca(OH)2 undergoes a pozzolanic reaction, leads to the production of calcium silicate hydrate (C–S–H) gel, calcium aluminate silicate hydrate (C–A–S–H) gel, and other hydration reaction products, which played a cementing role between contaminated soil particles (Jose et al., 2020).

The reson behind this change due to the high peciic area for these materials relative to their volume, this is a key feature of nano scale paticles. This provides the ability of Nano Silica to react chemically to a greater extent. Another significant factor is the pozzolanic reaction of NS in lime systems contributes to triggering the consumption of Ca(OH)2, to form C-S-H compounds. The incorporation of nanoparticles in a binder (lime) can introduce enhanced properties and offer systems with significant properties for specific applications. The small size of NSP allows them to act as a filler, taking up the voids in the lime composites, thus reducing porosity and thus reducing porosity and thus leads to enhancing mechanical performance (Nuaklong et al., 2020).

Also, on another hand, the UCS value of (SH2N7L5) was decreased compared to (SH2N5L5) at curing days (7,14,28), Also the UCS value of (SH2N7L10) was decreased compared to (SH2N5L10) at the same curing days as shown in figures (2)(3). The justification behind this fact is that adding a high percentage of NS, minimizes the effects of surface area that led to the formation of the C-S-H gel during the pozzolanic reaction, and also contributes to the formation of weak clusters that can't support large strength, allowing the mortar sample to decrease its compressive strength. On the hand, another possible reason, the water used is not adequate to coat this large amount of NSP causing formed of C-S-H gel and defects in the hydration process accordingly decreasing compressive strength (Onaizi et al., 2021). It can be inferred that slight changes in NS ratios or particle size lead to significant changes in compressive strength. Also, The presence of (Pb and Cd) ions in contaminated soil maybe help the dissolution of aluminate and silicates from contaminated soil on the surfaces of the mineral particles that appeared, which increased the UCS of the stabilized contaminated soils.

Among all NS specimens, (SH2N5L10) proved to be the best mix ratio with higher strength along curing time. This increase is attributable to a sample being nearly dry after 28 days of curing and becoming harder than a sample tested at the initial curing time due to the chemical action of the nanomaterials, which needed water for the reaction to occur. However, at the initial curing time, the sample has high moisture content. Thus, it may take a longer time to apply a load sufficient to fail the sample because possibly the water contained in the very small voids in the artificially contaminated soil needs more time to escape. A higher ratio of surface to volume and, in turn, a higher cation exchange capacity exists. Therefore, they interact very actively with contaminated soil such that very minute amounts may lead to considerable effects on the physicochemical behaviour and engineering properties of contaminated soil (Zomorodian et al., 2017).

Leachability of lead and cadmium from stabilized soil remediation by nano-silica with lime

Figures (4) and (5) present the leached concentration levels of ions (Pb+2 & Cd+2) for solidified soil-treated which was mixed at percentage (5% & 10%) Lime with (3%,5%,7%) Nano silica.

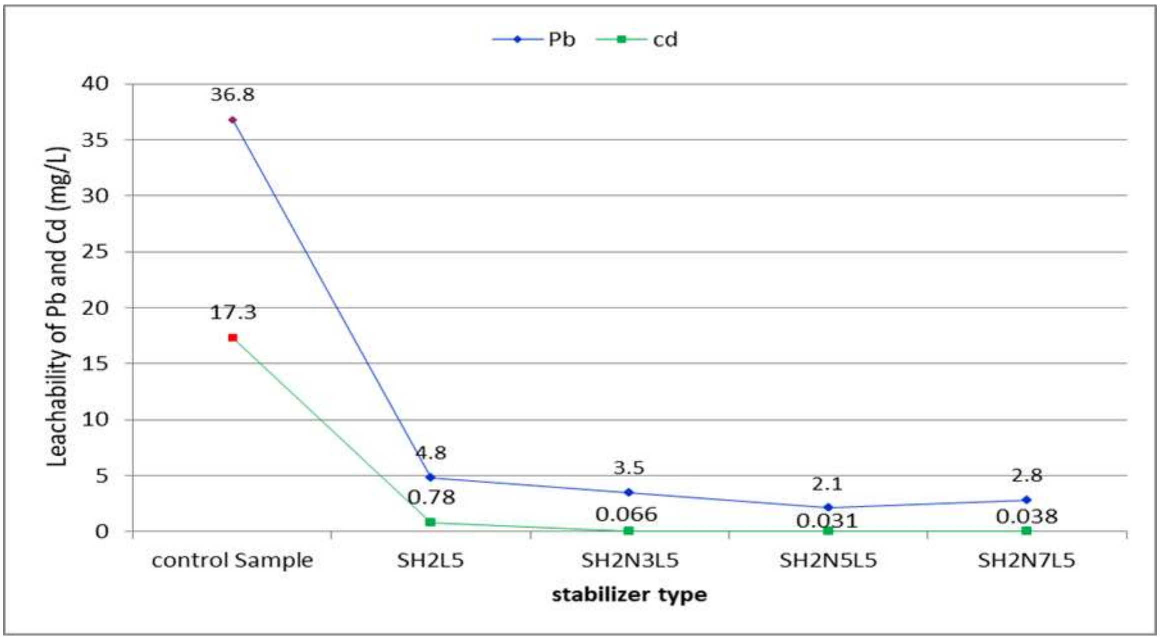

Figure (4) Leachability of Lead and cadmium from Stabilized Soil Treated by Ns with 5% lime

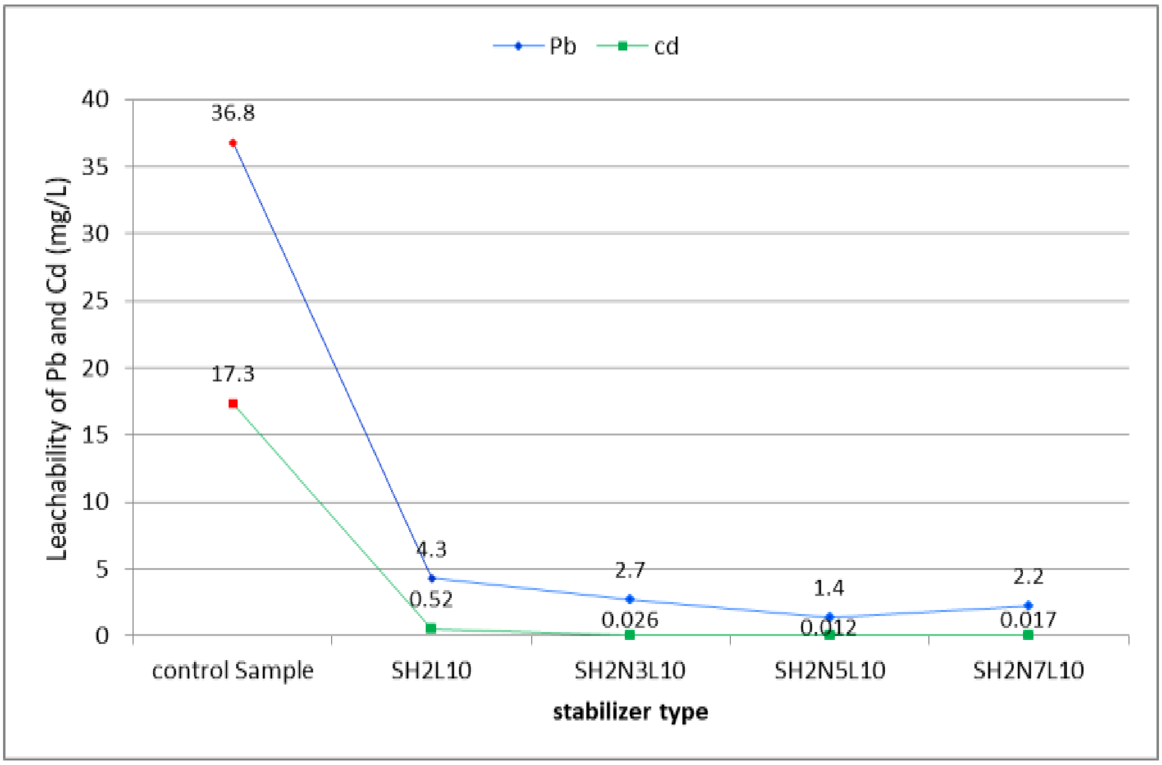

Figure (5) Leachability of Lead and cadmium from Stabilized Soil Treated by Ns with 10% lime.

As seen in Figures (4) and (5), the (Pb and Cd) concentration leached from all cured samples is below the EPA (Pb & Cd) waste disposal limit of (5 mg/l & 1mg/l). Also, these figures show high remediation efficiency when compared with the leaching of the control sample.

The cured samples which used lime only showed a reduction in the leachability rate of (Pb & Cd) ions. When using 5% lime, the efficiency of remediation of Pb and Cd was (87% & 95.5%) respectively. While it was (88.3%, and 97%) respectively when using 10% lime only.

Similarly, with (3%,5% and 10%) NS addition and 5% lime , the leaching concentration of Pb was (3.5, 2.1 and 2.8 mg/l) with efficiency (90.5 %, 94.3 % and 92.4 %) respectively. While the Cd concentration was reduced to (0.066, 0.031 and 0.038 mg/l) with efficiency (99.6%, 99.8% and 99.7%) at the same stabilizer.

Moreover, It shows that with mixing (3%,5% and10%) NS with 10% lime , the lead concentration was (2.7, 1.4 and 2.2 mg/l) with efficiency (92.7%, 96.2% and 94%) respectively. While the Cd concentration was reduced to (0.026,0.012 and 0.017 mg/l) with efficiency (99.85%, 99.93% and 99.90%).

Generally, all the results indicated concentrations of Pb and Cd were below the proposed leaching criteria. It also showed the effect of nano-silica ratios in reducing the leaching concentration when used (3%,5%,10%) ratios. So the mix ratio which attained high treatment efficiency of (Pb and Cd) was obtained at mix ratio (SH2N5L10) under addition and remediation 10% lime with nano-silica, followed by mix ratio (SH2N5L5) when addition and remediation 5% lime with nano-silica. This behaviour is related to the micro filling for aggregation by rich NS, which trapped more heavy metals inside the solidified matrix because the movement of Pb and Cd is leached by a diffusion process. So the higher strength in compressive strength leads to a lower rate of (Pb^{+2} and Cd^{+2}) leach (Wang et al., 2018). The reduction in lead and cadmium concentration extracted when using lime with NS, is related to the solidified phase containing hydrated products such as calcium silicate hydrate (CSH) and ettringite. These hydrated products can inhibit the leaching performance of Lead and cadmium ions through adsorption, encapsulation, and ion exchange (Li et al., 2021).

Changes in soil pH influence HM retention in soil, where HM precipitate to metal hydroxide upon remediation due to the high Ph of all samples remediation with lime and NS. Ca^{+2} can be decomposed and released OH ions upon the reaction of Ca(OH)2 with water, hence resulting in an elevated soil pH . Reducing the pH value to less than 8.3 leads to the melting of lead and cadmium in soil, which greatly enhances the movement of lead and cadmium in soil (Tyler and Olsson, 2001). The immobilization rate of Pb and Cd of the content-contaminated soil by lime was only less than the immobilization rate by remediation chemically with NSP. NS remediation for contaminated soil can Various ratios reduce the leachability content of lead and cadmium in artificially contaminated soil, Based on the results of this study.

Relationship between Maximum UCS and Leachability for the Treated Soil

Figure (6) represents the relationship between maximum UCS and the Pb and Cd concentration which were leached at the same mix ratio. Also shows the comparison of the leaching rate and the maximum UCS for the control sample and nano-silica with lime.

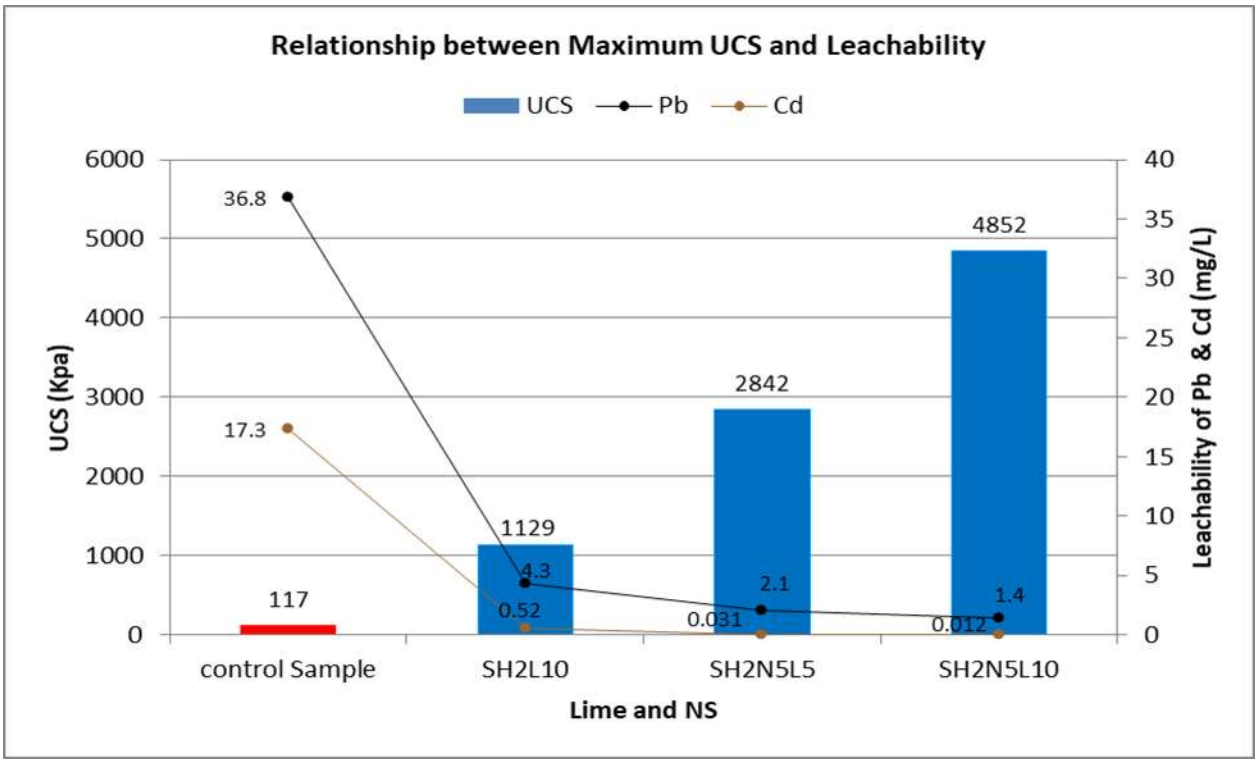

Figure (6) Relationship between Maximum UCS and Leachability for Treated Soil

As shown in the figure (6), it can be seen that the Pb and Cd leachability through the matrix of solidified contaminated soil is related to the gained strength. The high level of leaching which was obtained in the TCLP for (Pb+2 and Cd+2) was (36.8 and 32.1 mg/l) respectively for the control sample when the corresponding UCS was 117 kPa. The lead TCLP test of 4.3 mg/l, 2.1

mg/l and 1.4 mg/l were obtained with SH2L10, SH2N5L5 and SH2N5L10 corresponding to the UCS of 1129kPa, 2842 kPa and 4852 kPa respectively which were below the EPA leachability limit (5 mg/l). While the cadmium TCLP test of 0.52 mg/l, 0.031 mg/l and 0.012 mg/l were obtained with SH2L10, SH2N5L5 and SH2N5L10 corresponding to the same UCS.So, it can be concluded that the solidified sample with higher strength had a lower rate of Pb and Cd during the TCLP test. The control sample as compared with final solidified soil has a high level of leaching of Pb and Cd ions, This is related to the silica content which increases the formation of pozzolanic material and is retained in the solidified matrix (Abdel-Gawwad 2021) . On the other hand, the introduction of NS to lime produces more cementitious compounds which may strongly bind the soil particles together and incorporate more (Pb and Cd) in siliceous solids. Also, Nanomaterials have a high specific surface area and a strong adsorption capacity.

4. Conclusion

Soil stabilization is the method which is used to enhance the physical properties of the soil and thus make it more stable. By-product waste materials have been performed with chemical additives on artificially Pb and Cd-contaminated silty clay soil. The UCS uses nano-silica with lime and nano-silica showed enormous development in strength with progress of time. the optimum mix ratio for each binder which gives maximum strength was attained with (5%nanosilica with 10% lime) and (5%nanosilica with 5% lime). All the solidified sample has gained UCS value that exceeded the limit of landfill disposal (340 KPA).A leachability test was conducted on the samples for 28curing days, showing the reduction in the lead and cadmium leaching rate below the EPA regularity limit (5 mg/l and 1mg/l) respectively. indicates that 5% nano-silica has better efficiency when mixed with (5% and10%) lime. Also, the higher strength of solidified soil can lower the rate of lead and cadmium.

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