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LEACHATE COMPOSITION OF HAZARDOUS WASTE (HEAVY METALS) FROM CEMENT MORTAR MIXED WITH MICROBIAL INDUCED CARBONATE PRECIPITATION

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Abstract

The growth in industrial development leads to the accumulation of several contaminants, like heavy metals, which induce environmental and human health issues. There is a growing need to immobilize/stabilized hazardous waste to minimize their leaching to the environment. At the site, various solutions are used to handle pollutants, including heavy metal remediation and hazardous wastes through solidification/stabilization (S/S) with a binder. This paper will discuss the (S/S) by using bacterial admixed cement mortar. Microbial Induced Calcite Precipitation (MICP) shows the ability to enhance the transmission and durability aspect of Ordinary Portland Cement mortar (OPC) and enhance its performance. Recently, ureolytic bacteria had also suggested as promising micro-organisms well-known for calcite precipitation via the Microbiologically Induced Calcite Precipitation (MICP) procedure.

Key words: bacteria; biocementation; calcite precipitation; cement; MICP.

Introduction

Solidification/Stabilization (S/S) is now a process of technology that can be used to manage contaminated soil, sludge, solid waste, and sludge. This approach minimizes or eliminates the disposal of the toxic contaminants into the ecosystem. The process objectives are: 1. Develop waste management. 2. Minimization of the hazardous substances risk, plants and air, filtering surface and ground waters and soils. 3. Makes optimal use of solidified waste under different circumstances (Ebrahim and Hussain, 2017). Industrial solid waste leachate pollution is one of the major environmental issues in the world by adversely affecting social system physically, economically and with people in everyday life (Yilmaz *et al.,* 2003), There are several landfill restrictions in many parts of the world, waste is banded of land dumping, the land cost and the necessities for remediation are increasing dramatically. That's anywhere (S/S) technology comes in handy for the key part in helping to make landfill waste acceptable (Wiles, 1987). Solidification/stabilization (S/S) is used to decrease the potential risk of hazardous waste by altering the contaminants into their least soluble, mobile, toxic form, and changes in valence state by the addition of binding agent. Thus after using S/S treatment method, the waste will no longer exhibit their hazardous characteristic and can be disposed of as non-hazardous waste(Yilmaz *et al.,* 2003). S/S is one of the utmost public technologies for the remediation of industrial wastes and contaminated soils (Francoy *et al.,* 1998). Portland cement is most widely used for (S/S) as a binding material. The stabilization process using cement depends on the creation of silicate-calcium hydrate ($CaO{\cdot}SiO_2{\cdot}$ nH_2O, abbreviated as C–S–H), ettringite hydrate (3 $CaO{\cdot}Al_2O_3$ 3 $CaSO_4{\cdot}32$ H_2O) and monosulphate (3 $CaO{\cdot}Al_2O_3{\cdot}CaSO_4{\cdot}12$ H_2O) in the mortar, as a result of the portland cement hydration reactions (Tiwari *et al.,* 2015).

As a result of those reactions and the formation of the primary products above, the cement particles bind the adjacent grains together and form a hardened Skelton Matrix. This matrix enclosed the soil particles. Moreover, the cement hydration process results in a rise in the pore water pH as a result of the hydrated lime dissociates. The strong based solution formed directly reacts with the soil silica and soil alumina strong acid. This reaction will gradually produce insoluble compounds (Secondary Cementitious products) that play a big role in the

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stabilization of soil (Ebrahim and Hussain, 2017). So, heavy metals get chemically immobile in the lattice of hydration products as well as physically encapsulated in the solidified cement matrix (Tiwari *et al.,* 2015). Various additives were used with hydraulic cement to increase the efficacy of contaminant S/S, such as microbial induced carbonate precipitation (Khadim *et al.,* 2019). So, this paper provides a detailed overview of the effects of MICP on certain selected physico-mechanical characteristics of cement-based materials. These characteristics include durability, permeability and compressive strength, and their relation to reducing leachate from the solidified cement mortar. The effects of pH and temperature on the optimum MICP process are also presented.

Solidification and Stabilization (S/S) Technology

Inappropriate removal of metal ions can cause significant ecological and environmental issues since water is recognized as the main vector that brings toxic contaminants into the ecosystem. Such risks have prompted a special focus on appropriate heavy metal treatment technologies. One powerful technique is hydraulic binding (S/S), in particular cement. The utilize of cement as a hydraulic binder is among the greatest frequently utilized techniques as a result of its small cost, very good mechanical properties, chemical fixation, low porosity, and the resulting alkaline pH which makes these metals insoluble with minimized environmental impact (Cherif *et al.,* 2018). The main tool available to determine the efficacy achieved by a hazardous waste (S/S) procedure is the chemical analysis of the leachate obtained from the solid product. Furthermore, it is recognized the leachate pH is the utmost important factor in controlling the liquidity of solidified metal-bearing waste, So the lowest leachate concentrations of a lot of significant metals appear within the optimal range of this pH (Francoy *et al.,* 1998). Contamination by industrial solid waste leachate of water sources and soil is one of the causes of the recent diseases. Leachate is the liquid produced once water infiltrates through any porous layer and typically contains either soluble or suspended matter, or both (Tiwari *et al.,* 2015). The disposal of significant quantities of waste to landfill has continued for the near future with many wastes containing heavy metal ions and following substantial waste management and minimization initiatives. By using the (S/S) technique, ions of heavy metal can be encapsulated By linking them together and converted them to solid matrix reluctant to leaching (Ebrahim and Hussain, 2017). Cement-based (S/S) procedures are presently providing an effective alternative for the disposal and treatment of contaminated waste, soils and sediments, particularly those with an aqueous form of waste because cement utilizes water in its hydration phase. Treatment and remediation based on cement (S/S) are ideal for polluted waste forms from heavy metal ions because cement creates a very alkaline environment that can hold such pollutants (Shi and Spence, 2004). Numerous additives have been admixed with cement mortar to increase the effectiveness of S/S of hazardous waste. Some specialized additives are materials created synthetically, while others are naturally present materials (Shi and Spence, 2004). The additives utilized in (S/S) procedure are of various types and are applied at varying levels and mix designs based on the quality of the waste and pollutants to be processed and the final goals of the (S/S) procedure. The major additives are (zeolite, rice husk, calcium-bentonite carbon activated, silica, and kaolinite), microbially induced calcite precipitation (MICP)). Carbonate precipitation via (MICP) process has been investigated commonly for heavy metals removal due to its extensive range of technological applications (T. Sheriff, C. Sollars, D. Montgomery, 1989), (Khadim and Ebrahim, 2019). Table 1 describes some of key binder and additive studied, checked, and utilized in various (S/S) system(Ebrahim and Hussain, 2017).

Principle of biocementation process

The bio-cementation process is a promising technique to reduce contaminants leaching to the environment. Biocementation includes the immobilization of contaminants via (MICP) utilizing ureolytic bacteria (Mwandira *et al.,* 2019). Urea will be hydrolyzed via MICP into carbonate and ammonium via the urease enzyme, which leads to $CaCO_3$ formation with the existence of Caþ ion. The suggested utilization of MICP to hold heavy metals is anticipated to decrease water infiltration and reinstating the polluted site (Mwandira *et al.,* 2019). The calcite is precipitated because of the following factors: (i) calcium ion concentration, (ii) dissolved inorganic carbon and (iii) pH favorable to bacterial metabolism (Ariyanti and Handayani, 2011). MICP includes a sequence of biochemical reactions by urease-producing bacteria. A part of urease, this process requires calcium ions at a concentration that allows carbonate precipitation, while nucleation sites with a strong cation affinity allow calcium ions to accumulate on the cell wall (Kumari *et al.,* 2016).

Applications of carbonate biomineralization by ureolytic bacterial strains include the generation of biomaterials and bioremediation via leaching, solid-phase capturing of inorganic pollutants or plugging biocementation in porous media (Khadim and Ebrahim, 2019). One of the major significant engineering aspects

Table 1: Binders Used in (S/S) Processes.

Binders	References
Cement	Buchler et al,2008.(Pedro Büchler , Rosângela Abdala Hanna, Humayoun Akhtet and B, 2008); Halim et al. 2004(Halim et al., 2004)
Gypsum + Lime + fly ash	Ghosh and Subbarao, 1998(Ghosh et al., 1998)
Cement + H202+ Lime + fly ash	Dutre et al ., 1999(Dutré et al., 1999)
Pozzolan + Lime	Moon et al ., 2004(Dermatas et al., 2004)
Cement + Lime	Leist et al.,2003(Leist et al., 2003);Vandecasteele et al.,2002(Vandecasteele et al., 2002)
Cement + Lime + Iron	Voigt et al ., 1996(Voigt et al., 1996)
Cement + Fly ash	Shih and Lin, 2003(Shih and Lin, 2003)
Cement + Organophilic clay	Buchler et al.,2008(Pedro Büchler , Rosângela Abdala Hanna , Humayoun Akhtet and B, 2008)
Cement + Thermoplastics material	Lin et al 1995(Lin et al., 1995) / British Cement Association 2001)(British Cement Association, 2001)
Microbially Induced Calcium Carbonate Precipitation (MICP)	Wilson Mwandira,2019(Mwandira et al., 2019)

in MICP-mediated procedures is $CaCO_3$ content. The unconfined compressive strength (UCS) of biocement increased with content, which proposes that has a noteworthy role in the strength of the matrix. Also, throughout immobilization, hydraulic conductivity decreasing is wanted since it decreases the capability of water to interact with pollutants, and so, decreases rates of pollutant leaching. The reduction in hydraulic conductivity attained via This method has the potential to limit the entry of water and oxygen into the landfill, and thus reduce heavy metal leaching (Mwandira *et al.,* 2019). MICP has established operative wherewithal to catch heavy metals through groundwater movement (Fujita *et al.,* 2000), (Fujita *et al.,* 2004), (Li *et al.,* 2013). In the MICP method, heavy metals (for example, M^{+2}) can be combined with calcites on their surface through replacement of appropriate cation Ca^{+2} in the calcite lattice (Eq.1), (Khadim and Ebrahim, 2019).

$$M^{+2} + OH^{-} + HCO^{-3} \rightarrow MCO_3 + H_2O \quad \ldots\ldots\ldots(1)$$

MICP produces enzyme urease, and catalyzes urea hydrolysis into ammonia (NH_3) and carbonic acid (H_2CO_3), as shown in Equations (2) and (3). and are transformed into ammonium (NH^{4+}), bicarbonate ions (HCO^{-3}) and hydroxide ions (OH^-) by reaction with water, as shown in Equation (4) and (5). The production of hydroxide ions (OH^-) rises the pH value in the adjacent area. As pH rises, bicarbonate ions (HCO^{-3}) are transformed into carbonate ions (CO_3^{-2}), Equation (6), This renders the surfaces of bacterial cells more negative and draws positively charged calcium ions from the environment to accumulate on the cell surface, as shown in Equation (7), which finally result in the calcium carbonate precipitation in Equation (8) (Lee *et al.,* 2018).

$$CO(NH_2)_2 + H^2O \xrightarrow{urea} NH_2COOH + NH_3 \ldots(2)$$

$$NH_2COOH + H_2O \rightarrow NH_3 + H_2CO_3 \quad \ldots\ldots(3)$$

$$H_2CO_3 \leftrightarrow HCO^{-3} + H^+ \quad \ldots\ldots(4)$$

$$2NH_3 + 2H_2O \leftrightarrow 2NH_4 + 2OH^- \quad \ldots\ldots\ldots\ldots(5)$$

$$HCO^{-3} + H^+ + OH^- \leftrightarrow CO_3^{-2} + 2H_2O \quad \ldots\ldots(6)$$

$$Ca^{2+}\ cell \leftrightarrow Cell - Ca^{2+} \quad \ldots\ldots(7)$$

$$Ca^{2+} + CO_3^{-2} \leftrightarrow CaCO^3 \quad \ldots\ldots(8)$$

Heavy metals

Heavy metals can be defined as Metallic contaminants with relatively had high density (>5 g/cm^3) (Ebrahim and Hussain, 2017). From an environmental point of view, the concept of heavy metal is relatively broad and includes metallic substances that exhibit similar environmental properties; usually highly toxic at low concentrations and long soil residences (Binkley and Simpson, 2003). The term "trace metals" is also often used to describe heavy metals because of their comparatively low natural occurrence in sediments, soil, water, and organisms (Ebrahim and Hussain, 2017). The toxicity of heavy metals depends upon the chemical form in which they are present (Binkley and Simpson, 2003). Most popular heavy metals pollutants are Sn, As, Cr, Pb, Hg, Cd, Sb, Co, Zn, and Cu (Arias *et al.,* 2017). Industrial operations produce vast amounts of waste each year, the bulk of which includes heavy metals that may be harmful to human health and cause environmental problems (Chaabane *et al.,* 2016). The source of the heavy metals related to the disposal of these waste to the landfills without any separation of hazardous contaminants from it, later, these landfills are releasing toxic substances such as heavy metals, into groundwater

(Tantemsapya *et al.,* 2011),. Heavy metal contaminations in soil and groundwater are causing serious threats to the ecosystem. Pretreatment methods should be done properly to control the potential environmental hazard associated with the disposal of heavy metals (Reza *et al.,* 2019). Cement-based (S/S) is a very well-established and commonly used technology for heavy metal processing before landfill disposal (Chaabane *et al.,* 2016), which makes heavy metals released and disperse slowly into the environment after the application of S/S technique as a treatment option (Reza *et al.,* 2019).

Various Micro-Organisms Used for Bio-Cementation

Preceding research has shown that the adding of different organisms to cement - sand mortar deposits inorganic materials inside matrix pores leading to an increase in cement -- sand mortar resistance and water absorption (Abo-El-Enein *et al.,* 2013). Different types of microorganisms can be used but because of the high pH value of cement mortar, Only the so-called alkaliphilic bacteria can live in this form of soil, and after mixing with the cement paste, bacterial spores were found viable. As a result of their minutest cell size (0.5 to 2 µm) and their capability to expand within the soil and great physiological versatility, thus, the classes of chemotrophic prokaryotes are most appropriate for bio-cementation. Table 2 indicates the use of bacterial types with cement paste (Verma *et al.,* 2015).

(Abo-el-enein *et al.,* 2012) Using a mildly alkalophilic aerobic Sporosarcina pasture that has been mixed with the mixing water at various cell concentrations. The analysis showed that the compressive strength of cement mortar increases in 28 days. Within the adding of one optical density (1 O.D) of bacterial cells via mixing water, the bacterial cell achieves. Development in strength and water absorption is attributable to the formation of calcite crystals in the cement – sand matrix pores as asserted by the microstructure achieved from scanning electron microscopy (SEM) analysis (Abo-El-Enein *et al.,* 2013).

(Varenyam Achal *et al.,* 2013), Here the analytic calcifying bacterium *Bacillus* sp. It is being used for cremated bioremediation (Cr (VI)) based on (MICP) from chromium slag. Chromate mobility was reported to have reduced significantly in the interchangeable portion of chromium slag and subsequently significantly increased chromium concentration in the carbonate fraction after bioremediation. These chromium slag bricks were found to produce high compressive strength with low permeability (Achal *et al.,* 2013b).

Optimum conditions for bio-cementation

Bacterial Cell Concentration

Hydrolysis of urea has a linear effect with the concentration of bacterial cells and therefore, affects the rate of calcite deposition. The quantity of calcite precipitation by MICP is increasing with High bacterial cell concentrations (10^6 - 10^8 cells) as a result of the increase in the urease enzyme level produced by bacteria for hydrolysis of urea (Khadim and Ebrahim, 2019). Absorption of water by cement mortar reduces as bacterial cell concentration increases, whereas the compressive strength improves with bacterial cell concentration up to 1 OD; but a reduction in strength development was identified when cement mortar blended with 1.5 OD of a bacterial cell. Hence, the optimal concentration of bacterial cells that result in the highest mortar enhancement provides higher compressive strength and less water absorption is 1 O.D. In cement mortar, the degree of crystallinity of calcite crystals deposited by 1 O.D is greater than that caused by 1.5 O.D of bacterial cells. Also, the volume and size of calcite crystals precipitated by 1 O.D in cement mortar are further than that caused by 0.5 O.D in bacterial cells (Abo-El-Enein *et al.,* 2013).

pH tolerance

Besides this restriction for microbial life, the harsh environment of concrete with extremely high pH can be handled by only a few bacteria such as MICP (Zhu and Dittrich, 2016). Cement mortar matrix has a high pH value. Such high pH values are a prerequisite of MICP, where the organic compounds are reduced to oxide and water in carbon (IV). (Sahoo *et al.,* 2016) Noted that bacterial cells expand gradually during the initial healing cycle as a result of the high pH of the mortar matrix, as they accustom themselves to the new high pH environment (Mutitu *et al.,* 2019). Every microorganism has an optimum pH range and avoiding extreme pH values for the microorganism of interest aids its survival and growth (Williams *et al.,* 2017). If the pH media are above which a specified bacterium may tolerate, then either the bacteria either dead or becomes an endospore. Bacterial

Table 2: Few microbes used in concrete.

No. Applications	Types of bacteria
Microbial concrete as a crack healer	S. pasteurii -Deleya halophila Halomonas eurihalina Myxococcus xanthus
Microbial concrete as surface treatment	Bacillus sphaericus, B. subtili
Microbial concrete as a water purifier	Bacillus subtilis, B. sphaericus Thiobacillus sp

growth/survival is influenced by pH levels in the mortar matrix. For all MICP bacterial kinds, the medium initial pH raised throughout the precipitation, thus altering the environment for optimized precipitation. The effect of pH on MICP, is complicated, as it affects different processes such as microbial activity, urease activity, and calcite solubility (Mutitu *et al.,* 2019).

Temperature tolerance

The optimal temperature for calcite deposition varies from the bacterial activity optimal temperature. Urease was reported to be active at temperatures range between (10°C - 60°C), but urease activity was at its highest at 60, while calcite precipitation increased between 20°C and 30°C, with calcite precipitation highest at 30 (Mutitu *et al.,* 2019). The impact of temperature on MICP is complicated because it influences the urease activity of microorganisms, growth, and crystal nucleation rate and solubility of (Rebata-Landa, 2007) It showed that the production of ceased to occur at a temperature above 60°C due to the death of micro-organisms. It is therefore important to know the best temperature for crystals to form since it contributes to the best strength (Mujah *et al.,* 2016).

Application of MICP with Solidification /Stabilization process

The MICP can be inserted into the cement mortar matrix either through the technique/immobilization of a vascular network or may be added directly throughout the preparation of cement mortar by adding it as the mixing water (Mutitu *et al.,* 2019). The results obtained from different studies on cement mortar with and without bacterial concentrations revealed that the incorporated bacteria is playing a major role in strength improvement (Pawar and Parekar, 2018). The explanation for this change is that calcium carbonate, which is formed microbially, forms a mineral layer covering the bacterial cells. This layer is grown to the level that pores and cracks can be filled together in porous materials and adhesive sand particles, see Fig. 1 (De Belie, 2016).

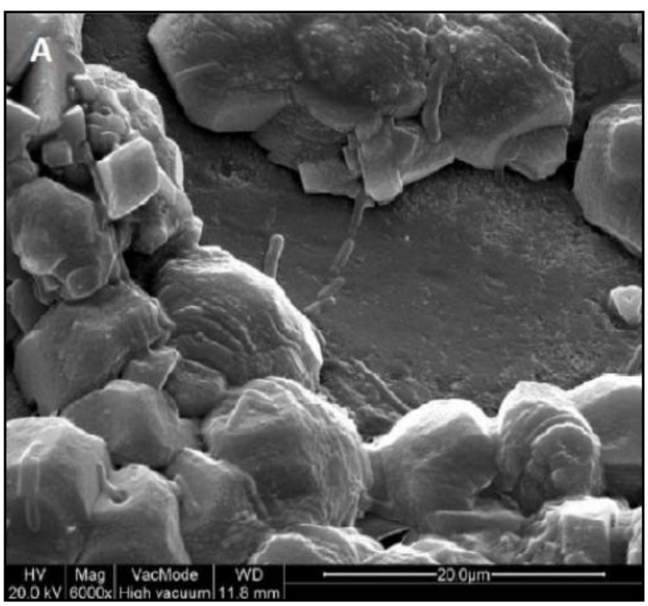

Fig. 1: SEM micrograph of bacterial CaCO3 precipitation on concrete samples (De Belie, 2016).

Another problem is that nutrients will be necessary for bacteria to be active. These nutrients are supplemented to the mortar paste or supplied in nutrient solutions by immersion of the mortar samples (De Belie, 2016). There are two reasons behind using this technique the first is the ability of the MICP to precipitate calcite which enhances the permeability of the cement mortar and the second reason is the potential ability of MICP for immobilization of heavy metals which reduce the future mobility of contaminants to the groundwater (Mwandira *et al.,* 2019).

Physio-mechanical properties of biocement mortar

Strength

Cement mortar admixed within bacterial cells has higher compressive strength values than those of control specimens. Moreover, the general increasing trend in compressive strength by 28 days could be attributed to the performance of bacterial cells inside the cement mortar matrix (Dhami *et al.,* 2016). Microbial cells obtained good nutrition during the initial healing phase since the mortar already porous; however, its growth might not be sufficient because of the entirely new climate for bacterial cells. It could also be likely that as the cement 's pH remained high, cells were inactive, and as the healing time increased, it started to develop slowly. Calcite on the cell surface and inside the cement mortar matrix would have precipitated upon cell growth. When most of the matrix capillaries were blocked, the nutrients and oxygen flow to the microbes paused, the cell gradually died or became endospore and behaved as organic fibers; this is correlated with increment in the compressive strength of the mortar cubes. This describes the idea of the comparatively higher compressive strength value for cement mortar cubes provided by bacterial cells after 28 days (Abo-El-Enein *et al.,* 2013), see Fig. 2. (Varenyam Achal *et al.,* 2015) (Achal and Mukherjee, 2015); Bacillus pasteurii which is an alkalophilic aerobic bacterium, stayed alive in nutrients media supplemented within urea and $CaCl_2$ and a cement mortar was cast utilizing it instead of water. A comparatively higher compressive strength (about 65 MPa) of cement mortar cubes was calculated at 28 days relative to the control mortars (55 MPa), whereby bacterial

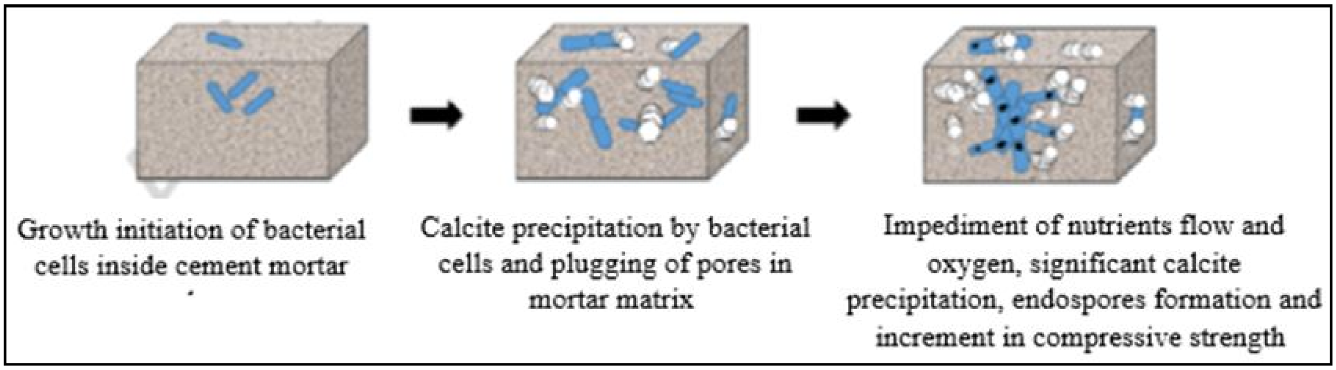

Fig. 2: MICP method for cement mortar strengthen (Achal *et al.,* 2015).

cells were not introduced. S. Maheswaran et al (Maheswaran *et al.,* 2014); This article provides descriptions of the experiments approved on cement mortar utilizing Bacillus pasteurii and Bacillus cereus in diverse cell concentrations. The test indicated that the adding of the two bacterial culture types, increased the cement mortar compressive strength because of the bio-mineralization of calcium carbonate in the mortar matrix. The outcomes of the test showed that compressive strength increased by 38 percent using B. Cereus and a rise of 29 percent for B. Pasteurii over the control cement mortar.

Water permeability

Permeability is seen as the main property for describing the cement mortar durability (Mutitu *et al.,* 2019). It depends largely on the porous network of cement materials, that are measured via variables like porosity, connectivity, distribution of size, tortuosity, specific surface, and micro cracks. MICP revealed the capability to significantly reduce the permeability of cement materials to the water(Achal and Mukherjee, 2015).

Achal *et al.,* (2011a) (Dhami *et al.,* 2016); Studied the effects of Bacillus pasteurii on water waterproofness in cement cubes and noticed a decrease in water infiltration that was more pronounced on the top side than on the sides due to better compaction and closure of pores on the top surface (Achal *et al.,* 2010b). Upon remediation of mortar specimens with Bacillus sp, a six-time reduction in water absorption was recorded. CT-5 as against untreated specimens. Table 3 show some past studies on permeability.

Advantages of Bio-Cementation

The bio-cementing method includes the following advantages over the normal cementing process (Verma *et al.,* 2015):

1. It depends on a bacterial cell that is further tolerant of the conditions of cementation.

2. Consolidation of porous media could be accomplished by using bacterial cultures directly without the need to concentrate the bacterial cells. There is therefore no need for an extra operation to create sand-stone for the bacterial culture.

3. Low energy needed as a result of reactants aqueous nature.

4. A reduction in water penetrability and absorption because of the deposition of calcium carbonate as a layer on the mortar specimen surface and interior pores. It was concluded that bacterial cells can enhance the resistance of cement materials in the degradation process by the existence of a layer of carbonate crystals on the surface.

Leachability mechanism

Table 3: Absorption of Water within bacterial admixed treatment cement mortar via using different bacterial species after 28 days of curing (Mutitu *et al.,* 2019).

Bacterial type	Authors	Absorption of Water after 28 day of curing
Bacillus.sphaericus	De Muynck *et al.,* (De Muynck *et al.,* 2010). Achal *et al.,* (Achal *et al.,* 2011)	45–50% reduction compared with the control sample
Bacillus. subtilis	Reddy *et al.,* (Achal *et al.,* 2013a), Muhammad *et al.,* (Muhammad *et al.,* 2015),Pei *et al.,* (Pei *et al.,* 2013)	about 50% reduction compared with the control sample
Sporosarcina pasteurii	Achal *et al.,* (Achal *et al.,* 2011), Pei *et al.,* (Pei *et al.,* 2013)	50–70% reduction compared with the control sample
Bacillus. pseudofirmus	De Muynck *et al.,* (De Muynck *et al.,* 2010).	50% reduction compared with the control sample

Leaching is a normal phenomenon that water-soluble pollutants are created to wash out of the soil or sources of waste. Such chemicals which are leached out are known as leachates and may contribute to ground and surface water contamination. The literature describes more than one percent method of leaching for extracting dissolved components from a solid matrix (Ebrahim and Hussain, 2017). generally, the effectiveness of S/S treatment methods is evaluated using various leaching tests, depending on several factors (Dermatas *et al.*, 2004). Leachability tests are aimed to evaluate the contaminant potential hazard without considering their exposure pathways (Mwandira *et al.,* 2019). Leaching is usually stated by way of leaching rates, L (t), or as leached by the cumulative fractions, F (t). The leaching rate is expressed as the amount of a species that crosses the leachant-waste interface by area per unit time (Pierre *et al.,* 1987). In particular, toxicity tests can significantly contribute to either the potential hazard of the toxic contaminant or its ecotoxicological characteristics. It is achieved by water leaching the contaminant and normal acidic solutions that reflect atmospheric precipitation (Mwandira *et al.,* 2019). Wastes are categorized as hazardous when the Toxicity Characteristics Leaching Procedures (TCLP) values of the heavy metals are above the standard set in the Resource Conservation and Recovery Act (Kim and Lee, 2017). The current well-known leaching tests which are used with solidified waste form consist of the EPA monolith batch leaching test and the toxicity leaching procedures (Ebrahim and Hussain, 2017). The results of laboratory leaching experiments are utilized to establish a conceptual leaching model which explains the patterns of leaching and specify control of the leaching mechanisms. Table 4 depicts physical, chemical, and biological factors affecting the leaching properties (Ebrahim and Hussain, 2017).

Numerous forms of leaching methods are accessible for determining concentrations of leached heavy metals further down different managing scenarios. A brief overview of the leaching measures employed in this analysis is:

Table 4: Factors affect leaching characteristic.

Physical Factors	Chemical & Biological Factors
shape and size of a particle	Kinetic or equilibrium
solid Matrix mineralogy	Governor of release
interest frame of time	Potential leachability of substances
a flow rate of Leachants	material pH or pH obligatory
Temperature	via its environments
Permeability of the matrix and porosity	Complexation
Hydro-geological condition	Reduction oxidation condition
	sorption procedures
	biologically intermediated procedures

The Semi-Dynamic Leaching test (EPA Test Method 1315)

This process is utilized to supply the mass transfer rate (discharge levels) of inorganic analytes found in a monolithic or compacted granular material, as a function of the leaching period, under diffusion-controlled release conditions. For cement-solidified wastes, this method was suggested. The leaching test method (1315) is a leaching test dependent upon flux. Casting the test samples into standard cylindrical molds. No decrease in particle size is introduced through the study. Leaching information collected from this test is often used to calculate the mass flux and cumulative release of the analyzed specimens to the leaching solution across the total exposed surface area. For inorganic constituents, the test method is specified (*EPA Leaching Method Test procedure 1315*) (US-EPA, 2017a).

The Toxicity Characteristics Leaching Test (EPA Test Method 1311)

The Toxicity Characteristic Leaching Procedures (TCLP) is premeditated to use an acidic medium to model urban solid waste disposal conditions to assess the recoverable organic and inorganic pollutants within a waste. (TCLP) anticipates the possibility of waste leaching when badly managed. If the (TCLP) test results include any of the components of the Toxicity Characteristics (TC) mentioned in section 261.24 of the Code of Federal Regulations (CFR) in a quantity equal to or beyond the defined permissible limit, then the waste is categorized as hazardous waste and the waste has a toxicity characteristic. In other terms, if the testing results (TCLP) exceed the permissible standard limits, then the waste must be further handled before discharge is allowed. (TCLP) is applied to predict a theoretical scenario in which waste is mismanaged by putting it in an unlined, acid-pH landfill simulating the rainwater infiltration of urban landfills (US-EPA, 1992).

The Batch -Extraction Leaching Test (EPA Test Method 1313)

This strategy of the leaching test procedure is developed to supply inorganic constituents (such as metals), with aqueous extracts reflecting the Liquid-Solid Partitioning (LSP) curve as a function of pH. The findings of this research procedure are being utilized for evaluating disposal, effective usage, treatment efficacy, and site treatment options as part of an environmental leaching evaluation. The obtained sieved particles then divided into nine groups each sample (20) gm by dry weight, then used for leaching test (LSP). Twelve (250 ml) polyethylene plastic bottles are being utilized in the extraction vessels included in this test (50 ml extra volume was given for each bottle to permit overhead mixing from top to bottom as required via EPA standard process). Each bottle does have a different pH solution in it. The test method begins via using (20 g) of the crushed sample solidified by pre-weight and applying it into the (200-mile litter) extraction solution. This mixture permits a liquid-to-solid ratio (L/S) of (10ml/g) needed under the testing process (EPA-Method 1313). Extract pH and analytical extract concentrations are calculated for the specified heavy metals. The concentrations are then plotted as an extract pH feature and compared with evaluation and regulatory limits (US-EPA, 2017b).

Conclusion

1- This analysis acknowledged that Bacterial forms can be utilized for improving the physico-mechanical properties of cement mortar when such critical optimal conditions occur.

2- The efficiency of precipitation of calcium carbonate can be affected by bacterial type, bacterial cell concentration, pH, temperature and calcium amount, and the added nutrients in the medium.

3- Mortar compressive strength was found to significantly raise with bacterial concentration increase up to 1 O.D.MICP have the removal ability to the heavy metals.

The use of the MICP leads to increase compressive strength, decrease water absorption, and permeability so that leads to minimizing the leachate of heavy metals from the solidified matrix.

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