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Stabilization of Heavy Metal Sludge to Pass the TCLP Test Using Cement with A Sinter As A Additive

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Abstract

According to the U.S. Stabilisation is the best-proven technology now in use, according to the Environmental Protection Agency's definition in Title 40, Part 268 of the Code of Federal Regulations (40 CFR 268). This method prevents harmful contaminants from leaking into the environment by physically and chemically trapping them all in a matrix. The investigations used 15 different water-mixed combinations of cement, fly ash, sinter, and lime. The study also examined the best solidification/stabilization method for encasing heavy metals, an inorganic hazardous waste, in cement to produce a non-hazardous end product. Compressive strength and metal concentration in the leachate of the stabilized/solidified product were analysed. The solidification procedure can produce sludge with a compressive strength of 68 kg/cm^2 when the additives are added and the mixture is cured at 23°C for 28 days. The best mixes (in terms of UCS) contained the highest compressive strengths, which are almost 18 times the minimal criteria value, proving the significant success of using sinter for solidification. The optimum mixtures have a sludge: additive ratio of 60:30 and additives with a cement content of 15%.

Keywords: Solidification, Stabilization, Digital compression testing machine, TCLP, ICP-OES.

INTRODUCTION

In India, annually about four million metric tons of hazardous waste is generated by thirteen thousand licensed industries, excluding small scale businesses like backyard smelters etc. [1]. This has led to stringent legislation throughout the world. India's turn came up in 1984 after seeing the dangerous realities of industrial hazards due to Bhopal disaster. This forced the government to formulate the Environment (Protection) Act, 1986 [2]. From then, respective state pollution control boards and committees should give authorization to every potential industry which generates hazardous waste [3].

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Based on quantity of hazardous waste generated, industries are classified. All industries except the ones generating less than a thousand kg of hazardous waste per month are termed as large quantity generators [4]. For example, if an industry generates 900 kilograms per month it is termed as small quantity generator [5]. Major producers of hazardous wastes include pulp and paper, electroplating units, thermal power plants, petroleum refineries, chemicals, tanneries, textile, paints, pesticides, and storage batteries industries [6].

Pretreatment of waste in situations where the waste characteristics do not permit for land filling or incineration directly is termed as stabilization [7]. In some instances, pre-treatment is also required in case of incineration. The basic underlying principle of stabilization is to immobilize or prevent the leachability of the toxic constituents [8]. The methods adopted for stabilization of hazardous wastes are chemical, physical, biological and thermal. The most commonly used stabilization processes are. Encapsulation [9]: In encapsulation, occlusion or entrapment of containment particles within a solid matrix is carried out [10] In this process wastes are enclosed within a water-resistant stable material.

Solidification: Solidification is a process of conversion of slurries into solids by addition of solidification and adsorption agents [11]. This procedure lessens the mobility of dangerous compounds and toxins in the environment through both physical and chemical ways. In this process contaminants are only trapped within their medium without removing through treatment. The majority of inorganics are sometimes rendered immobile and organic contaminants are destroyed by using electric current to melt soil or other earthy materials at extremely high temperatures [12] This vitrification, also known as solidification or stabilisation, produces a leach-resistant, chemically stable material that is glassy and crystalline and resembles obsidian or basalt rock [13]. When dumping potentially hazardous materials, the Toxicity Characteristic Leaching Procedure, or TCLP testing, is employed to guarantee the safety of the environment.

OBJECTIVES

1. The project's major goal is to find the best combination of binders and unconventional additional materials for stabilising the two heavy metal-laden waste sludges (from the PCB and electroplating sectors) in an environmentally and financially responsible way.
2. To provide a novel, unconventional partial substitute using waste materials for the conventional binder (cement) in the solidification-stabilization process.
3. To identify the conditions and practical factors that the heavy metal content in leachate must meet in order to be disposed of in a secured landfill.

MATERIALS

1. The solidification additives were Birla Cement, Fly Ash, Specially Prepared Sinter "S", and Lime [1].
2. The Birla Cement Company provided the cement. Raichur Thermal Power Plant provided Class F fly ash.
3. From Chemical Stores, lime of the AR grade was ordered.
4. In this experiment, two different types of sludge from local treatment were used.
5. To determine moisture content, volatile solids, Zn, Cd, Co, Cu, Cr, Fe, Pb, Mn, and Ni, the zinc sludge (ETP sludge) was characterised.
6. The sludge was dried in an oven for 24 hours at 60 degrees Celsius.
7. It was crushed to remove the stones, then sieved to produce a homogenised sample with particles smaller than 1 mm.
8. A typical sample collected from this area had its pH, specific gravity, calorific value, loss on drying, and loss on ignition evaluated.
9. The physical and chemical properties of water treatment sludge from T K Halli water works were evaluated.
10. Equal volumes of ETP and waterworks sludge were sintered at 1000 degrees Celsius for 4 hours in the oven shown above to form the Sinter"S" used in the stabilisation investigations.

METHODOLOGY

Stabilization is a pre-landfill waste treatment process, which has been used for different types of industrial wastes, but is particularly suited to those containing heavy metals [14] The solidification/stabilization (S/S) process utilizes chemically reactive formulations that, together with the water and other components in sludge and other aqueous hazardouswastes, form stable solids. The material used for solidification/stabilization(S/S) not only solidifies the hazardous waste by chemical means but also insolubilizes, immobilizes, encapsulates, destroys, sorbs, or otherwise interacts with selected waste components [15].

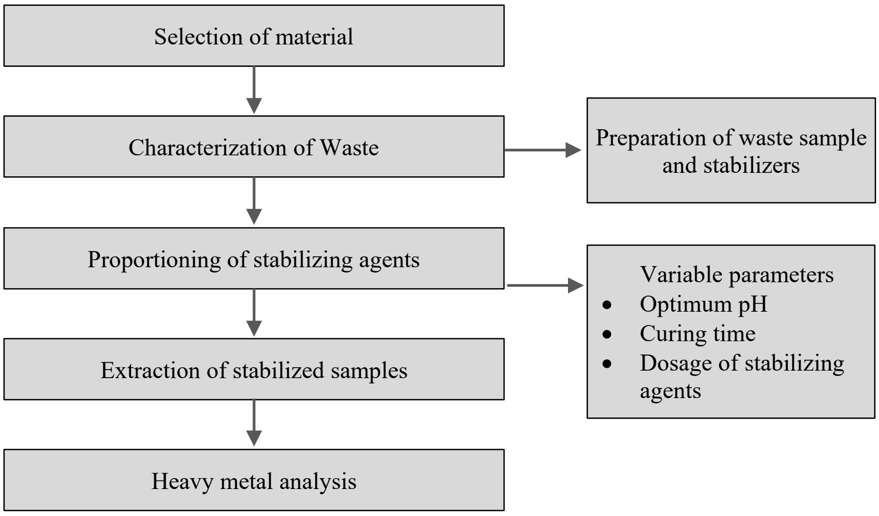

Figure 1. Flow chart of methodology.


Figure 2. Sample preparation.

This project focuses to substantiate the process of stabilization carried out for the samples in terms of both compressive strength and leach resistance. This validation is carried out in following sequential steps as shown in Figure 1.

Sample Preparation

1. 60 grams of the metal-rich soil were mixed with the appropriate weights of cement and solidification agents (fly ash, lime, and sinter "S") using distilled water as shown in Figure 2 [16].
2. The sample mixtures were then placed into 2.5 cm by 7.5 cm long PVC moulds for a 24-hour hardening period, and they were cured for three and seven days in a room with regulated temperature and humidity (23°C, 95% relative humidity).

Homogenizing, Agitating & Extracting Stabilized Samples

1. Stabilization of the wastes were carried out by taking 100 g of the wastes along with different dosage of stabilizing agents (as mentioned in Table 4) and minimum quantity of water in a plastic beaker. The contents were mixed well for a fixed time of 10 min using a mechanical stirrer.
2. Based on the pH of the homogenized sample, Extraction fluid No.1 or No. 2 (procedure given below) is added in the ratio of 1:20. The contents were agitated in a Rotary agitator for a period of about 18 hours &extracted using a TCLP filtration assembly under pressure the procedure of TCLP test is done as shown in Figure 3.

Figure 3. TCLP Procedure.

RESULTS

Heavy metal concentration

1. Table 1 Shows us the Result of Initial Concentration present in the sample, Tables 2 and 3 show that, in terms of unconfined compressive strength (being > 3.5 kg/cm^2), all mixes intended for both chromium and zinc sludges meet the requirements for disposal to SLF.
2. In a universal testing machine, the unconfined compressive strengths of all 30 mix designs (for both chromium and zinc sludges) were calculated, shown in Figures 4 and 5.
3. The UCS values were determined 3, 7, and 28 days following the curing time is as shown in the Figure 4 and Figure 5. (The total number of UCS tests conducted was 15*2*3 = 90.).
4. In all situations, it was found that just a 3-day curing period was enough to meet the required value for secured landfill disposal, which is 3.5 kg/cm^2.
5. Additionally, as rationally predicted, longer curing durations increased the samples' compressive strengths, which peaked at an extraordinary 52 kg/cm^2, or roughly 15 times the SLF criterion value.

Table 1. Heavy metal concentration in samples

S.N.	Sample	Cu	Cr	Fe	Mn	Ni	Pb	Zn	Co
1	Raw Chromium Sludge	350	650	24870	1290	72.4	5.3	200	0
2	Raw Zinc sludge	258	411	6218	2576	80	28.4	254	0
3	Water works sludge	6.2	19.3	789	10.67	0.9	0.2	9.2	0
4	Sinter S	379	257	2156	1235.3	68.6	9.5	134	
5	SLF Disposal Limits	10	0.5	-	-	3	2	10	0

Table 2. Unconfined compression strength of samples containing chromium sludge

Batch No.	3rd Day Unconfined Compressive Strength	7th Day Unconfined Compressive Strength	28th Day Unconfined Compressive Strength
1	19.3	36.6	40
2	29.9	41.8	52
3	19	35.6	39
4.	25.7	39	41.5
5	19.1	40.1	43.1
6	29.1	40.9	49.3
7.	20.4	35.8	42.1
8.	27.7	37	44
9.	18	34	39
10.	16.7	31.9	36.8
11.	17.5	32.8	37
12.	16.6	31.1	38.3
13.	15.7	26.6	33.7
14.	14.9	25.4	31
15.	16.6	27.9	36.8

Table 3. Unconfined compression strength of samples containing Zinc sludge

Batch No.	3rd Day Unconfined Compressive Strength	7th Day Unconfined Compressive Strength	28th Day Unconfined Compressive Strength
1	24.3	30.5	35.2
2	30.2	37.5	51
3	27.8	31.2	36
4.	20.7	33	38
5	25.6	31.5	36.6
6	28.3	35.1	47.8

Batch No.	3rd Day Unconfined Compressive Strength	7th Day Unconfined Compressive Strength	28th Day Unconfined Compressive Strength
7.	19.7	32.1	37.2
8.	22.1	32	37
9.	18.2	31.5	36
10.	17.1	28	34.1
11.	14.5	29.2	35
12.	15.4	27	34.6
13.	13.6	26.7	33
14.	12.5	24.3	31.2
15.	14.5	27	32.7

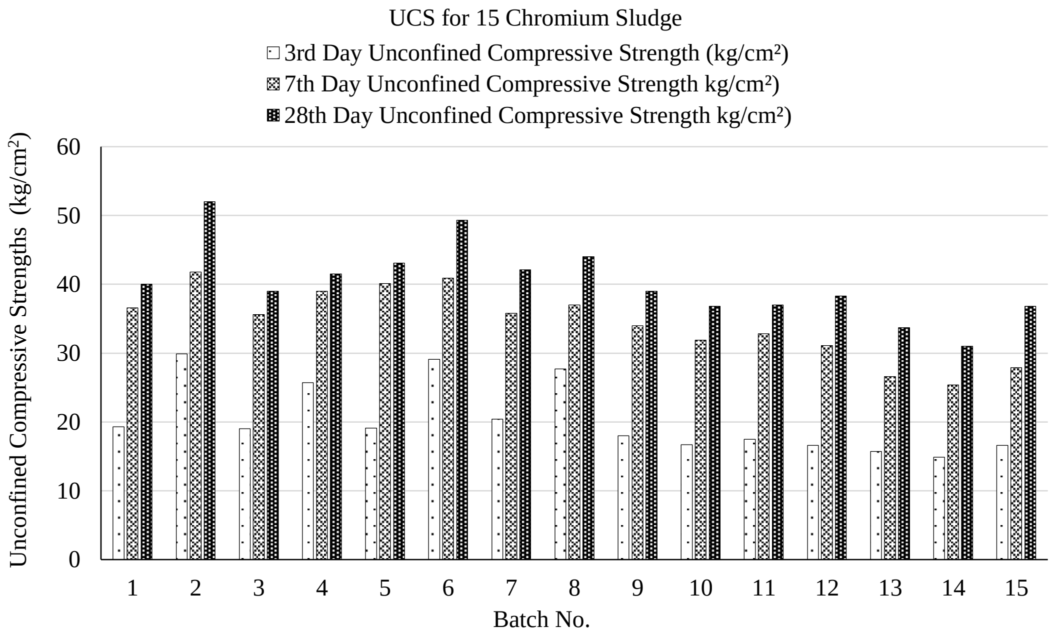

Figure 4. Unconfined compressive strengths after 3, 7, and 28 days for 15 chromium sludge cylinders.

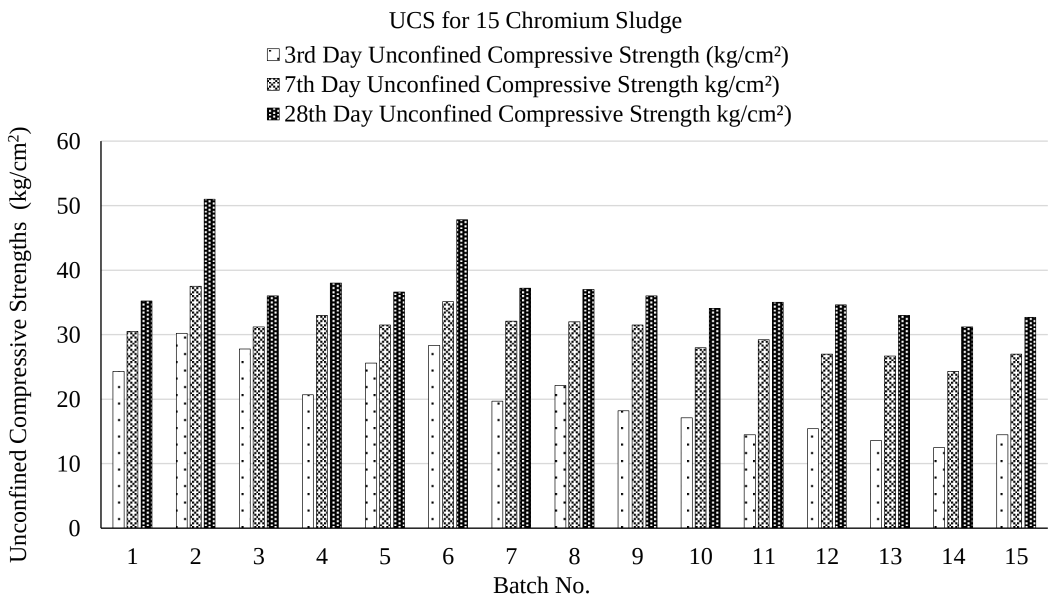

Figure 5. Unconfined compressive strengths after 3, 7, and 28 days for 15 zinc sludge cylinders.

TCLP HEAVY METAL ANALYSIS

The amounts of the various heavy metals found in the leachates collected from the 15 mix design batches for both ETP sludge samples were determined by the leachability experiments. These findings are shown in Tables 4 and 5

Table 4. Variation of HM concentration in leachate with additive: cement ratio in Chromium sludge laden samples

Mix Design Batch No.	Additive: Cement Ratio	HM concentrations in leachate							
		Cu	*Cr*	*Fe*	*Mn*	*Ni*	*Pb*	*Zn*	*Co*
Criteria Conc (ppm)->	*10*	*0.5*	*-*	*-*	*3*	*2*	*10*	*-*	*0.2*
1	20:80	6.57	0.08	0	4.5	1.6	0	6.3	0
2	20:80	6.72	0.05	0	2.73	1.72	0	6.52	0
3	20:80	8.28	0.04	0	2.58	2.34	0	7.25	0
4	30:70	8.15	0.02	0	0	2.9	0	7.3	0
5	30:70	7.71	0.09	0	0	2.0	0	6.92	0
6	30:70	7.82	0.03	0	0	2.68	0	7.48	0
7	40:60	8.95	0.2	0	3.92	2.57	0	7.72	0
8	40:60	9.27	0.1	0	4.15	2.92	0	8.54	0
9	40:60	8.69	0.24	0	4.94	2.4	0	8.26	0
10	50:50	9.92	0.34	0	4.57	1.9	0	9.43	0
11	50:50	9.82	0.49	0	4.56	2.47	0	8.73	0
12	50:50	9.54	0.4	0	4.8	2.5	0	9.75	0
13	60:40	15.27	0.61	0	5.54	4.47	0	10.7	0
14	60:40	17.27	0.62	0	5.31	5.2	0	11.68	0
15	60:40	20.87	0.5	0	5.67	5.6	0	12.6	0

Table 5. Variation of HM concentration in leachate with additive: cement ratio in Zinc sludge laden samples

Mix Design Batch No.	Additive: Cement Ratio		HM concentrations in leachate						
		Cu	*Cr*	*Fe*	*Mn*	*Ni*	*Pb*	*Zn*	*Co*
Criteria Conc (ppm)->	*10*	*0.5*	*-*	*-*	*3*	*2*	*10*	*-*	*0.2*
1	20:80	0	0	0	0	0.7	0.04	5.37	0.06
2	20:80	0	0	0	0	0.9	0.02	5.29	0.8
3	20:80	0	0	0	0	1.6	0.06	5.8	0.5
4	30:70	0	0.02	0	0	1.38	0.4	6.72	0.67
5	30:70	0	0.03	0	0	1.97	0.9	6.3	0.73
6	30:70	0	0.03	0	0	2.1	1.2	6.61	0.84
7	40:60	0	0.07	0	0	1.43	0.8	7.2	1.9
8	40:60	0	0.01	0	0	2.54	0.5	6.5	1.5
9	40:60	0	0.03	0	0	2.38	0.84	7.39	1.4
10	50:50	0	0	0	0	2.7	0.37	7.6	1.9
11	50:50	0	0	0	0	3.1	1.49	8.3	2.6
12	50:50	0	0	0	0	3.4	1.53	8.27	2.35
13	60:40	0	0.2	0	0	4.8	1.4	8.67	2.7
14	60:40	0	0.29	0	0	4.6	1.7	10.2	2.8
15	60:40	0	0.35	0	0	4.48	1.3	9.47	2.6

CONCLUSION

The final phase in the treatment process before disposing of hazardous wastes has long been the employment of these solidification/stabilization technologies utilising cementitious materials. In order to stabilise metal-rich soils from various areas, this research study intends to identify a novel waste addition called "S" that may be put to cement. The mix design with a higher percentage of Sinter demonstrated superior stabilisation effectiveness for a fixed Cement: Additive ratio. In the majority of the situations, mixes with a higher amount of lime showed to be more effective for stabilisation for a specific Cement: Additive ratio and a constant quantity of sinter. During the curing process, fly ash and lime combinations could continually produce pozzolanic reaction. Fly ash can operate as a filler in the solidification matrix because of its extremely small particle size, greatly minimising the leaching of metals.

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