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Stabilization of Industrial Sludge

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ABSTRACT: Rapid industrialization is creating lot of problems in present scenario; the total volume of hazardous waste increases significantly which can adversely affect our environment and human health. The dangerous character and eco-toxicity of industrial sludge is related to high concentrations of leachable metallic species, particularly the transition metals like chromium, nickel and copper. In recent years, with the rapid development of the electroplating industry, electroplating sludge has reached much attention. Electroplating sludge contains heavy metals such as nickel, copper, cadmium and chromium. To avoid these metals from leaching into the ground water, solidification and stabilization method have been evaluated. Solidification and stabilization method have been analyzed for electroplating sludge using different stabilizing materials such as ordinary Portland cement, flyash, bentonite and kaolinite in different proportions such as 10%, 20% and 30% for flyash, bentonite, kaolinite and 2%, 4%, 8% for ordinary Portland cement, for a curing period of 7 days and 28 days. The immobilizing characteristics of these stabilizing materials over metals such as chromium, lead, copper, barium, arsenic and aluminium were evaluated using USEPA method 1311 (Toxicity characteristic leaching procedure). Flyash of 30% and 28 days curing period have shown promising immobilizing characteristics for all the metals under study.

KEYWORDS: Industrial sludge, Heavy metals, Stabilization and solidification, Immobilization, Removal efficiency.

I. INTRODUCTION

Leaching of heavy metals is a huge problem for industries generated hazardous waste containing high amount of heavy metals and recovery of metals from waste is not feasible all the time so various technologies have been developed to convert hazardous waste into non-toxic form. Stabilization and solidification is one of the techniques used to convert hazardous waste into stabilized product. Day by day the generation of hazardous waste is increasing significantly which can adversely affect our environment and health. Therefore, appropriate management is required. Due to limited sites, cost, technology and strict environmental standards for landfilling, waste disposal has become a major concern in most of the industries of India. Recycling of all industrial wastes is not feasible and with the increasing contamination of the natural environment, the problem of heavy metal mobilization becomes more and more significant. Various technologies have been developed to convert hazardous waste into non-toxic form or to reduce the potential release of the toxic compounds into the environment. Stabilization and solidification are physicochemical processes widely used in management of hazardous waste. The terms solidification/stabilization and stabilization/solidification are often used interchangeably and are referred to as S/S. Both techniques are incorporated as one treatment method for immobilization of waste containing high amount of heavy metals using different binding material. Solidification and stabilization refer to a group of cleanup methods that prevent or slow the release of harmful chemicals from wastes, such as contaminated soil, sediment, and sludge. These methods usually do not destroy the contaminants. Instead, they keep them from "leaching" above safe levels into the surrounding environment. Leaching occurs when water from rain or other sources dissolves contaminants and carries them downward into groundwater or over land into lakes and streams.

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1.2 Stabilization and solidification

Solidification/Stabilization improves the handling and physical characteristics of the waste and decrease the surface area across which transfer or loss of contaminants can occur. Stabilization and Solidification have been widely applied in the management of hazardous wastes. The technologies are being applied to (1) The treatment of industrial waste, (2) The treatment of wastes prior to secure landfill disposal, and (3) The treatment of contaminated land where large quantities of soil containing contaminants are encountered.

Thus, stabilization may be described as a process employing additives by which the physical nature of the waste (as measured by the engineering properties of strength, compressibility, and/or permeability) is altered during the process. Thus, objectives of stabilization and solidification would encompass both the reduction in waste toxicity and mobility as well as an improvement in the engineering properties of the stabilized material. The U.S. Environmental Protection Agency (EPA) has identified S/S as the best demonstrated available technology for 57 RCRA (Resource Conservation and Recovery Act)-listed hazardous wastes.

Stabilization is a process employing additives (reagents) to reduce the hazardous nature of a waste by converting the waste and its hazardous constituents into a form that minimizes the rate of contaminant migrating into the environment, or reduces the level of toxicity. Fixation is often used synonymously with stabilization. Stabilization is accomplished through the addition of reagents that (1)Improve the handling and physical characteristics of the waste (2)Decrease the surface area across which transfer or loss of contaminants can occur (3)Limit the solubility of any pollutants contained in the waste (4)Reduce the toxicity of the contaminants.

In contrast, solidification is described as a process by which sufficient quantities of solidifying material, including solids, are added to the hazardous materials to result in a solidified mass of material. Solidifying the mass is accomplished through the addition of reagents that increase the strength, decrease the compressibility, and decrease the permeability of the waste.

The category of solidified/ stabilized material (other x hazardous) is always defined by the categories of modified waste.If the solidified/ stabilized wastes are disposed of in landfills, Waste Act defines the obligation to pay a fee for the total amount of solidified/ stabilized waste disposal.

1.3 The phenomena of leaching

Metal plating has been identified as an environmentally risky industrial sector concerning the potential hazardous nature of its own waste streams. The dangerous character and eco-toxicity of industrial sludge is related to high concentrations of leachable metallic species, particularly the transition metals like chromium, nickel and copper. The large increase of sludge originating from the waste water treatment process has resulted in significant disposal problems. This disposal attitude leads to serious disadvantages, as it contributes to a great build up of environmentally hazardous materials on the earth's crust.

When huge quantities of industrial sludge are deposited for a long time, hazardous substances may be released in the landfill and may percolate through the soil layers and reach groundwater. It is widely accepted that the impact of heavy metals on the environment cannot be assessed by measuring only the total concentration of individual metals. Proper evaluation of the effect of heavy metals on the natural environment is possible by knowing their chemical forms and bindings with soil, sediment, sludge or solid waste components. The chemical association of metals in sludge greatly influences their release into the environment. That is connected with a large number of physical (e.g., particle size, temperature, mode of contact with water) and chemical (e.g., pH, redox, sorption properties, complexing agents) parameters . The most abundant metallic species which are mainly leached from sludge coming from electroplating plants are nickel, chromium, copper, zinc and iron. From an economical point of view, nickel, zinc, chromium and copper are the most interesting metal values to recycle, but the toxicity allied to the high levels of chromium cannot be forgotten.

1.4 Field application of S/S technique

Industrial sludge is characterized by its varied plural types; from drinking water sand filters backwash to very fatty food sludge, meat processing, heavy metals sludge, hydroxide sludge, DAF sludge from variety of sources, printing (boxboard printing), paint, resins, electronic, wafers processing, pulp and papers, textile, anaerobic sludge and others.

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According to EPA, wastes that are defined and regulated under the Resource Conservation and Recovery Act (RCRA) and subsequent revisions and regulations (40CFR261), including state regulations, as being “hazardous wastes”. While this term includes many wastewater streams, its use is confined to more concentrated waste, called “non-wastewater”

The processes and techniques of S/S matured into an accepted, and important, part of environmental technology. The history of S/S for use on hazardous waste residues dates only from about 1970, when the EPA was established.

The roots of most present-day systems go back to four primary areas of technology that were practiced long before then. These are (1) Radioactive waste solidification and disposal (2) Mine backfilling and tailings “stabilization” (3) Soil stabilization and grouting (4) Production of “stabilized” construction base.

Sludge stabilization can be done in field by two methods: (i) In-situ and (ii) Ex-situ

1.4.1 In-situ stabilization

The procedure for an in-situ treatment process may utilize the existing lagoon as a mixing area. Large-scale remediation projects are typically better suited for in-situ remediation, which is usually less costly in such situations. From a regulatory standpoint, in-situ treatment does not trigger Land Disposal Restrictions. Advantages of in-situ stabilization are that a smaller area is required for support and worker exposure to hazardous contaminants is minimized. However, quality control may be difficult to achieve during in-situ mixing.

1.4.2 Ex-situ stabilization

Ex-Situ processes are typically performed on-site using mobile mixing equipment (NAVFAQ). Small batches of waste may also be mixed in drums. Alternatively, area mixing may be implemented, in which waste and reagent are mixed in layers at the final disposal site. Ex-situ processes provide better control over reagents, mixing, and sampling. They are more practical for shallow sites or sites without access for large machinery. Important considerations for ex-situ mixing include swelling during mixing, which can double the original volume of waste, and the generation of harmful odours, dust, and especially organic vapours that are difficult to capture

II. REVIEW OF LITERATURE

A. Andreis et al (1998) performed study on the use of an industrial byproduct, anhydrite (CaSO_4), as an inorganic binder in the solidification/stabilization (S/S) process of heavy metal sludges. The influence of the variables such as binder:waste ratio, anhydrite particle size and water amount on the S/S process of a synthetic sludge containing Cd, Cr and Pb were studied. The Toxicity Characterization Leaching Procedure was used to evaluate the leaching behaviour of heavy metals after treatment with anhydrite. A synthetic sludge containing cadmium, chromium and lead was considered as a reference material, its behaviour was related to industrial heavy metal sludges. It was concluded that significant reductions were achieved in the metal leaching. Lead, cadmium and chromium mobility were reduced near to 90%, depending on the processing variables: binder:waste ratio, particle diameter of the binder and water amount in the mixture; according to the Toxicity Characterization Leaching Procedure (TCLP). Therefore, it was experimentally shown to use anhydrite as binder in S/S processes of hazardous wastes containing heavy metals, in order to satisfy defined regulations of landfill disposal.

K. Sakr et al (2002) made study in which portland cement was mixed with kaolinite clay and epoxy polymer at different ratios to immobilize radioactive waste ions. The physical and mechanical properties of the mixtures in presence and in absence of some chemicals were investigated. Thermal analysis and infrared spectra of each mixture were also determined. Solutions of Cs(I), Co(II), and Ce(III) were prepared by dissolving the chloride salts in 100 ml of distilled water to obtain concentrations of 10–3 mol/l. Cement, kaolinite (100 : 7.5) mixtures were prepared with 2%, 3%, 6% epoxy in presence of 40% water.

Density, initial and final setting times, consistency, water absorption percent and porosity percent of all samples were determined for controlling the immobilization process. The compressive strengths of all samples were determined after 3, 7, 14, and 28 days of preparation. Leachability of ions was measured following the HESPE’s leaching test. Results showed that the retention capacity of kaolinite (milli-equivalent of metal ions taken by one gram of the clay) for Cs(I), Co(II), and Ce(III) were found to be 5.1, 5.4, and 5.3, respectively. These values indicate that kaolinite clay

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cans fix and adsorb suitable amounts of ions from solutions. The presence of 7.5% kaolinite and 6% epoxy polymer increased the mechanical strength of cement mixed by 40% water, and decreased leachability of ions from mixture.

Miljana Prica et al (2011) performed study on the use of sludge from cardboard mill as stabilizing agent in the solidification/stabilization(S/S) treatment of lead polluted sediment. The effectiveness of S/S treatment was evaluated by determining cumulative percentage of lead leached and by applying different leaching tests. TCLP was used to evaluate efficiency of treatment for a given waste in terms of reduction of contaminant mobility and toxicity (USEPA, 2002) .A comparison of the concentrations obtained in the TCLP test showed that lead concentration in treated samples was below concentration obtained for untreated sediment which means that the lead was successfully incorporated in treated matrix .The TCLP Pb concentration was 2.5 mg L⁻¹ of leachate for untreated sediment, which was lower than the regulatory limit of 5 mg L⁻¹ for hazardous waste (USEPA,2002). This was in agreement with the results of sequential extraction procedure. Despite of high pseudo-total lead concentrations lead poses low risk based on the results of TCLP. The immobilization treatment with cardboard mill sludge applied appeared to be efficient in the remediation of sediment contaminated with lead.

III. MATERIALS AND METHODS

3.1 Identification of sludge for the study

There are 400 registered electroplating units in the state located in Thiruvallur, Kancheepuram, Krishnagiri, Madurai and Coimbatore. There are 80 electroplating units located in a mixed residential area in Madurai. These units are mainly operating in small scale sector and 90% of them are carrying out zinc, nickel and chromium plating. The industrial sludge from the T.V.S Sewing Needles Limited situated in the Kaalavasal area of Madurai is collected for the study .This sludge has been produced as a result of the electroplating process undergone in the industry .

3.2 Selection of stabilizing agents

3.2.1 Ordinary portland cement

Ordinary Portland Cement of 53 grade was selected as one of the stabilizing agents for this study because of its high binding capacity. This cement was mixed with the sludge in the ratio of 2%,4% and 8% with the water to sludge ratio of 0.6 and left for curing for a period of 7days and 28days. Water in the sludge reacts chemically with Portland cement to form hydrated silicate and aluminate compounds. Sludge act as an aggregate to form a “concrete”. The optimum combination of the sludge and Portland cement, will vary with the type of sludge and its composition.

3.2.2. Flyash

Low calcium flyash (ASTM class F) was collected from Tuticorin Thermal power plant . Flyash was mixed with the sludge in the ratio of 10%,20% and 30% with the water to sludge ratio of 0.6 and left for a curing period of 7days and 28days.

3.2.3. Bentonite

Bentonite is a clay mineral consisting mostly of montmorillonite. It forms from the weathering of volcanic ash. It was mixed with the sludge in the ratio of 10%,20% and 30% with the water to sludge ratio of 0.6 and left for a curing period of 7 days and 28 days.

3.2.4. Kaolinite

Kaolinite is a clay mineral, with the chemical composition of $Al_2Si_2O_5(OH)_4$. It is produced by the chemical weathering of aluminium silicate minerals like feldspar. It was mixed with the sludge in the ratio of 10%,20% and 30% with the water to sludge ratio of 0.6 and left for a curing period of 7days and 28days.

3.3 Stabilization and Solidification of the sludge using different stabilizing agents

Electroplating sludge was collected from a sewing needle industry which generates sludge from the electroplating processes carried out there. Electroplating sludge contains heavy metals such as zinc ,lead ,chromium. The characteristics of the sludge was analysed by ICP-OES after digesting the sludge with acid. Based on the characteristics of the sludge, suitable stabilizing agents were selected.

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Here OPC , flyash , Bentonite and Kaolinite were selected as stabilizing agents and collected from the local market. Each agents were mixed with the sludge in different proportions, so as to arrive to the optimum proportion at the end. Trails were done to arrive to the most suitable moisture content, here a water to sludge ratio of 0.6 was found to be suitable. The sludge should be finely grinded and sieved through 2mm sieve. Two control samples were prepared ,packed and sealed in a plastic bag, for 7 days and 28 days curing period.

After the curing period, Toxicity Characteristics Leaching Procedure Test was done. TCLP was done to determine the leaching behaviour of the samples. The tests were carried out following the guidelines provided by U.S EPA which describes the standards to be followed for the TCLP test (method 1311). TCLP analysis by EPA 1311 is a leaching procedure designed to replicate the leaching of contaminants in municipal landfills due to typical municipal landfill leachates TCLP was done for both the control samples and the samples mixed with the stabilizing agents. This methodology was developed to estimate the mobility of specific inorganic and organic contaminates that are destined for disposal in municipal landfills. The TCLP extraction is performed by subjecting the material to be tested to a simulated landfill leachate. Acetic acid was chosen as the extraction fluid because it is the major component of typical municipal landfill leachates. The pH of the acetic acid buffer solution is maintained at 4.93. This sample/acetic acid mixture was subjected to an 18 (\pm 2 hours) rotary extraction, designed to accelerate years of material/landfill exposure in the shortest possible time.

Samples were oven dried and mixed with 0.1 M of acetic acid in the ratio of 1:20 of sludge and acid. Here 10g of the sample was mixed with 200ml of the acid, kept in an agitator for about 18 hours .Then the mixture was allowed to settle down. By filtering the mixture in whatman filter paper, extract can be taken out. Leaching behaviour of the extract was analysed through ICP-OES.

IV. EXPERIMENTAL RESULTS

4.1 Analysis of sludge characteristics

Metal characterisation was done to identify the prevalence of various heavy metals in the electroplating sludge. Selection of binders were based on the characteristics of the sludge. Characterisation was done using ICP-OES after digesting the raw sludge with acids.

Table 4.1: Chemical composition of the Electroplating sludge

Metals	Concentration (mg/g)
Chromium	164.5
Lead	2.475
Copper	1.875
Barium	0.8
Aluminium	0.4375
Arsenic	0.2

Since the sludge was an electroplating sludge, it contains larger concentration of chromium which accounts for about 164.5 mg/g of sludge. Next to chromium ,lead accounts for about 2.475 mg/g .Other heavy metals present in the sludge

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are Copper, Barium , Aluminium and Arsenic , accounts concentration of 1.875 mg/g , 0.8mg/g , 0.4375mg/g and 0.2 mg/g respectively. Heavy metals such as manganese, molybdenum, nickel, selenium, zinc are also present.

4.2 Analysis of leaching behaviour using TCLP

Table 4.2 Results of leaching of sludge stabilized by Flyash

Curing Period : 7 days

Stabilizing Agent	Proportion (%)	Heavy Metals					
		Cr (mg/g)	Pb (mg/g)	Cu (mg/g)	Ba (mg/g)	Al (mg/g)	As (mg/g)
Flyash	0	20.92	0.76	0.56	0.28	0	0.04
	10	11.86	0.14	0.32	0.10	0.12	0.04
	20	11.14	0.14	0.30	0.08	0.06	0.04
	30	7.7	0.08	0.18	0.06	0.04	0

The results of leaching shows there was zero migration of Arsenic when stabilized with flyash of 30% in a curing period of 7 days. Hence for controlling Arsenic 7 days curing period with 30% flyash is optimum .Lead, chromium, copper , Aluminium ,Barium have also been considerably reduced.

Table 4.3 Results of leaching of sludge stabilized by Flyash

Curing Period : 28 days

Stabilizing Agent	Proportion (%)	Heavy Metals					
		Cr (mg/g)	Pb (mg/g)	Cu (mg/g)	Ba (mg/g)	Al (mg/g)	As (mg/g)
Flyash	0	16.72	0.76	0.48	0.32	0.08	0.04
	10	9.64	0.08	0.56	0.04	0.08	0.02
	20	4.16	0.04	0.56	0.08	0.08	0.02
	30	2.94	0.02	0.08	0	0	0

Barium ,Aluminium and Arsenic has been completely arrested from leaching. Chromium, Lead, Copper has leached in very lesser amount. Hence for arresting Chromium ,lead ,Copper Barium, Arsenic, Aluminium, 30% flyash in 28 days curing period was found to be very effective

Table 4.4 Results of leaching of sludge stabilized by Ordinary Portland Cement

Curing Period : 7 days

Stabilizing Agent	Proportion (%)	Heavy Metals					
		Cr (mg/g)	Pb (mg/g)	Cu (mg/g)	Ba (mg/g)	Al (mg/g)	As (mg/g)
Ordinary Portland Cement	0	20.92	0.76	0.56	0.28	0	0.04
	2	14.42	0.16	0.26	0.12	0.38	0.04
	4	9.40	0.16	0.26	0.12	0.42	0.04
	8	7.72	0.14	0.22	0.12	0.42	0.02

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Leaching of Aluminium was found to increase when stabilized with cement as cement already has alumina content in it. Hence OPC should never be preferred for sludge if the sludge is found to have larger proportions of Aluminium. But it has shown promising immobilizing characteristics for Cr, Pb, Ba.

Table 4.5 Results of leaching of sludge stabilized by Ordinary Portland Cement

Curing Period : 28 days

Stabilizing Agent	Proportion (%)	Heavy Metals					
		Cr (mg/g)	Pb (mg/g)	Cu (mg/g)	Ba (mg/g)	Al (mg/g)	As (mg/g)
Ordinary Portland Cement	0	20.92	0.76	0.56	0.28	0	0.04
	2	6.56	0.16	0.24	0.02	0.10	0.04
	4	5.04	0.12	0.20	0.02	0.28	0.04
	8	4.26	0.08	0.16	0	0.64	0.02

OPC of 8% has completely immobilized Barium. It also has immobilized chromium to a greater extent but not as great as that of 30% of flyash. Aluminium had leached in greater amount, that is negative immobilization was taken place for Aluminium. Lead is immobilized efficiently than that of 7 days period.

Table 4.6 Results of leaching of sludge stabilized by Bentonite

Curing Period : 7 days

Stabilizing Agent	Proportion (%)	Heavy Metals					
		Cr (mg/g)	Pb (mg/g)	Cu (mg/g)	Ba (mg/g)	Al (mg/g)	As (mg/g)
Bentonite	0	20.92	0.76	0.56	0.28	0	0.04
	10	16.40	0.16	0.36	0.04	0.14	0.02
	20	15.68	0.16	0.26	0	0.16	0.02
	30	13.82	0.14	0.24	0	0.28	0.02

Bentonite of 20% has tremendously immobilized Barium at 7 days curing period. 10% of bentonite in 7 days and 30% bentonite was found to be effective over 28 days curing period in controlling As and Cu respectively.

Table 4.7 Results of leaching of sludge stabilized by Bentonite

Curing Period : 28 days

Stabilizing Agent	Proportion (%)	Heavy Metals					
		Cr (mg/g)	Pb (mg/g)	Cu (mg/g)	Ba (mg/g)	Al (mg/g)	As (mg/g)
Bentonite	0	16.72	0.76	0.48	0.32	0.08	0.04
	10	10.94	0.10	0.36	0	0.04	0.04
	20	10.84	0.08	0.30	0	0.08	0.04
	30	8.52	0.06	0.24	0	0.08	0.04

Bentonite has shown lesser efficiency in immobilizing Cr comparatively to other stabilizing agents. 30% bentonite has shown good results in immobilizing Pb. Hence bentonite could not be preferred for stabilizing electroplating sludge as it mainly contains chromium.

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Table 4.8 Results of leaching of sludge stabilized by Kaolinite

Curing Period : 7 days

Stabilizing Agent	Proportion (%)	Heavy Metals					
		Cr (mg/g)	Pb (mg/g)	Cu (mg/g)	Ba (mg/g)	Al (mg/g)	As (mg/g)
Kaolinite	0	20.92	0.76	0.56	0.28	0	0.04
	10	14.22	0.14	0.34	0.10	0.08	0.02
	20	11.80	0.10	0.32	0.10	0.08	0.02
	30	4.38	0.08	0.12	0.02	0	0

Kaolinite of 30% had completely arrested Al and As migration. Al had not shown greater results for other stabilizing agents, hence kaolinite is the best stabilizing agent for controlling Al with the optimum proportion of 30% and optimum curing period of 7 days. It also had immobilized Cr more efficiently than 28 days curing period.

Table 4.9 Results of leaching of sludge stabilized by Kaolinite

Curing Period : 28 days

Stabilizing Agent	Proportion (%)	Heavy Metals					
		Cr (mg/g)	Pb (mg/g)	Cu (mg/g)	Ba (mg/g)	Al (mg/g)	As (mg/g)
Kaolinite	0	16.72	0.76	0.48	0.32	0.08	0.04
	10	5.86	0.06	0.16	0.06	0	0.04
	20	4.98	0.04	0.12	0.02	0	0.04
	30	4.38	0.04	0.10	0.02	0	0.04

Kaolinite of 28 days curing period has immobilized lead in greater efficiency than 7 days curing period. Kaolinite of 10% has completely immobilized Aluminium. Hence if kaolinite has to be opted as a stabilizing agent 7 days curing period was found to be optimum for arresting the migration of all the metals.

Table 4.10 Efficiency of immobilization

Curing period : 7 days

S.NO	Stabilizing Agent	Percentage Immobilization					
		Cr (%)	Pb (%)	Cu (%)	Ba (%)	Al (%)	As (%)
1	Flyash 10%	92.79	94.34	82.9	87.50	72.57	80
	Flyash 20%	93.22	94.34	84.00	90.00	86.29	80
	Flyash 30%	95.32	96.77	90.4	92.50	90.86	100
2	Cement 2%	91.23	93.50	86.13	85.00	13.10	80
	Cement 4%	94.29	93.50	86.13	85.00	4.00	80
	Cement 8%	95.30	94.34	88.27	85.00	4.00	90
3	Bentonite 10%	90.03	93.50	80.80	95.00	68.00	90
	Bentonite 20%	90.47	93.50	86.13	100	63.43	90
	Bentonite 30%	91.77	94.34	87.20	100	36.00	90
4	Kaolinite 10%	91.36	87.00	81.87	87.50	81.70	90
	Kaolinite 20%	92.83	95.95	82.90	87.50	81.70	90
	Kaolinite 30%	97.34	96.77	93.60	97.50	100	100

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Kaolinite of 30% has shown utmost immobilization of chromium of about 97.34% in 7 days and bentonite of 10% proportion has shown least immobilization characteristics. Kaolinite of 30% and flyash of 30% proportions have immobilized lead to higher efficiency of 96.77%. It also has immobilized copper to a greater extent of 93.60% and also has completely immobilized Arsenic. For controlling migration of Barium, bentonite of 20% proportion of 7 days curing period was found to be optimum.

Table 4.11 Efficiency of immobilization

Curing period : 28 days

S.NO	Stabilizing Agent	Percentage Immobilization					
		Cr (%)	Pb (%)	Cu (%)	Ba (%)	Al (%)	As (%)
1	Flyash 10%	94.14	96.77	86.13	95	77.10	80
	Flyash 20%	97.47	98.38	91.47	100	100	80
	Flyash 30%	98.23	99.20	95.73	100	100	100
2	Cement 2%	96.01	93.50	87.20	97.50	77.14	80
	Cement 4%	96.69	95.15	89.33	97.50	36	80
	Cement 8%	97.41	96.77	91.47	100	0	90
3	Bentonite 10%	93.34	95.96	80.80	100	90.86	90
	Bentonite 20%	93.41	96.77	84.00	100	81.80	90
	Bentonite 30%	94.82	97.58	87.20	100	81.80	90
4	Kaolinite 10%	96.43	97.58	91.47	92.50	100	90
	Kaolinite 20%	96.97	98.38	93.60	97.50	100	90
	Kaolinite 30%	97.34	98.38	94.67	97.50	77.14	100

Flyash has immobilized chromium with greater efficiency of 98.23% for a proportion of 30%. Cement should never be chosen if the sludge is found to have greater Aluminium content. For controlling lead from leaching, 20% of flyash and 20% of kaolinite was found to be very effective. 30% of flyash was found to be the best agent for immobilizing copper. Flyash 20%, 30%, cement of 8%, Bentonite of 10%, 20%, 30% and kaolinite of 10% has completely immobilized. Flyash and Kaolinite have completely immobilized aluminium and barium.

4.3 Identification of best stabilizing agent

From the study, it has been found that 30% of flyash with a curing period of 28 days exhibits excellent characteristics in immobilizing chromium with the removal efficiency of 98.23% and also accounts for 99.20% of Lead immobilization. 30% of flyash of 7 days curing also had shown promising immobilizing characteristics with efficiency of 95%. This 30% flyash with 7 days curing period completely immobilized Arsenic, 20% and 30% flyash of 28 days has completely immobilized Barium.

Cement was also found to be an efficient stabilizing agent for all the metals except Aluminium, immobilization of Barium (85%) remains the same for 2%, 4% and 8% of cement of 7 day curing period. 8% cement of 7 days curing period accounts for 90% removal of Arsenic. Also 28 days cement of 8% has reduced leaching of chromium for about 97.41%. and also accounts for about 96.77% removal efficiency of lead.

Bentonite was not found to be very effective in immobilizing chromium comparing other stabilizing agents. 20%, 30% bentonite of 7 days and all the 10%, 20% and 30% bentonite of 28 days completely immobilized barium. Hence 20% of bentonite with a curing period of 7 days was found to be optimum. Also 10% of bentonite has immobilized Arsenic by 90% in 7 days period. For immobilizing Arsenic it was found that 7 days period has shown greater results over 28 period. It also has immobilized copper upto 87.2%

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Kaolinite exhibits maximum efficiency in immobilizing lead, copper and chromium. It could immobilize upto 98.38% for 30% kaolinite in 28 days period. 30% kaolinite of 7 days has 100% immobilization of arsenic, 97.34% immobilization of chromium, 96.77% of lead and also has reduced copper for about 93.6%. Hence if kaolinite is used as a stabilizing agent its optimum period can be taken as 7 days.

In this study, the electroplating sludge has chromium in dominance. The best stabilizing agent was found to be flyash which has the maximum efficiency to remove these metals, the optimum period was found to be 7 days with the optimum proportion of 30%

V. CONCLUSION

The sludge taken for study was Chromium rich, from the study it was found that flyash of 30% proportion for 28 days curing had shown superior immobilization characteristics of about 98.23% of chromium, which was concluded to be optimum for chromium laden electroplating sludge. The sludge also contains other heavy metals such as lead, barium, arsenic, copper, aluminium. Considering them, for copper, Kaolinite of 30% with 28 days curing has superior immobilization over other stabilizing agents. Kaolinite of 30% proportion with 28 days curing period found to be optimum for arresting migration of lead. For controlling aluminium, cement should never be considered as it already has alumina content in it. Flyash of 20% and kaolinite of 20% have proved to be efficient for aluminium. For controlling Barium, bentonite of 20% over 7 days curing period proved to be most effective. Kaolinite 30% of 7 days has completely arrested Arsenic from leaching and hence proved to be optimum for barium. Kaolinite of 30% and flyash of 30% over 7 days period have found to be optimum for arsenic. Overall, flyash of 30% proportion over 28 days curing period was found to be optimum for the electroplating sludge taken for the study.

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