HOLOS ENVIRONMENT

IMMOBILIZATION OF CHROMIUM IN CEMENT MATRICES AFTER TREATMENT BY STABILIZATION/SOLIDIFICATION OF SOLID CHEMICAL RESIDUES

IMMOBILIZAÇÃO DO CROMO EM MATRIZES DE CIMENTO APÓS TRATAMENTO POR ESTABILIZAÇÃO/SOLIDIFICAÇÃO DE RESÍDUOS QUÍMICOS SÓLIDOS

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Abstract: Residues generated at the Universities represent 1% of the total waste in relation to other sources that generate solid waste, however, they have difficulty in treatment due to the amount and diversity of compounds present in a single waste. The residues are classified according to characteristics of flammability, corrosivity, reactivity, toxicity and pathogenicity (Class I) or biodegradability, combustibility or solubility in water (class II A or class II B). When they are classified as dangerous, they cause damage to health and the environment. An alternative treatment is stabilization/solidification, which promotes the incorporation of waste into cementitious matrices. The objective of this work was to immobilize chromium present in solid residues from chemical laboratories in cementitious matrices, aiming to reduce the environmental impact caused by the inappropriate destination of this type of residue. The specimens were made with pozzolonic Portland cement, fine sand, gravel and solid chemical laboratory residue. After integrity/durability tests and immobilization of contaminants, the best results were found for the incorporation of 5% of solid laboratory residues. Despite the 35% matrix having failed the leaching test, all treatments showed chromium retention efficiency above 93%, indicating that there was a significant reduction in the metal concentration in the residue after treatment.

Keywords: Treatment. University. Solid Residue. Leaching.

Resumo: Os resíduos gerados nas Universidades representam 1% do total de resíduos em relação às demais fontes geradoras de resíduos sólidos, porém, apresentam dificuldade de tratamento devido à quantidade e diversidade de compostos 67ignific em um único resíduo. Os resíduos são classificados de acordo com as características de inflamabilidade, corrosividade, reatividade, toxicidade e patogenicidade (Classe I) ou biodegradabilidade, combustibilidade ou solubilidade em água (classe II A ou classe II B). Quando classificados como perigosos, causam danos à saúde e ao meio ambiente. Um tratamento alternativo é a estabilização/solidificação, que promove a incorporação dos resíduos nas matrizes cimentícias. O objetivo deste trabalho é 67ignific a imobilização do cromo presente em resíduos sólidos de laboratórios químicos em matrizes cimentícias, visando reduzir o impacto 67ignifica causado pela destinação inadequada desse tipo de resíduo. Os corpos-de-prova foram confeccionados com cimento Portland pozolônico, areia fina, brita e resíduo sólido de laboratório químico. Após testes de integridade/durabilidade e imobilização de contaminantes, os melhores resultados foram encontrados para a incorporação de 5% de resíduos sólidos de laboratório. Apesar da matriz de 35% ter falhado no teste de lixiviação, todos os tratamentos apresentaram eficiência de retenção de cromo acima de 93%, indicando que houve redução 67ignificative na concentração do metal no resíduo após o tratamento.

Palavras-chave: Tratamento. Universidade. Resíduo Sólido. Lixiviação.

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1 INTRODUCTION

The National Solid Waste *Policy* (BRASIL, 2010), states that in a waste management plan it is recommended to have a description of the enterprise or activity; the recognition of solid waste generated as origin, volume and characterization; covering related environmental liabilities. In addition to the determination of those responsible for the management steps and operational procedures; the identification of joint or common solutions with other generators; the objectives and ways related to minimizing the generation of solid waste, among others.

The laboratories of Higher Education Institutions, even though they are not large generators of chemical waste, contain a large amount of stored material, which is used almost daily in activities performed by students, that is, the generation of waste becomes unquestionable, even if in small quantities.

The management of chemical waste in Brazilian [HEIs] is still a relatively new concept, especially when it comes to chemical residues generated in laboratory practices (ANTONIASSI *et al.*, 2017). In Brazil, very few Federal Higher Education Institutions have created chemical waste management programs. Regarding federal institutions, 44.6% have a consolidated program or have a plan drawn up. In State Universities the number is lower, only 28.6% have chemical waste management programs in execution or under development. A waste management project collaborates to minimize risks, or eliminate the unhealthiness and dangerousness of various locations, and also to motivate students, technicians and teachers to perceive that they are competent to generate knowledge and correctly discard what may cause serious risk to health or the environment (OLIVEIRA JUNIOR, 2012).

Universities have a primary role in issues of sustainable development and must go beyond the three dimensions of sustainability - economic, social, and environmental - also including the dimensions of its fundamental teaching, research and extension activities. In order to reduce costs and adapt internal processes to environmental needs, universities are gaining more and more strength to modernize their management systems to provide better quality of their discharges, enabling environmental technological innovations that contribute to sustainable development (GONÇALVES *et al.*, 2014).

Seeking to become sustainable educational spaces, universities have been involved with the principles of sustainability and environmental protection, assuming their responsibility in the training of subjects and in the preparation of future generations for the construction of a more sustainable and fair society (WACHOLZ *et al.*, 2015).

Solidification Stabilization (S/S) appears as a viable alternative for the treatment and disposal of solid chemicals residues. It is a procedure that has the ability to convert toxic residue to a physically and chemically more stable form, as it chemically modifies hazardous residues in order to obtain a less toxic form of it. This process allows to reduce the mobility of species harmful to the environment and living beings, reducing the mobility and leaching of these contaminants into the environment.

The Stabilization/Solidification has advantages and disadvantages that can influence the process. The S/S has advantages such as the low cost of materials and equipment for mixing; ability to establish a physical barrier even in adverse cases; versatility in the shape of the properties according to the application. The disdavantages are: The specimens that have porosity can facilitate the leaching of contaminants when there is no efficient immobilization; the volume of the residue may increase due to the addition of the binding agent, therefore, each case should be evaluated considering all its individual peculiarities (WANG *et al.*, 2018).

In the stabilization/solidification process, a fixative (binder) is usually used as a solidifying agent. The main fixatives used are: Portland cement, lime, asphalt, polymer, etc. Among these, the most widely used is Portland cement, since chemical reactions are activated only by water (hydration reactions), occurring at room temperature and hardening (adherence), which leads to the formation of a solid microstructure in a few hours. Stabilization/solidification process has been presenting itself as an efficient and reliable technology for the treatment of hazardous materials (CHEN *et al.*, 2019).

In this research, the attenuation of chromium will be evaluated as it is a highly toxic metal commonly found in solid residues of chemical laboratories and when discarded in high concentrations in the environment, it can cause a series of damage in the short term to fauna, flora and humans.

In humans, chromium toxicity occurs mainly through the respiratory tract, which can generate sinusitis, bronchial irritation, septal perforation and lung cancer. But it can also cause gastrointestinal, hematological, cardiovascular, renal, hepatic and dermatological effects (KOTÀS *et al.*, 2000; LEON; CAETANO, 2015; SPRADA, 2018). The contact with this substance happen the ingestion of contaminated water and food, through contact with the skin, handling chromium in the work environment, breathing contaminated air and even living close to places with chromium in the toxic, dichromate and hexavalent form (SPRADA, 2018).

When it comes to physical stabilization, there is a change in their physical form, but not all cases cause chemical bonding of the waste constituents. Chemical solidification (S/S) stabilization alters the chemical form of the constituents of the waste, generating less water-soluble forms. Two criteria are important when it comes to S/S, the integrity/durability of materials and the immobilization of contaminants, which are related respectively to the compressive strength analysis, water absorption capacity, humidification/drying; leaching and solubilization (BRITO el al., 2009).

Sousa *et al.* (2018) used the stabilization/solidification to perform the treatment of waste generated from the removal of lead from a synthetic effluent, where he found that the metal retention efficiency after S/S was quite significant, considering that it managed to remove up to 100% of the heavy metal, i.e. maximum lead removal. Rocha *et al.* (2010) applied the mass balance to the Solidification Stabilization process aiming at the treatment of Synthetic Solid Waste (RSS). Through mass balance, Rocha *et al.* (2010) observed that the longer the curing period in water, the lower the concentration of heavy metals present in the leachate solutions. He concluded that the mass balance is a primordial tool in the treatment of the S/S material, considering that only through it, it was possible to confirm the most efficient method to reduce the dangerousness of the analyzed heavy metals.

Andrade *et al.* (2014) carried out the treatment of oily sludge and the kinetic study of the Solidification Stabilization process. With the results obtained, they concluded that Stabilization by Solidification, using Portland cement as a binder, proved to be a viable technique for the treatment of oil sludge. The oily sludge is converted from a hazardous waste to a non-hazardous waste and when applying the S/S technique it was observed that the contaminant was actually trapped inside the solid matrix, preventing its leaching into the environment and consequently the contamination.

The differential of the present study is related to the fact that it evaluates the solid residues generated in chemical laboratories of superior institutions, which are rarely treated by the stabilization/solidification technique before being discarded without any previous treatment, causing serious environmental damages due to its composition to off content of heavy metals. The main objective of this work was to perform the immobilization of chromium in cementitious matrices after the treatment by Stabilization/Solidification of solid residues from chemical laboratories. Integrity/Durability tests (Resistance to compression, Ability to absorb water and Humidification/Drying) and immobilization tests of contaminants (Leaching and solubilization) were be carried out. Based on the resultsof these tests, it is possible to manufacture non-structural cement blocks feasible, aiming to reduce the environmental impacts caused by the inappropriate destination of this type of waste.

2 MATERIAL AND METHODS

2.1 Characterization and classification of the solid laboratory residue, cement, sand and gravel

The characterization of laboratory solid residue was carried out by means of physical analyzes of: Determination of Total Solids (TS), Total Volatile Solids (TVS), Fixed Total Solids (FTS) and Humidity (% H2O) (APHA, 1998). The present research, Portland Common Cement CPII - Z32 was used, which has a compressive strength of 32 MPa guaranteed after 28 days of curing. For the preparation of the specimens, sand and gravel were used.

The granulometric analysis carried out classified the sand as fine aggregate, since its granulometry is in the range of 0.075 mm to 4.8 mm in diameter and the gravel as coarse aggregate, presenting granulometry in the range of 4.8 to 9.5 mm (ABNT NBR 7211, 2009).

A leaching test was carried out for the classification of the solid laboratory residues, cement, sand and gravel and subsequently chromium was determined by atomic absorption analysis realized by the company Funmineral. The results obtained were compared with the literature (ABNT NBR 10.004, 2004).

2.2 Experimental planning

In the present research, regression analysis was adopted in one-way planning. Regression in the analysis of variance is a statistical technique to model and investigate the relationship between dependent and predictor variables. A regression model that contains one or more of a regressor is called a linear regression model (MONTGOMERY *et al.*, 2003). A linear regression model can describe the relationship between input variables and the output variable, Equation (1):

$$y = \beta_0 + \beta_1 x + \varepsilon \tag{1}$$

Where, y represents the measured response variable, x represents one of the influencing factors in the response variable, and ε is a random error term or residual. β_0 and β_1 are the parameters of the model.

The one-way factorial planning was carried out, where the percentage factor of solid chemical laboratory residue was used, fixing the cure time at 28 days. Initially, tests were carried out to define the best range of the predictor factor, that is the percentage of residue establishing 3 levels and 3 repetitions for each level, totaling 9 experiments. The final percentages studied were 0%, 5%, 20% and 35% of laboratory solid residue. The response variables (y) were: Compressive strength, Absorption capacity, Humidification/Drying, Total chromium concentration present in the leached and solubilized extract. The Minitab 17.0 software was used, which incorporates a series of routines for data manipulation, reliability analysis, graphs and statistical analysis.

2.3 Preparation of the specimens

In order to provide an appropriate percentage of chemical laboratory residue for application of S/S, preliminary tests of classification and characterization of the material were carried out. The preparation of the specimens was carried out using the following constituents: Portland cement CP II - Z32 fine sand, gravel, residue and water, maintaining constant cure time of 28 days and varying the percentage of residue. The solid laboratory residue and the other constituents were weighed separately on an analytical balance with an accuracy of 0.01 g. After the individual weighing of the constituents, they were homogenized in the presence of water in order to favor the chemical reaction of the cement, obtaining a homogeneous mass.The interior of the molds was properly lubricated with mineral oil to facilitate the removal of the specimen. Then, the homogeneous mass of the cementitious matrices was placed inside the cylindrical molds in compacted layers to avoid the formation of empty spaces in the specimen. Glass plates with dimension of 70 mm by 70 mm edge and 5 mm thick were lubricated with mineral oil and placed on the surface of the molds to prevent water loss caused by evaporation. The material was left to stand for a period of 24 hours to harden the paste. Finally, after the 24-hour period, the specimens were demoulded and cured for testing in terms of integrity and durability and immobilization criteria after curing time (BRITO, 2009).

2.4 Compressive resistance

The compressive resistance test was performed to verify the ability of the Stabilized/Solidified material to resist different loads of mechanical compression. In this test, cylindrical cementitious matrices of 50 mm in diameter and 100 mm in height were used. Each was placed directly on the bottom plate of a press in order to be strictly centered in relation to the loading axis. The compressive strength parameter was calculated using Equation (2), in kgf / cm², where it will be obtained by dividing the breaking load by the area of the specimen section (ABNT NBR 7215, 1996).

$$RC = \frac{F}{A} \tag{2}$$

Through the mechanical resistance of the Stabilized/Solidified material, the destination route of the material can be defined. This can be used for: execution of masonry works without structural function, roofing material, paving in highway works, use in red ceramics (solid bricks, ceramic blocks and tiles) and manufacture of concrete artifacts.

2.5 Water Absorption Capacity

The Water Absorption Capacity test is used for the determination of water absorption, voids index and specific mass and evaluates the porosity of the hardened or Stabilized/Solidified material. Initially the specimens were weighed and then taken to the oven at 105 ° C for 24 hours. Subsequently, the samples were removed from the oven, weighed and immersed in water at 23ºC for cycles of 24, 48 and 72 hours, which were removed from the water, dried with absorbent paper, weighed and immersed in water at each cycle. Five hours before completing the 72-hour water saturation period, the samples were gradually boiled in the hot plate to 100ºC. Then, “it was cooled due at room temperature and the last weighing was carried out. The result, therefore, was expressed in %, knowing the mass of the specimen after saturation in water and the mass of the specimen dried in the oven. (Equation 3). To pass the water absorption capacity test and to be considered as a Stabilized/Solidified material, the water absorption capacity obtained cannot exceed 40% (BRITO, 2007).

$$WAC = \frac{M_{sat} - M_{dried}}{M_{dried}} x100 \quad (3)$$

2.6 Humidification/Drying

The humidification/drying test consists of simulating and evaluating the material resulting from the Stabilization/Solidification process, in terms of its ability to resist changes in state.

It consists of humidifying the material with water at 22 ± 3 ºC and drying at 105 ± 5 ºC, in order to evaluate its durability and loss of mass after successive periods of humidification / drying.

In this test, the sample is humidified with water and subsequently subjected to drying (BRITO, 2007).

$$LW(\%) = \frac{\text{Wnat} - \text{Wcycle i}}{\text{Wnat}} \text{ x } 100 \quad (4)$$

Where, Wnat t is the weight of the natural sample; Wcycle i is the weight of the sample after the humidification/drying cycle.

2.7 Leaching

The leaching test was used to evaluate the immobilization of chromium, that is, to evaluate the capacity of the residue to release chromium into the environment after being discarded. The leached extract resulting from cement, solid laboratory residue, sand and cementitious matrices was evaluated.

The leaching test was carried out according to the procedure described by ABNT NBR 10.005, 2004, where 100 g of a sample was placed in a 2000 ml flask with distilled water, free of organic matter and the leaching solution (glacial acetic acid and Water). The solution was subjected to agitation in rotating equipment at 30 revolutions per minute for a period of 18 ± 2 hours (ABNT NBR 10.005, 2004). The concentration of Chromium in the leach solution was determined by atomic absorption spectrometry.

2.8 Solubilization

According to the solubilization test, the sample was mixed with distilled water in a suitable container, always maintaining a ratio of 1:4 in relation to the sample and the distilled water, and stirred at low speed for 5 minutes. The container was covered with PVC film, remaining at rest for seven days at a temperature of 25ºC. After this period, the solution was filtered using a filtering membrane with 0.45 µm porosity to obtain the solubilized extract, in which it was possible to determine total chromium concentration (ABNT NBR 10.006, 2004). For the determination of chromium, samples were subjected to analysis by atomic absorption spectrometry.

2.9 Contaminant retention efficiency

The efficiency of the Solidification Stabilization process was calculated with the aim of evaluating and comparing the masses of agents that influenced the contaminant retention efficiency, according to Equation (5) (BRITO *et al.*, 2009):

$$X_{ER\%} = \left[1 - \left(1 + \frac{M\ LSR(gross)}{MCPC}\right) x \left(\frac{[y]Treated}{[z]gross}\right)\right] x100 \quad (5)$$

Where, $X_{ER\%}$ is the contaminant retention efficiency (%); $M\ SLR$ (gross) is the mass of the contaminant present in the LSR (untreated) (kg); MCP is the mass of common Portland cement (kg); [y] Treated is the concentration of the contaminant after treatment by S/S (mg.kg^{-1}); [z] gross is the concentration of the contaminant before treatment by S/S (mg.kg^{-1}).

2.10 Mass balance of the S/S process

The mass balance was performed for the contaminant chromium, in order to determine the attenuation in each treatment after stabilization by solidification in terms of application mass, leaching and accumulation (BRITO, 2007). The mass balance was calculated using Equation (6):

$$Mass_{contam.retained} = Mass_{Contam.(LSR\ gross)} - Mass_{contam.(treated)} \quad (6)$$

Where, $Mass_{contam.retained}$ is the mass of the contaminant retained in the cement matrix; $Mass_{Contam.(LSR\ gross)}$ is the mass of the contaminant present in the LSR before treatment in g; $Mass_{contam.(treated)}$ is the mass of the contaminant present in the S/S material after treatment in g.

3 RESULTS AND DISCUSSION

3.1 Characterization of Portland cement, LSR, sand and gravel

The concentration of total solids obtained for the residue was 87.57% and indicates the total amount of organic and inorganic matter present in the residue. The total fixed solids content of the residue was 79.0%. This value indicates that the solid laboratory residue has a high inorganic mass to be treated. The moisture content of the residue was 12.43%. As the residue presented a low moisture content, it is considered viable for the treatment by Stabilization/Solidification, considering that the excess of water can separate the agglomerating agents and hinder the reactions between the residue and the solidifying agents.

The pH of the residue showed a value of 4.87 indicating its acidity. The gravel used presents in its constitution 99.98% of total solids, of the total solids content 99.90% corresponds to the total volatile solids, indicating that it consists basically of organic matter. The sand had a total solids content equal to 99.92%, while the moisture content was 0.08%. The cement used had a total solids content equal to 99.25% and 98.97% of total fixed solids, this high amount can be explained by the chemical composition of the binder. The moisture content for the cement was less than 1%. The low humidity of the cement is responsible for the ease with which chemical reactions occur between the binder and the residue.

3.2 Classification of Portland cement, sand, gravel and residue

Through the leachate extract, it was observed that chromium showed values above the maximum permitted limits found in the literature (5 $mg.L^{-1}$). The leached extract of the residue showed a concentration of total chromium of 114 $mg.L^{-1}$. As at least one of the waste parameters has a concentration higher than that established by the maximum allowed standards, it can be classified as hazardous waste, Class I. These are dangerous due to toxicity. Therefore, it appears that these residues should not be disposed of in the environment without prior treatment. One way to treat it for a final disposition is to use the Stabilization/Solidification technique.

3.3 Evaluation of integrity and durability

The compressive strength test was used to verify the ability of the Stabilized/Solidified material to resist different loads of mechanical compression, that is, its physical integrity. All treatments showed compressive strength greater than 1 MPa, thus, these materials can be used as base covering materials in paving works and civil construction artifacts. The treatment with the lowest percentage (5%) obtained the highest resistance, being within the limit of 4.5 MPa to 16 MPa, which can then be used to make hollow blocks of common concrete. The treatments with 20% showed an average compressive strength of 4.0 MPa and can be used as a base material in paving. The treatments with 35% of incorporation of residue presented an average resistance of 2.5 MPa, and can also be used as solid bricks.

For the Water Absorption Capacity tests the treatment that showed the lowest water absorption was the one referring to the cement matrix with 5% residue with an average of 5.90% water absorption capacity. The higher the percentage of residue the greater the water absorption capacity, concluid that the percentage of residue has influence in the water absorption capacity. All the results obtained are in accordance with the literature, which showed a percentage of water absorption below 40%, indicating that the treated material has low porosity. Thus, it favors the control of the control of the leaching of contaminants present in the Solid Waste of Laboratory for the environment (ABNT NBR 9778, 1987).

All treatments were approved in the Humidification/Drying test because they are within the maximum allowable limit, that is, a loss of mass less than 15%. The best result average found refers to the treatment with a percentage of 5% of residue in its composition, which presented a mass loss of only 0.75%. A very satisfactory result, because the lower the mass loss of the cementitious matrices more efficient will be the stabilized material. It was observed that the highest percentage of humidification and drying occurred for the matrix with incorporation of 35% SLR, obtaining an average loss of mass of 1.61%, a result still satisfactory because it is within the desired range of 15% loss of mass (BRITO, 2007).

3.4 Evaluation of immobilization of contaminants

Table 1 shows the concentrations of total chromium determined from the leachate extract expressed in $mg.L^{-1}$ and in accordance with the Maximum Permissible Limit (MPL) of 5 $mg.L^{-1}$, following the literature (ABNT NBR 10.005, 2004).

Table 1 - Response of the chromium concentration in the leaching extract

Experiment	Factor Level (% LSR)	Average Chromium concentration value ($mg.L^{-1}$) MPL - 5 mg/l[(1)]
Exp.0	0	0,21 ± 0,006
Exp.1	5	0,91 ± 0,055
Exp.2	20	4,02 ± 0,237
Exp.3	35	5,1 ± 0,06

Exp- Experiment; LSR- Laboratory Solid Residue.

The leaching test was used to assess chromium immobilization and the total chromium concentration was determined from the leached liquid. As the tests with control residue (0%) already present Cr levels, these values were subtracted from the tests of 5, 20 and 35%. The treatments using the percentages of residue of 5% and 20% obtained satisfactory results of the total chromium concentration when compared to the Maximum Permissible Limit (5 $mg.L^{-1}$) (ABNT NBR 10.005, 2004). When analyzing the treatment with 35% of residue, it is observed that the total chromium concentration is above the maximum limit allowed for disposal in the environment with a concentration of 5.09 $mg.L^{-1}$.

Thus, this cementitious matrix is classified as dangerous - Class I and the waste will be sent to landfill. The other compositions were immobilized and classified as Class II non-hazardous waste and will undergo a solubilization test to determine whether they are inert or not inert. Table 2 shows the chromium concentrations according to the solubilized extract.

Table 2 - Response of the chromium concentration in the solubilized extract

Experiment	Factor Level (% LSR)	Average Chromium concentration value ($mg.L^{-1}$) MPL - 5 mg/l[(1)]
Exp.1	5	0,85 ± 0,04
Exp.2	20	3,6 ± 0,108
Exp.3	35	5,12 ± 0,984

Exp- Experiment. [1]Parameters and maximum limits in the solubilized extract (ABNT NBR 10.006, 2004).

The concentrations of total chromium in the solubilized extract of all experiments were higher than the Maximum Permissible Limit (0.05 $mg.L^{-1}$), (ABNT NBR 10.004, 2004). Thus, all cementitious matrices failed the solubilization test, being possible to classify them as noninert residues (Class IIB). It should be noted that depending on the destination of these cement residues, this chromium immobilization can be dangerous.

3.5 Mass balance and contaminant retention efficiency

The mass balance is based on Lavoisier's Law of Conservation of Mass. To check the stability of the contaminants in the cementitious matrices as well as the chemical evaluation of the solidified matrices, mass balance was used in all treatments for total chromium present in the leachate’s extracts.

Table 3 shows the average values of the masses of the Stabilized/Solidified process of the cementitious matrices of all treatments in relation to the chromium present in the leached extract to obtain the mass balance and efficiency of the process.

Table 3 - Mass balance and efficiency of the Stabilization/Solidification process in the leachate extract

Experiment	Mass of SLR gross[1] (g)	Mass of Contam. Treated[2] (g)	Mass of Contam. Ret[3]. (g)	Retention efficiency (%)
Exp.1 (5%)	199,70	1,56	198,14	99,27
Exp.1 (5%)	199,70	1,81	197,89	99,15
Exp.1 (5%)	199,70	1,79	197,91	99,16
Exp.2 (20%)	199,70	7,90	191,80	95,77
Exp.2 (20%)	199,70	8,01	191,69	95,71
Exp.2 (20%)	199,70	6,90	192,80	96,30
Exp.3 (35%)	199,70	10,15	189,55	93,88
Exp.3 (35%)	199,70	9,94	189,76	93,96
Exp.3 (35%)	199,70	9,76	189,94	94,08

Exp-Experiment (1): Mass of the laboratory solid residue; (2): Mass of the contaminant treated; (3): Mass of the contaminant retained in the matrix.

According to Table 3, it was observed that the lowest values of leached mass in relation to the treated contaminant were attributed to the treatment averages using 5% of residue. Thus, the best results presented both for the retained mass of contaminant and for the efficiency of the Stabilization/Solidification process were also presented by the average of the Exp.1 experiments, managing to retain an average of 197.98g of the contaminant, reaching an efficiency average of 99.19%.

According to the percentages of incorporation of residues studied, the retention of total chromium inside cementitious matrices varied on average from 189.75g to 197.98g, being an inversely proportional process. Thus, as the amount of waste increases, decreases the retention capacity of total chromium, consequently, more total chromium is leached.

Although there was an increase in the percentage of residue and consequently a reduction in the retention capacity of the total chromium concentration. For all treatments, there was an average efficiency of the experiments greater than 93%.

4 CONCLUSION

All treatments passed the integrity/durability tests. The leaching test was satisfactory for the incorporations of 5% and 20%. For the 35% of the residue, the test was not approved, however it was above the maximum limit with only 0.09mg.L^{-1}. All treatments showed a significant efficiency of total chromium retention. Despite the cement matrix with 35% of residue having a total chromium concentration above the maximum permissible limit, the retention efficiency reached an average of 93.97%.

The reduction (compared to its concentrations in the crude residue) in the chromium concentration confirms that it has undergone some effective immobilization mechanism in the cement matrix, indicating that stabilization/solidification is a viable alternative to attenuate the concentration of chromium present in the solid residue of chemical laboratories. However, as in all experiments the solubilization tests failed, it is necessary to take into account the risks caused by this material if it is disposed of inappropriately. An alternative would be to dispose of the material in specific landfills for waste that has this type of characteristics.

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