Stabilization/solidification of zinc containing sludge using Portland cement

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Summary

Stabilization/Solidification process using Portland cement was applied for the treatment of sludge from hot-dip galvanization process. It is a process aimed at protecting and improving the quality of steel parts against the corrosion and oxidation caused by the humidity. Ordinary Portland cement was chosen as a binder for its affordability as a one of the cheapest type of binder and well known for its usability for hazardous waste treatment. Effectiveness of the process was evaluated using leaching tests according to both the EN 12457-4 standard and the Toxicity Characteristic Leaching Procedure. The effect of the mixture composition on the process was analysed in terms of the extract toxicity and ability to retain pollutants in the concrete matrix. Furthermore, the obtained data were evaluated using statistical analysis, namely, multi-level factorial design of experiment. This paper deals with the waste from the pre-treatment of steel pieces by degreasing and chemical cleaning the surface before the hot-dip galvanization process. This waste does not meet the regulatory levels of the pollutant leaching and thus its treatment is required before land disposal. The aim of this study was to stabilize and solidify this toxic waste and thus fulfil the limit values required for land disposal.

Keywords: *zinc plating waste; stabilization/solidification; leaching tests; toxicity.*

Introduction

One of the most widely used methods for surface treatment of various industrial products is metal plating, which, however, produces a large amount of waste containing mainly zinc and other toxic metals. The waste sludge from the pre-treatment process contains mainly the iron oxides (rust) and other impurities removed from the surface and, of course water (content of solid particles is typically about 30 % by weight). In the last stage of the pre-treatment process, the treated surface is dipped in a solution of zinc ammonium chloride ($ZnCl_2.2NH_4Cl$), and then the surface is immersed into a molten zinc bath at 450 °C, in which a thin layer of zinc (150 μm) on the surfaces is gained. This final procedure generates a large amount of dust waste containing zinc, ammonium and chlorides[1].

Significant problems of metal-containing sludge or similar waste from metal industry are a release of pollutants to surface and ground water. A usual way for the assessment of a waste in Spain is leaching test, which is set by the decree 38414-34 compliance test[2], in accordance with the European regulations. This paper focuses on the waste treatment by stabilization and solidification. Stabilization/Solidification (S/S) of hazardous wastes is one of the methods used to immobilize pollutants (especially toxic metals) in the matrix and thus to reduce the pollution of the environment. It is used for the treatment of many industrial wastes to improve their physical and chemical properties. The waste is less hazardous after this type of treatment and can be disposed of in a landfill or used as a construction material[3-5].

Many papers on treatment of galvanic waste reported usage of cement or low-cost binders to treat waste as a pre-landfill treatment[6-8], but usage of asphalt emulsions[9] or calcium oxide with activated carbon[10] were also reported. One of the approaches for optimization of the S/S process is the response surface methodology (RSM), which seems to be a very powerful tool to identify interactions between particular components[11]. It uses a sophisticated set of statistical and mathematical calculations for modelling and analysis of multiple interactions. An advantage of this method is the ability to predict the interactions among the considered factors and find the best solution[12].

The main goal of this study is to optimize the stabilization/solidification processes for galvanic sludge to find the best ratios between cement addition, waste and water added, and thus to enable a safer way of landfill disposal and minimizing the operational and landfill disposal costs. For this purpose, the relative amount of water, cement and waste added to mixtures were considered and their effect was studied. Consequently, the toxicity of the treated waste extract and the percentage of metals retained were measured to determine the effectiveness of the process.

Experimental

Waste

The sample of waste was obtained from the factory Galvanizadora Valenciana, S.A located in Spain near Valencia. The sludge waste was collected from the filter press, which decreased the water content in the sludge from the first step of pre-treatment of steel pieces prior to immersion in the molten zinc at the bath. According to the European Hazardous Waste List, the sludge should be classified as a hazardous waste with the code 11 01 09, as the sludge and filter cakes containing hazardous substances from chemical surface treatment and coating of metals or other material[13]. The sample of the waste was measured for density and moisture content. Density was obtained by introducing an amount of waste sample into water and measuring the volume of water displaced. The moisture content was determined in accordance with the EN 14346:2006 standard[14]. All measurements were carried out in triplicate.

Binder

A commercial binder CEM II/B-L (Cementos El Molino, Spain) based on Portland cement was used for S/S of the sludge waste from hot-dip galvanizing by the cementation process. It contained 65 – 79 % of clinker and 21 – 35 % of calcite[15].

Acid digestion

For the determination of the zinc content in the untreated waste, the mineralization method in sulphuric acid was used. The process was performed in the following way: 5 g of sample were weighted and put into a beaker with 60 ml of 0.5 mol/L H_2SO_4. After that, the mixture was stirred for 15 minutes and after, the liquid phase was filtered through 0.45-micron filter, and then analysed by atomic absorption spectrometry[16].

Stabilization and solidification of sludge waste

The experimental work was designed considering the following parameters:

- Relative amount of water added to the mixture, ranging from 10 to 40 wt. %
- Relative amount of cement in mixture with waste sludge (without added water), ranging from 10 to 55 wt. %

The process of a mixture preparation was as follows: The components (water, cement and waste) were mixed by a laboratory mixer in a plastic cup for 15 minutes, and then the mixture was placed into a plastic tray (30×24×6 cm). The weight of the fresh mixture was recorded, and the mixture was left for 28 days under room temperature and humidity conditions. After 28 days of curing, the mixture was weighted again, and the weight loss was calculated. Then the mixture was subjected to the leaching test and the values of density were determined for the purposes of a volume balance of the treatment process.

The used mixture nomenclature was W-**Y**-**Z**, where **Y** refers to the relative amount of water added, and **Z** refers to the relative amount of cement in the mixture with waste sludge. For example, the mixture W-10-40 were prepared by mixing 54 weight units of waste sludge with 36 weight units of Portland cement (i.e. 40 wt. % of cement), and then 10 weight units of water was added (i.e. 10 wt. % of water).

Leaching tests

Leaching tests were performed in triplicate to evaluate the release of toxic metals (iron and zinc) from untreated waste, cement used and the mixtures after 28 days of curing. Leaching tests were performed using two mediums: distilled water and acetic acid.

Leaching test using distilled water

European regulations[17] establish the criteria for the acceptance of waste in landfills, which are based on DIN 38414-S4 compliance test[18]. Table 1 shows the leaching limit values for zinc at different types of landfills (for inert, non-hazardous and hazardous waste). For the leaching test, the solidified waste was pulverized to particle size less than 10 mm using mortar and pestle, then 400 ml of distilled water was added to 40 g of the pulverized sample (solid/liquid ratio 1:10) and the suspension was stirred with a magnetic stirrer at room temperature for 24 hours. Then the liquid phase was filtered through 0.45-micron filter, and analysed by atomic absorption spectrometry.

Table 1. Leaching limits values for waste acceptable at landfills, calculated at a liquid to solid ratio (L/S) of 10/1 l/kg, according to European regulations (European Commission 2003) for the acceptance of waste in landfills.

	Leaching limit value (mg/kg dry matter) – Leachate classes		
	I. Inert waste	II. a-b Non-hazardous waste	III. Hazardous waste
Zinc	4	50	200

Leaching tests using acetic acid

The leaching tests using acetic acid were performed in the following way: 40 g of the pulverized sample was weighed and mixed with 640 ml of distilled water (solid/liquid ratio 1/16). Then the pH-value was adjusted to 5.0±0.2 with 0.5 mol/L acetic acid (the maximum volume of acetic acid added was 4 ml per gram of solid sample). After 24 hours under permanent stirring at room temperature, more distilled water was added according to the following equation[16]:

$$\mathbf{V}\ (\mathrm{ml}) = \mathbf{4}\ (\mathrm{ml/g}) \times \mathbf{W}\ (\mathrm{g}) - \mathbf{A}\ (\mathrm{ml}) \qquad (1)$$

where V is the volume of distilled water to add, in ml; W is the mass of the solid sample, in g; and A is the total volume of acetic acid added, in ml. Thus, the final value of the solid/liquid ratio was equal to 1/20 by weight. The obtained solution, after adding the calculated volume of water, was filtered through a 0.45-micron filter and then was analysed using the toxicity analyser M-500. The zinc concentration was determined by atomic absorption spectrometry.

The leaching test using acetic acid was performed to characterize the waste according the mentioned Spanish regulations and with regulations set by European commission. This test subjects the waste to an acid solution in slowly rotating container and characterizes its hazardous residues. The waste is classified as toxic if its acetic acid extract shows after 15 min at 15 ºC the toxicity value EC_{50} equal or greater than 333.3 TU in the bacterial luminescence test.

Analytical techniques

The effectiveness of the waste treatment was evaluated by chemical analysis of extracts and also by tests of eco-toxicity, which complement each other in the classification of waste according to the catalogue as hazardous or non-hazardous.

Atomic absorption spectrometry

The concentrations of metals were determined by means of a PerkinElmer model AAanalyst 100 atomic absorption spectrometer (PerkinElmer Inc., USA) using an air-acetylene flame. Instrumental parameters were adjusted according to the manufacture's recommendations: spectral bandwidth of 0.2 nm, wavelength of 325.7 nm and an operating lamp current of 5 mA (Zn). The parameters for iron were as follows: spectral bandwidth: 0.1 nm, wavelength 372 nm and operating lamp current of 10 mA. The calibration solutions for the determination of zinc were prepared from $ZnCl_2$ in a range from 1 to 6 mg/L and the calibration solution for the determination of iron were prepared from $(NH_4)_2FeSO_4.6H_2O$ in a range from 10 to 100 mg/L.

Toxicity

The toxicity of extracts of solidified waste samples was tested using the Microtox model M-500 Analyser (Strategic diagnostic Inc., USA) on the marine bioluminescent bacteria *Vibrio fischeri*, which it is one of the most sensitive microorganisms across a wide range of chemicals. The toxicity was expressed in n-TU (toxicity units) as the dilution that caused a 50 % reduction in the bioluminescence after 15 min exposure. Assays were carried out at 15 °C, salinity level of 2 % NaCl and pH range of 6 –8. The value of half maximal effective concentration (EC_{50}) was calculated from the data by the MicrotoxOmni software supplied by the instrument manufacturer.

Statistical analysis

In order to find the optimal mixture composition, data obtained in leaching and toxicity tests, as well as the values of the mass and volume increase, were subjected to statistical analysis known as Response Surface Method[19] using the Statgraphics Centurion XVI software. The main observed factors were contents of cement and water. Other measured parameters such as: volume increase, mass increase, zinc leached into distilled water, toxicity and ability to retain pollutants were response variables. The multilevel analysis was performed to obtain the Pareto charts and significant proof of influence cement or water in the mixtures.

Results and discussion

The untreated waste sample examination

As is shown in Figure 1a, the untreated sludge had a brownish colour and pasty consistency due to its high moisture content of 75 wt. %. The measured data for the untreated waste sample are summarized in Table 2. The analysis of solutions obtained by the acid digestion procedure showed that the content of zinc in the dry matter of sludge waste was 328 g/kg. As reported in the literature, iron ions could affect the efficiency of zinc immobilization in the stabilization/solidification processes[10]. However, iron was detected in the tested sample of waste only in a negligible amount.

Table 2. Characterization of waste and cement

Parameter	Waste	Cement
Characteristics of the untreated material:		
Zinc in dry matter (g/kg)	328.0 ± 0.85	0.0033 ± 0.0029
Moisture content (wt. %)	74.96 ± 0.5	< 0.1
Bulk density (g/cm^3)	1.67 ± 0.04	1.51 ± 0.03
Characteristics of the water leachate		
Leached zinc (g/kg)	179.9 ± 4.59	0.0001 ± 0.00003
Retained zinc (%)	45	96
Characteristics of the acetic acid leachate		
Leached zinc (g/kg)	222.1 ± 3.64	0.0006 ± 0.0002
Retained zinc (%)	29	86
Leachate toxicity (EC$_{50}$ (TU))	22234.5 ± 884.5	636 ± 100

The content of zinc in the extract of the cement was also determined. Table 2 also shows the mean values of triplicate analysis of the cement sample. Zinc content (mg/kg dry matter) in cement was negligible, but in a comparison to values obtained by Ogunbileje[21], were it was 400 times lower. The toxicity level of the cement was negligible prior to toxicity determined in the sludge waste.

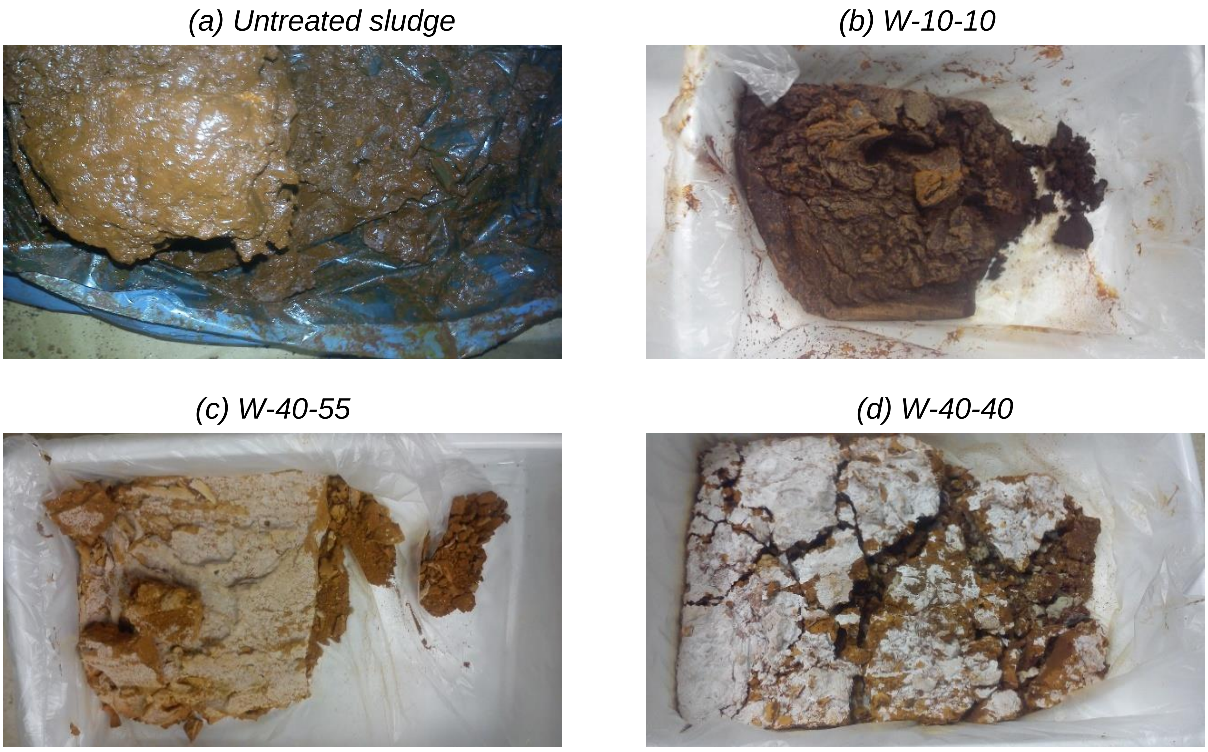


Figure 1. Samples of untreated and solidified waste

Aspects of cured mixtures

After 28 days of curing, images of selected solidified sludge samples were taken, and they are shown in Figures 1b (W-10-10), 1c (W-40-55), and 1d (W-40-40). The type CEM II/B-L of Portland cement was used for the treatment of all samples. The samples with the most cement addition (45 wt. %) showed light orange-brownish colour and had the best compressive strength after 28 days of curing. The mixtures with the smallest cement addition had dark brown colour and pasty structure with white spots on the surface. The colour of solidified samples depended on content of water and cement in mixtures, because during the curing process the mixtures lost the plasticity due to reactions between cement and water (hydration process) and evaporation of water.

Weight and volume increase

The density of the untreated sludge waste was 1.67 g/cm^3 and the density values for the solidified samples were ranging between 1.40 to 2.01 g/cm^3. Except the W-10-10, all mixtures showed an increase in the weight as well as in the volume. A negative value of increase in mass means that water, which was contained in the sludge, probably evaporated during the curing process. Obvious trend in increasing weight with the cement addition could be observed and the volume increase showed similar tendency as the mass increase.

Characterization of the mixtures by leaching in distilled water

To evaluate an effectiveness of the S/S process according to EN 12457-4, the leaching tests using distilled water after 28 days of curing were used. All measurements were done in triplicate. The zinc concentration in extracts of solidified sludge samples was lower than in the extract of untreated waste for all ratios prepared. It showed that S/S process was effective. Values of retained zinc were calculated, and they are summarized in the Table 3. The lowest zinc concentration was 5.67 mg Zn/kg of dry matter for W-40-40, which met the European regulation 200 mg/kg for acceptance of wastes in landfills[21], as can be seen in Table 1. The lowest zinc concentration was determined in the samples with the highest cement addition and the lowest water addition.

Another parameter, which is relevant for an efficient S/S, is the ability to retain pollutants to show whether a dilution effect might take place when the waste is mixed with cement. The value of retained zinc was 45 % in the case of the untreated waste and in a range from 84 % to 99.99 % for solidified waste, so the S/S process was rated as effective for this type of waste.

The zinc limit value for hazardous waste landfill disposal is set by European regulations to 200 mg/kg of dry matter, so that the untreated sludge could not be disposed in any landfill, because the zinc concentration was determined to 328 g/kg. However, seven solidified samples of the sludge could be disposed of in landfill as non-hazardous wastes, because they met the limit of 50 mg/kg dry matter of zinc for landfill disposal, and one sample fulfilled the landfill acceptance criteria as a hazardous waste.

Characterization of the mixtures by leaching in acetic acid

The leaching tests were performed after 28 days of curing the mixtures, all tests were carried out in triplicate and the values are expressed as mg per kg of mixture. As can be seen in the Table 3, the results showed that the zinc concentrations in the acetic acid extracts of solidified waste samples were higher than those obtained by leaching tests with distilled water and the highest zinc concentration was determined up to 123 g/kg, while the lowest zinc concentration measured was 10.9 mg/kg. This data confirmed the fact that the lowest zinc concentration was determined in the ratios with the highest cement addition. Moreover, the acid leaching is considered to be more aggressive and it should better simulate processes in a landfill. The limit value for the zinc in the acid leaching test is stricter than in European regulations[17] and according to universal treatment standards[22] (UTS) is set to 4.3 mg/L. Thus, only 4 samples met this criterion. Nevertheless, the zinc concentration in the acid extracts of solidified samples was lower than in the untreated waste (see Table 2), so the S/S process appeared to be effective.

Table 3 shows the percentage of zinc retained in the matrix. Most of the retained zinc values were greater than the value in case of untreated waste so the S/S process is effective, and the cement did not dilute the waste only in those cases. However, in the case of acid leaching, eight solidified sludge samples were worse than the untreated sludge.

Table 3. Results of leaching tests and toxicity measurements for solidified waste

Mixture	Water leaching		Acid leaching		
	Leached Zn (mg/kg)	Retained Zn (%)	Leached Zn (mg/kg)	Retained Zn (%)	Toxicity EC_{50} (TU)
W-10-10	7472	91.1	122999	0	15042
W-10-25	1012	98.1	43691	20.1	5513
W-10-40	67.72	99.8	11117	74.68	266.7
W-10-55	20.39	99.9	12	99.96	4
W-20-10	4606	94.0	112116	0	9578
W-20-25	1114	97.7	46123	6.44	5637
W-20-40	24.16	99.9	9863	77.24	1067
W-20-55	21.33	99.9	10.86	99.97	9.5
W-30-10	8387	99.3	106887	0	12099
W-30-25	434.2	99.9	46195	5.35	2412
W-30-40	7.532	99.9	11537	75.23	1180
W-30-55	12.26	99.9	43.01	99.87	0
W-40-10	9160	84.9	80667	0	6911
W-40-25	354.0	99.3	44107	9.22	4534
W-40-40	5.670	99.9	7546	82.67	125.7
W-40-55	27.23	99.9	11.62	99.97	0

The toxicity limit set by Spanish Government[16] is following: the waste is toxic, if the acetic acid extract shows the value of EC_{50} (15 min, 15 °C) greater or equal to TU (toxicity unit) 333.3. Some of samples fulfilled the limit criteria for landfill disposal, thus these mixtures could be listed as a non-hazardous waste. It is obvious that the value of toxicity for solidified sludge was lower than that for the untreated waste, which was 22222 TU. In addition, the limit set by Spanish government appears to be insufficient, because in other parts of Europe, the limit for toxicity is stricter than in Spain[23] and is set to 10 TU. The results showed that this limit fulfilled only 4 mixtures and the limit 333.3 TU was accomplished by 6 mixtures prepared with sludge. As a conclusion, the mixtures with the highest retained zinc values had also the lowest toxicity values. Figure 2 shows a correlation between toxicity and concentration of zinc in leachate, the experimentally obtained data are interleaved by a curve to indicate the trend.

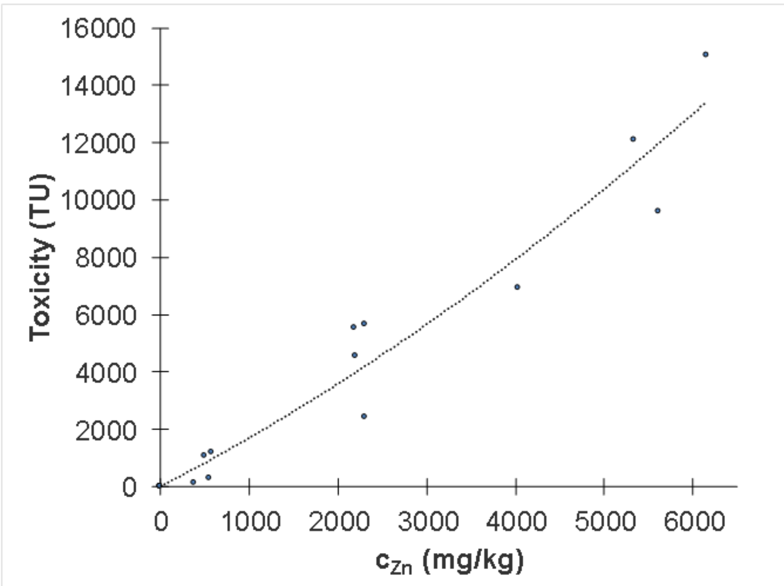


Figure 2. Dependence of toxicity on zinc concentration

Effect of the relative amount of cement and water on the S/S process

The relative amounts of cement and water were determined to find the optimum values used to prepare the mixtures and for bulking reduction. The relative amount of cement also significantly affected the solidified samples weight and volume. It was observed the weight of samples increased with the increasing cement dosage. The significance of this parameters was confirmed by the Pareto charts (Figure 3). Pareto charts are graphs where the obtained data are evaluated from the viewpoint of each content influence in the mixture with the aim to find the best ratio to be used. A Pareto chart contains bars marking the significance of each component. If the bars cross the vertical line, it indicates that the corresponding effect is significant at a confidence level of 95 % (p-value lower than 0.05). The bar above the line (+) means an increase of the response variable and the bar below the line (-) means a decrease of the response variable. In this study, only the effects, which cross the vertical line (significant coefficients), were considered to optimize the operating conditions. It was found that the relative amount of cement had greater effect on mass increase than on volume increase, which was obviously caused by a difference in density of untreated and solidified sludge. On the other hand, the water content showed a small or insignificant influence in the Pareto charts and the effect was negative (-) on both parameters. It can be concluded that the dosage of cement had the most significant effect on S/S process.

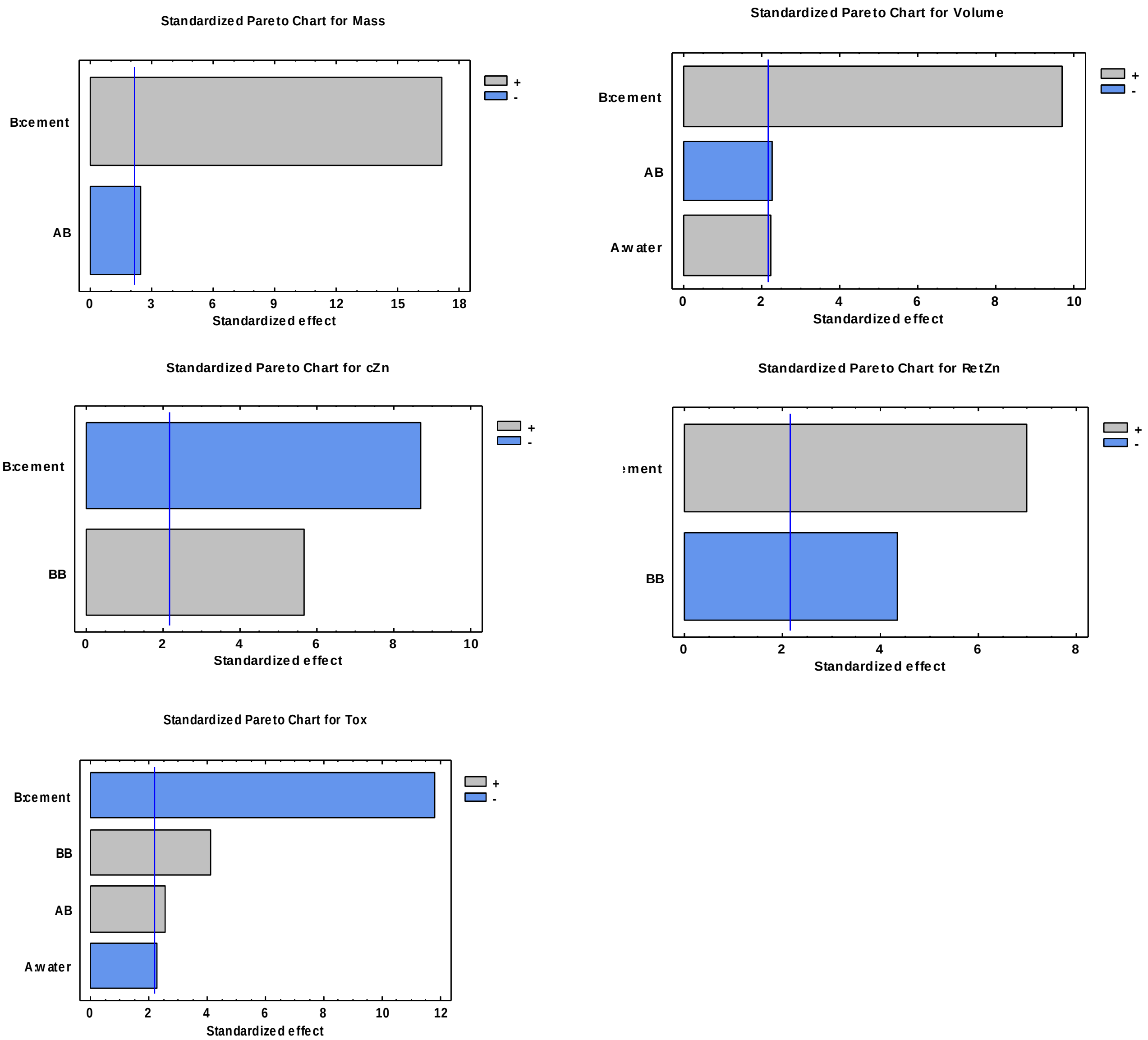


Figure 3. Pareto charts for solidified samples of sludge

In this study, the best samples of solidified sludge were W-40-40 and W-30-40. As can be seen in Figure 4, the zinc concentrations in leachates decreased below the limit value for landfill disposal of non-hazardous waste (i.e. leaching class IIa; leaching class III is for hazardous waste) to 5.7 and 7.5 mg Zn/kg, respectively. That means the most effective cement addition was 40 wt. %. The results obtained with acetic acid showed that the best sample had 55 wt. % percentage of cement and the lowest zinc concentration was determined to 10.9 mg Zn/kg for the ratio W-20-55. Pareto charts (see Figure 3) for the sludge showed that the effect of the relative amount of cement (B) on the metals leached using water was significant, because corresponding p-values were higher than 0.05. Figure 4 shows the zinc concentration in the log-scale as a function of the relative amount cement for different water additions, revealing a decreasing tendency of the zinc concentration with increasing amount of cement and decline to nearly zero after 25 wt. % cement addition. However, the results indicated relatively low dependency of zinc leachability on the water content, except the line with the 40 wt. % cement addition, where it caused a decrease of zinc concentration by an order of magnitude. Also, the Pareto charts (Figure 3) showed that the effect of the relative amount of water on zinc leachability was not significant, because it was below the vertical line, which defines 95 % of the confidence interval.

The value of solidified sludge toxicity decreased with the increasing dosage of cement, as can be seen in Figure 5. The Pareto charts (see Figure 3) revealed that the effect of cement content on toxicity was negative, i.e. the toxicity was decreased by the cement addition, whereas the water addition had a smaller effect, but also negative. According the obtained results, samples with 40 wt. % of cement were rated as non-toxic. However, the zinc concentrations were nearly zero in all extracts of samples with more than 25 wt. % of cement, which means the toxicity had to be influenced also by other factors.

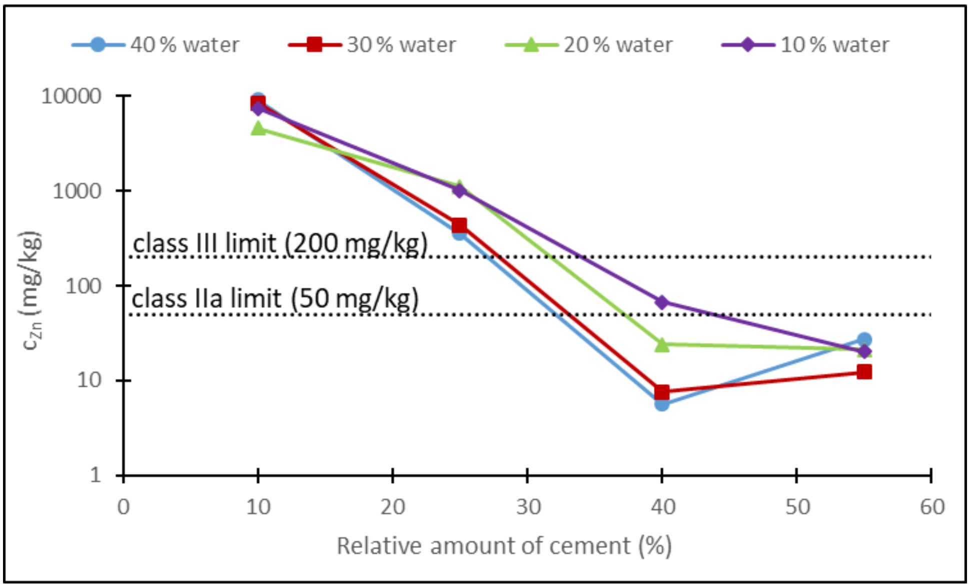


Figure 4. Effect of relative amount of cement on zinc concentration (logarithmic scale) in leachate

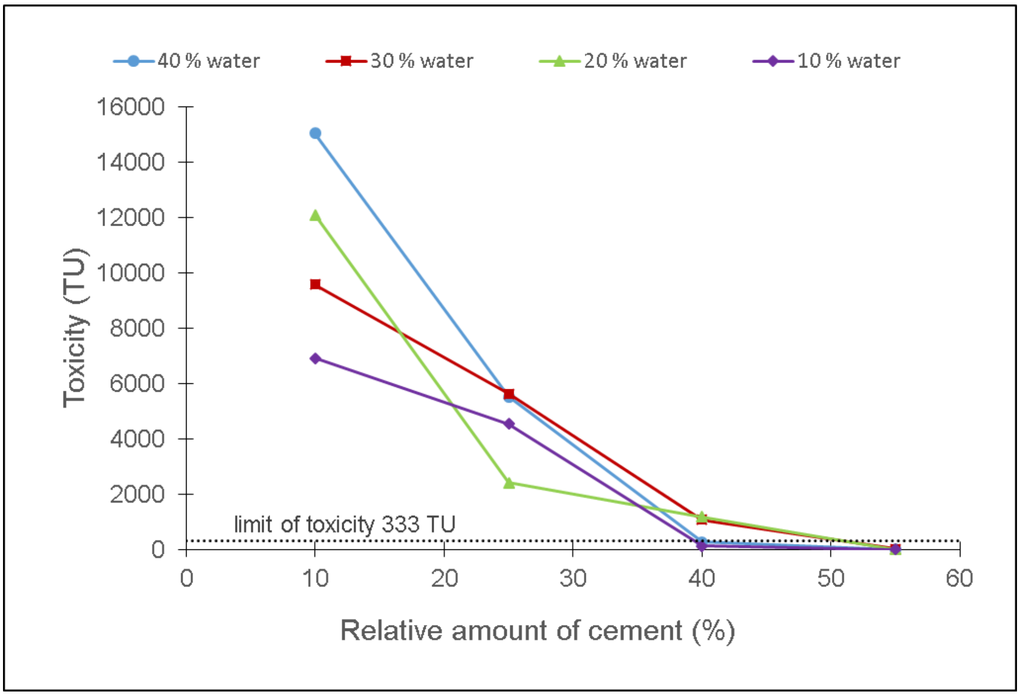
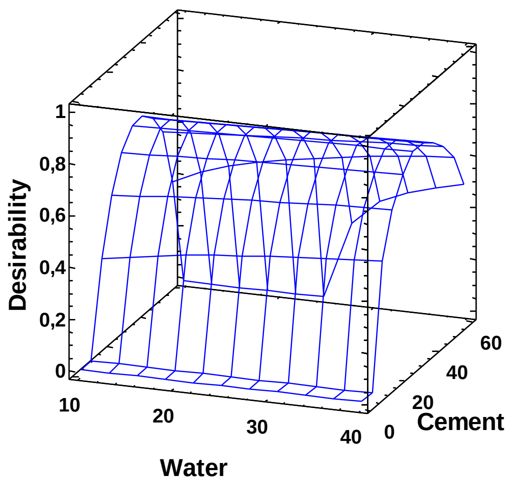


Figure 5. Effect of relative amount of cement on toxicity

Selection of the optimum operating conditions

Multiple response optimization was computed to find the optimum conditions (cement and water contents) which simultaneously minimized weight increase, volume increase, metals leached using water and toxicity. Each parameter was optimized for the best value, which satisfied e.g. leaching limits. The last goal was performed to find the best usable ratio for optimization by Portland cement which is shown in the Figure 6. Values of the operating conditions, that minimized the overall desirability function and corresponding response variable values, were predicted. The results showed the optimum operating conditions, which were following: 32 wt. % cement addition and 40 wt. % water addition.



Optimized factors:
Cement (wt. %): 32
Water (wt. %): 40

Overall desirability: 0.81

Predicted response variables
Weight increase (%): 77
Volume increase (%): 83
Leached Zn (mg/kg mixt.): 5.7
Toxicity EC_{50} *(TU):* 1221
Retained Zinc (%): 99.8

Figure 6. Optimized factors for solidified samples of sludge

The results showed that the lowest zinc concentration in leachate for solidified sludge was 6 mg Zn/kg. Despite the fact that, the best-optimized value for toxicity was 1221 TU, which was over two order of magnitude higher value than stricter limit suggested by some authors[23], which is set to 10 TU. The optimum values for volume and mass were 83 % and 77 %, respectively. Thus, it was impossible to optimize toxicity value, because it depended on higher values of weight and volume increases, but the zinc concentration depended on lower values of both parameters.

The presented results showed that stabilization and solidification of the sludge was successful in half of the samples. The used type of Portland cement showed the ability to immobilize contained toxic metal, especially zinc. The zinc concentration decreased from initial value of 328 g Zn/kg to the range of 5.7 – 67.72 mg Zn/kg. Thus, the statistical analysis recommended these operating conditions as the most desirable: 32 wt. % cement addition into the solid components of the mixture and balanced with sludge, and 40 wt. % water addition added to the mixture. For comparison, the best mixture with the lowest toxicity and zinc concentration found, had contents of cement and water both 40 %.

Conclusions

S/S process using cement for zinc containing galvanic sludge was applied to find a safer way of landfill disposal this waste to reduce its hazardous intrinsic characteristic. The toxicity, zinc concentration in leachates and values of retained zinc were measured for the analysing the effectiveness of the process. The following conclusions may be made:

1. The S/S process was effective in half samples of solidified sludge.
2. The values of retained zinc confirmed that the S/S treatment did not cause only a dilution of the sludge.
3. The untreated sludge could not be disposed of in any landfill (not even a hazardous one) since the leached zinc value was very high. Half of the solidified sludge samples could be disposed of in landfill, most of them in non-hazardous waste one.
4. The minimum zinc concentration was determined to 5.7 mg Zn/kg for the solidification mixture W-40-40.
5. Four samples of solidified sludge had negligibly low toxicity values below the regulatory levels.
6. Multilevel response analysis for the sludge showed that cement had a significant influence of the S/S process. On the other hand, the water addition had no significant effect or small influence on S/S process. The optimum operating conditions corresponded to the highest cement addition (32 wt. %) and mid water addition (40 wt. %).
7. The used type of Portland cement could be recommended for S/S process of the galvanic sludge.

List of symbols

S/S	Stabilization/solidification
EN	European norm
TCLP	Toxicity characteristic leaching procedure
RSM	Response surface methodology
DIN	German Institute for Standardization ("Deutsches Institut für Normung" in German)
EC_{50}	The value of half maximal effective concentration
TU	Toxicity unit
UTS	Universal treatment standard
wt.	weight

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Stabilizace/solidifikace odpadního zinkového kalu pomocí cementu

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Souhrn

Proces stabilizace/solidifikace pomocí Portlandského cementu byl aplikován pro úpravu odpadního kalu z žárového zinkování. Portlandský cement byl zvolen jako pojivo pro svou dostupnost jako jedno z nejlevnějších pojiv dobře známých svou použitelností pro zpracování nebezpečných odpadů. Účinnost procesu byla hodnocena pomocí vyluhovacího testu dle normy EN 12457-4, a také pomocí vyluhovacího testu v kyselině octové (TCLP). Vliv složení směsi na proces stabilizace/solidifikace byl charakterizován parametry toxicity a retence polutantů v matrici. Získaná data byla podrobena statistické analýze za použití metody multi-faktorového návrhu experimentu. Práce se zabývá odpadem z odmašťování a chemického čištění povrchu ocelových výrobků před žárovým zinkováním. Tento odpad nevyhovuje legislativním požadavkům na obsah polutantů ve vodném výluhu, a proto jej není možné bez další úpravy ukládat na skládky odpadů. Hlavním cílem studie bylo stabilizovat a solidifikovat uvedený toxický odpad, a tak umožnit jeho bezpečné uložení na skládku odpadů.

Klíčová slova: *odpad z pozinkování; stabilizace/solidifikace; vyluhovací testy; toxicita.*