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STABILIZATION–SOLIDIFICATION OF WASTE INCINERATOR SALT AND ASH BY ASPHALT EMULSIONS

A procedure for stabilization–solidification (S–S) of salt and ash from a waste incinerator by aqueous asphalt emulsions was developed. The procedure consists in mixing waste with an anionic, slow setting emulsion whereby a partial coating of waste particles with asphalt binder is obtained. The dough-like mixture thus formed is subsequently provided with an asphalt coating by means of spraying with an anionic, rapid setting emulsion. The asphalt coating is impermeable and presents a secondary immobilizing barrier effectively preventing any pollutant getting leached by aqueous solutions. Leachability tests performed on the specimens of stabilized salt, stabilized ash, and on an asphalt-coated glass body, as blank test, show very low values of parameters being determined. In addition, the values of these parameters for both wastes and blank test are the same and thus convincingly demonstrate both the efficiency and universal applicability of the elaborated S–S procedure. Ecotoxicity tests indicate the toxicity of both stabilized wastes is reasonably low, as opposed to the very high leachate toxicity of these wastes when untreated.

1. INTRODUCTION

Stabilization–solidification (S–S) of salts based on applying hydraulic binders is questionable, with a view to the ionic character of salts [1]. The restriction is true to a lesser extent also of ashes. Waste incinerator ash may often contain toxic inorganic anions (e.g. NO_3^-, CrO_4^{2-}, F^-) and relatively considerable quantities of amphoteric metals (e.g. Pb, Cr, Al, Zn, Sb, Sn). The fixation of anions by cement is unsuitable on principle because anions are easily leachable out from a concrete matrix with water and, moreover, their contents represent potential interference with the S–S process [1]. As a matter of principle, the fixation of amphoteric metals with hydraulic binders is also inappropriate because high pH values of aqueous leachates of wastes thus stabilized induce chemical transformation of these amphoteric metals into very well soluble hydroxo-complexes. Ash and salt from waste incinerators may also contain

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POPs (persistent organic pollutants). Long-term immobilization of POPs in a concrete matrix is illusory, owing to the inorganic character of this matrix [2].

On the contrary, employing asphalt binder in S–S processes is characterized by a number of positive circumstances. Asphalt, as a highly hydrophobic substance, forms a perfect immobilizing barrier which is very efficient in preventing the leaching of pollutants from stabilized waste into the environment [3], [4]. Asphalt is distinguished by exceptionally favourable properties such as creep, inertness and stability in the environment. Chemical and biological resistance of asphalt is exceptional. Evidence for that is provided by the state in which ancient objects made from asphalt have been preserved. Biological resistance of asphalt to the attack of microbes, insects, rodents and plants has been extensively investigated for the purposes of protective pipeline coatings [5]. The quoted study leads to conclusions that asphalt is quite exceptionally resistant to biological influences. Chemical resistance of asphalt binder to aqueous solutions of inorganic acids, organic acids, inorganic alkalies and inorganic salts has also been subjected to thorough study [6]. Here it is serviceable to select and present but a few data on the chemical resistance at ambient temperature (i.e. temperature relevant for land disposal of stabilized waste) valid for oxidized asphalts (these are taken into consideration for S–S of wastes): attack of hydrochloric acid (10–30%), sulphuric acid (up to 50%), nitric acid (up to 10%), lactic acid (10%) and butyric acid (10%) after an exposure time of 5 years was verbally evaluated as "not affected", the attack of formic acid (85%) and acetic acid (20%) after a 9-month exposure time was without effect; the attacks of caustic soda (up to 30%) and soda solution (10%) after 42 months were without effect, and the attacks of waterglass and seawater after a 5-year exposure time were of no effect either. In the light of these facts, it will be fully justified to assume that life of asphalt-stabilized wastes in landfills will be completely satisfactory. Successful S–S of salt and ash from a waste incinerator by means of melted asphalt binder was described in our previous works [3], [4]. Heating the asphalt binder and mixing its melt with waste are, however, unpleasant operations involving in addition a power consumption not to be disregarded. Elimination of these objective difficulties is offered by employing aqueous asphalt emulsions. It must be emphasized that aqueous asphalt emulsions, nowadays produced on an industrial scale, represent a dispersion of asphalt in water which is sufficiently stable to be comfortably repumped, stored and transported. The correct choice of emulsion of an appropriate chemical character makes possible its setting on contact with waste in a mixing device or on spraying onto solidified waste. The asphalt binder formed by setting of aqueous emulsion nevertheless preserves all properties of asphalt the emulsion was made from [7]. This is true of both its chemical properties (composition, stability in the environment, water resistance) and of its physical properties (adhesion, creep, viscosity).

Works can be found in literature on the use of asphalt emulsions in S–S of soils contaminated with organic substances [8], [9]. On the contrary, our work deals with employing asphalt aqueous emulsions for S–S of two exemplary wastes. Both salt and ash from waste incinerator are an example of wastes that have to be subjected to an

S–S process as they represent otherwise intractable wastes. In Czechia, S–S of these wastes is directly prescribed by law.

2. EXPERIMENTAL

2.1. WASTES

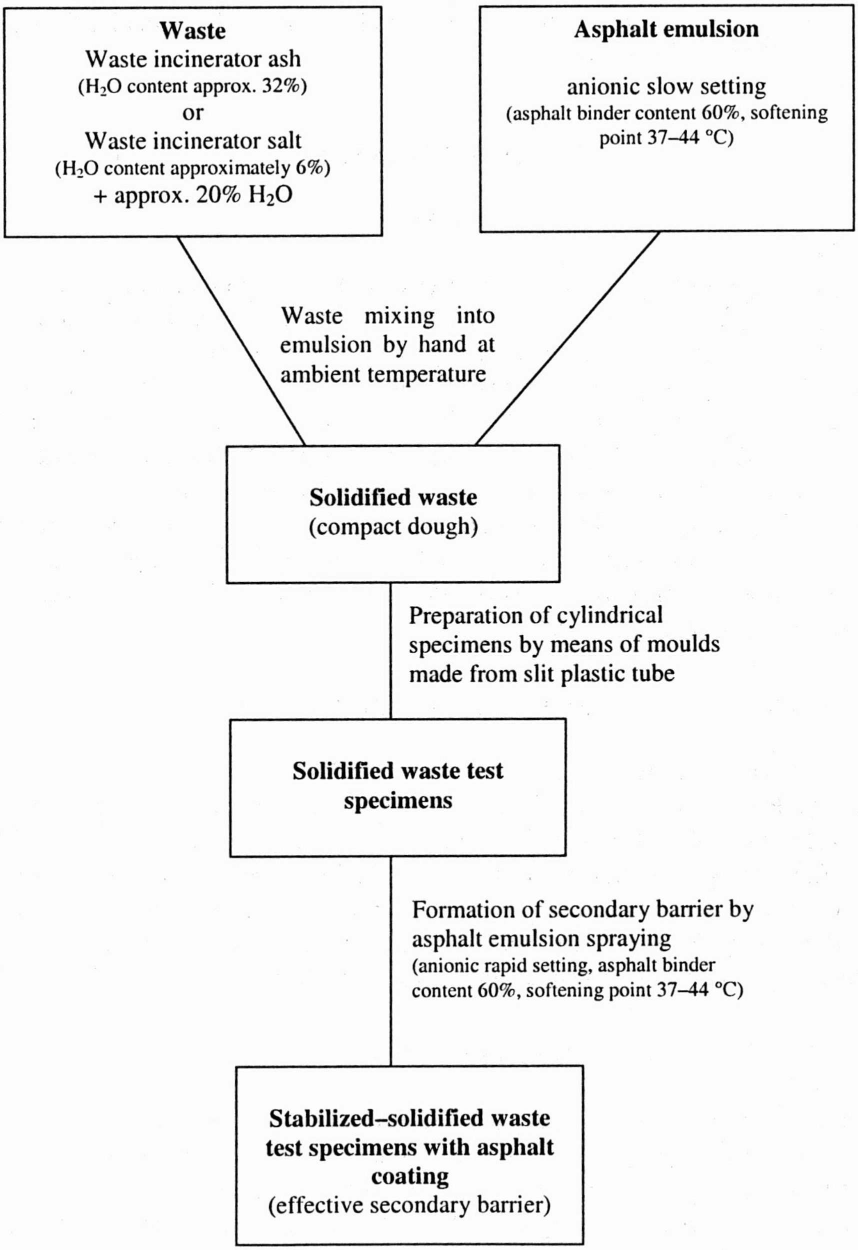
The salt came from a waste incinerator (waste oils, solvents, paints, sanitary waste and others) of the EMSEKO Co. in Zlin, Czechia, Europe. It was actually a mixture of salt and fly ash originating during cleaning of waste gases by the so-called semi-dry wash technique employing an aqueous suspension of $Ca(OH)_2$. The composition of the salt varies, depending on the waste being incinerated; main components are $CaCl_2$, $Ca(NO_3)_2$, $CaSO_4$, excess $Ca(OH)_2$ and captured fly ash. Following homogenization, the taken sample had the character of a fine powder (dry matter 94.05 %, density 2.1 g/cm^3, bulk density 0.4 g/cm^3, soluble compounds 59.5%). Ash was from the same incinerator, wet (drawn through a water siphon trap) and after homogenization possessed the following properties: dry matter 68%, density 2.1 g/cm^3, bulk density 0.8 g/cm^3, soluble compounds 4.9%.

2.2. AQUEOUS ASPHALT EMULSIONS

The products employed were from the PARAMO Co., Pardubice, Czechia, Europe; SILERYL OG is an anionic, slow setting emulsion containing 60% of asphalt binder (softening point at 37–44°C, emulsifying agent is a blend of salts of higher saturated fatty acids, emulsion pH is 12–13); SILEMBIT S60 is an anionic, rapid setting emulsion with all parameters corresponding to the foregoing emulsion except for content of emulsifying agents and setting regulators; both emulsions are produced on a commercial basis and find application in road engineering.

2.3. S–S OF WASTES BY ASPHALT EMULSIONS

The procedure being developed and verified consists in mixing ash or salt with anionic, slow setting emulsion at ambient temperature (see the figure). Mixing was performed by hand for 10–15 minutes so that a homogeneous mixture was formed, appearing as a black compact dough. For S–S of salt, a 20% addition of water (per salt dry matter) is required to facilitate mixing. In the case of S–S of ash, no similar addition of water was necessary because ash itself contains water (32%). Mixtures containing 5%, 10%, 15%, 20% and 30 % of asphalt were prepared. Test specimens prepared for leachability tests were cylinder-shaped (height and diameter were the same, equalling 37 mm). Their preparation from mixed blends of waste + asphalt



Block diagram of the S–S procedure of incinerator salt and ash by asphalt emulsions, including preparation of test specimens

emulsion was performed by means of a slit tube of plastic and of usual aids (meaning no special tools or procedures were needed): after filling, the employed plastic mould was opened and test specimen of solidified waste thus produced. An asphalt coat on test specimens was achieved through a double spraying of hanging specimen with rapid setting emulsion. This rapid setting anionic emulsion immediately sets on the surface of both solidified wastes, forming a non-porous asphalt coat similar to chocolate icing (layer thickness is in the range of approx. 0.2–0.7 mm, whereas the thinner layer is formed on test specimens of higher asphalt content).

2.4. LEACHING TESTS

Untreated wastes, test specimens of both asphalt-coated stabilized wastes and blank specimen (see the following paragraph) were subjected to leaching tests of two kinds. The first test determined leachability with water (Czech regulations): such a volume of water is used for preparing leachates that corresponds to the ratio of 1 dm^3 of water per 100 g of dry matter of sample (dry matter of ash and salt is determined at 105 °C, a 100% dry matter content is assumed for test specimens of stabilized wastes); after 24 hours in a reciprocating shaker the leachate is filtered through a glass-fibre filter of 0.7–1.3 μm pore size and subjected to chemical analyses for relevant parameters. The test employed as the second was the TCLP (EPA – method No. 1311) determining leachability with an aqueous solution of acetic acid (extraction fluid No. 2).

2.5. BLANK TEST

In order to satisfactorily determine the value of blank test for S–S of wastes with asphalt emulsions, a blank specimen was prepared in the manner as follows: a glass body of approximately the same surface area as that of the prepared bodies of stabilized wastes was provided with an asphalt coat in the manner described above, i.e. by a double spraying with rapid setting anionic asphalt emulsion. This asphalt-coated glass body was leached in the same volume of leaching medium as test specimens of stabilized wastes. Determined parameters of this blank specimen leachate represent leachability of asphalt coating itself and hence the required value of blank test.

2.6. ECOTOXICOLOGICAL ASSESSMENT OF S–S PROCEDURE

Bacteria *Pseudomonas putida* growth inhibition test was performed in accordance with European standard EN ISO 10712:1995 [10]. The test strain was obtained from the Czech Collection of Microorganisms, where it is deposited as strain No. 3423/1065. All dilutions and controls were prepared in triplicates.

For the higher plant root elongation tests 40 seeds of the plant for each dilution of leachate were placed in Petri dishes on filter paper discs moisturized with 7 cm^3 of the particular dilution of leachate or distilled water as a control. The dishes were incubated for three days at 25 °C in the dark and subsequently root lengths were measured and inhibitions calculated by comparison with the control. As test plants we selected lettuce (*Lactuca sativa*) and white mustard (*Sinapis alba*) obtained from a conventional supplier (Moravoseed, Czech Republic).

2.7. ANALYTICAL METHODS

Determination of the DOC parameter (dissolved organic carbon) in aqueous leachates was performed by means of carbon analyzer TOC-5000A (Shimadzu Corp., Japan). Determination of PAHs (sum of polynuclear aromatic hydrocarbons: fluoranthene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, benzo(b,h,i)perylene, indeno(1,2,3-cd)pyrene) in aqueous leachates was executed with liquid chromatograph LC Module I (Waters, U.S.A.) equipped with fluorescence detector (Waters 470). The concentrations of inorganic anions in aqueous leachates were determined by the ion chromatography method (LC Module I, Waters) employing a conductivity detector. Determination of metals in aqueous leachates and in leachates using a solution of acetic acid (TCLP) was performed by means of atomic absorption spectrophotometer GBC 933 AA (GBC Scientific Equipment Pty. Ltd. Australia). Measuring conductivity of aqueous leachates was done by microprocessor conductometer LF 3000 with automatic temperature correction to 25 °C (Wissenschaftlich Technische Werkstätten G.M.B.H., Germany). The content of non-polar extractable substances (NES, extraction with trichlorotrifluoroethane) in aqueous leachates of the blank sample was determined by means of a FTIR spectrophotometer (ATI MATTSON, 3000, U.S.A.). The content of ammonia ions in aqueous leachates was determined applying the Nessler reaction with subsequent measurement of absorption at a wavelength of 430 nm.

3. RESULTS AND DISCUSSION

3.1. PROCEDURE OF WASTE S–S

The S–S procedure for salt and ash from a waste incinerator employing asphalt emulsions is the result of experimental research and prolonged development. A number of various emulsions were tried out as well as the quantities of added water and the methods of mixing blends.

The procedure shown in the figure results from experience and knowledge thus acquired. During the first step, i.e. mixing emulsion into waste, slow setting of emulsion is of advantage for facilitated homogenization and the best possible coating of waste particles, hence the choice of slow setting emulsion is, as a matter of principle, the best. In addition, ash and salt reveal a markedly basic character and it is thus clear that the applied emulsion should also be basic, i.e. anionic. Employing cationic emulsion, which is acid, implies an undesirable direct neutralization reaction that would lead to a counterproductive dissolving of wastes, thus to the opposite of what S–S is to bring about. Apart from that, immediate setting of asphalt binder would also occur, prior to the mixed blend getting homogenized. Consequently, waste particles would not be perfectly coated with asphalt binder; on the contrary, an agglomeration of asphalt particles would then take place and the formed compact asphalt phase would complicate the mixing of such a blend. For this reason, the correct choice appears to be the anionic emulsion which is basic and cannot, therefore, undergo immediate setting due to a neutralization reaction between waste and emulsifier. Setting of emulsion takes place, of course, even without being caused by contact (contact of emulsion with waste surface) also because waste (salt in the first place), as has already been mentioned, largely binds water. This binding of water, as seen through experiment, is the priority mechanism of emulsion setting. The process, however, can be affected with ease by adding water to waste (see the figure) and so facilitating, as has been said, homogenization of the blend being mixed. Thus, it is obvious that S–S by means of asphalt emulsions can be performed even with wet wastes.

When forming an asphalt coating it is naturally important that the emulsion should immediately set. That is why a rapid setting emulsion was employed. The reason for using anionic emulsion lies in the fact that solidified waste (above all specimens with low emulsion contents, e.g. 5% and 10%) has on its surface waste particles bearing a positive charge (not being perfectly coated with asphalt binder). Anionic emulsions immediately set on this positively charged surface, which is of course desirable. Another reason for applying an anionic emulsion was our empirical finding that an asphalt coating produced from it by spraying onto the surface of solidified wastes, when compared with an applied analogous cationic emulsion, was perfect, i.e. non-porous and compact. If waste is basic, as are salt and ash from waste incinerators, then contact with acid cationic emulsion leads to direct neutralization reactions, hence to potential generating of CO_2 from the surface being coated. This consequently causes undesirable foaming and porosity of asphalt coating. As leachability test results have shown (see further), the produced asphalt coating presents an efficient secondary barrier against pollutant leaching.

3.2. LEACHABILITY PARAMETERS

Table 1 collects the values of several selected leachability parameters of both wastes studied. Aqueous leachates of both wastes are markedly basic and exhibit a high (extremely high in salt) content of dissolved substances, with a corresponding high conductivity value. The content of polyaromatic hydrocarbons (PAHs) in both wastes is negligible, leachates exhibit a certain value of parameter DOC (dissolved organic carbon). A high quantity of lead is leached from salt as well as certain minor quantities of chromium and barium. Contents of a number of further metals determined are below LOD (limit of detection) of the AAS method. From our experience, such analytical results of metals in leachates of wastes from incinerators are quite common: wastes usually contain a rather small number of toxic metals, but the presence of metals largely varies, depending naturally on their content in the waste being incinerated. The fact emphasizes even more the necessary requirement that in view of this, developed and implemented S–S technology should be universal.

Table 1

Selected leachability parameters of wastes

Parameter	Aqueous leachate of untreated salt	Aqueous leachate of untreated ash
pH	11.97	11.44
Conductivity, mS/m	8 100	770
Soluble substances, g/dm^3	59.5	4.88
PAH, ng/dm^3	41.8	7.31
DOC, mg/dm^3	8.4	13.8
Pb, mg/dm^3	148.6	< 0.05
Cr, mg/dm^3	0.074	< 0.05
Ba, mg/dm^3	0.607	< 0.5

< – limit of detection of AAS method.

The leaching of both untreated wastes with an aqueous solution of acetic acid (TCLP) was not performed. Owing to the pronounced basic character of both wastes it would have immediately effected a corresponding neutralization reaction producing an even greater quantity of dissolved substances than on aqueous leaching. Of course, the TCLP test has been carried out with the stabilized wastes (see further).

Determined parameters of the aqueous leachate of blank sample are presented in table 2. These values represent the level of blank test, i.e. leachability of the asphalt coating itself. As is obvious from the results obtained, leachability of asphalt that forms the specimen coating is satisfactorily low. Particularly parameter NES (non-polar extractable substances), which might be regarded as crucial owing to the hydrophobic nature of asphalt, is very satisfactory. Table 2 further presents leachability results for several metals of the blank sample by the TCLP method, from which it is obvious that even usage of an acid leaching medium does not lead to leaching of metals from asphalt.

Assessment of the developed S–S procedure for salt, employing relevant parameters of aqueous leachates of test specimens provided with asphalt coating, is shown in table 3. Lead, which is present in salt in large quantities, is apparently not leached from test specimens at all. Leachability of barium and chromium is also zero. In our previous work [3], pH and conductivity values of leachates of salts stabilized–solidified with molten asphalt binder precisely equalled values of water used for preparing the leachate. As is obvious from table 3, pH and conductivity values obtained in this work are somewhat higher than those of water used for preparing leachates. In reality, this increase is entirely negligible if real S–S is taken into account. We assume it is caused by emulsifier leaching from the surface of specimens and not by leaching of the basic salt; partly because no such leachability increase occurred in the case of the coating preparation by molten asphalt, partly because pH and conductivity values of blank specimen are effectively the same. Results also confirm the well-known fact [3], [4] that leachability of asphalt-coated test specimens does not depend on quantity of asphalt dosed into solidifying mixture on condition that the asphalt coating is perfect. The DOC values in table 2 and table 3 approximately attain a 10 mg/dm^3 level in both the stabilized salt and blank test. They are, therefore, higher when compared with the employed water (1.56 mg/dm^3) and the increase is again caused probably by leaching out of emulsifier found on the surface of specimens.

Table 2

Leachability of blank sample (asphalt-coated glass body)

Parameter	Aqueous leachate	TCLP test
DOC [a], mg/dm^3	9.5 ± 1.9	–
Conductivity [a], mS/m	1.1 ± 0.2	–
pH value [a]	7.45 ± 0.12	–
PAH, ng/dm^3	8.90	–
NES [b], mg/dm^3	0.070	–
Ammonium ions, mg/dm^3	< 0.4	–
Chlorides, mg/dm^3	< 0.3	–
Fluorides, mg/dm^3	< 0.3	–
Sulphates, mg/dm^3	< 1.0	–
Nitrates, mg/dm^3	< 1.0	–
Nitrites, mg/dm^3	< 0.1	–
Phosphates, mg/dm^3	< 1.0	–
Ag, mg/dm^3	< 0.1	–
Al, mg/dm^3	< 0.2	< 0.2
As, mg/dm^3	< 0.02	< 0.02
Ba, mg/dm^3	< 0.5	< 0.5
Be, mg/dm^3	< 0.002	–
Pb, mg/dm^3	< 0.05	< 0.05
Cd, mg/dm^3	< 0.005	< 0.005
Cr, mg/dm^3	< 0.05	< 0.05
Fe, mg/dm^3	< 0.2	–
Co, mg/dm^3	< 0.05	–
Cu, mg/dm^3	< 0.05	< 0.05
Mn, mg/dm^3	< 0.02	< 0.02
Ni, mg/dm^3	< 0.05	< 0.05
Tl, mg/dm^3	< 0.02	< 0.02
V, mg/dm^3	< 0.05	–

a – average values of seven independent determinations, ± standard deviations.

b – NES = nonpolar extractable substances.

< – limit of detection of analytical method (see Experimental).

Table 3

Assessment of S–S procedure for salt by relevant parameters of aqueous leachates of individual asphalt-coated test specimens

Asphalt content in solidified salt [%]	Conductivity [mS/m]	pH	DOC [mg/dm^3]	Pb [mg/dm^3]	Ba [mg/dm^3]	Cr [mg/ dm^3]
5	0.655	6.38	4.60	< 0.05	< 0.5	< 0.05
10	0.761	6.57	6.42	< 0.05	< 0.5	< 0.05
15	0.787	6.77	6.51	< 0.05	< 0.5	< 0.05
20	0.932	6.82	7.67	< 0.05	< 0.5	< 0.05
30	0.996	6.88	8.05	< 0.05	< 0.5	< 0.05
Untreated salt	8100	11.97	8.4	148.6	0.607	0.074
H_2O used	0.116	5.60	1.56	< 0.05	< 0.5	< 0.05

< – limit of detection of AAS method.

Table 4

Assessment of S–S procedure for ash by relevant parameters of aqueous leachates of individual asphalt-coated test specimens

Asphalt content in solidified ash [%]	Conductivity [mS/m]	pH	DOC [mg/dm^3]
5	0.632	6.33	5.2
10	0.677	6.23	5.9
15	0.682	6.35	6.48
20	0.845	6.31	7.11
30	0.912	6.37	7.26
Untreated ash	770.0	11.44	13.8
H_2O used	0.113	5.58	1.47

An assessment of the developed procedure for ash S–S employing relevant parameters of aqueous leachates of asphalt-coated test specimens is given in table 4. It is obvious that attained values of conductivity, pH and DOC are very favourable and also, within scope of experimental scatter, the same as corresponding values for stabilized salt and blank sample. This agreement provides convincing proof that the procedure developed for S–S of salt and ash with asphalt emulsions is universal.

Tables 5 and 6 present some leachability parameters of the TCLP test carried out on asphalt-coated test specimens of salt and ash. The results obtained accord fully with expectations. Ions of metals contained in salt are not leached out of test specimens of this waste at all. Conductivity and pH values of both stabilized waste leachates are identical with the values of these measured in leaching medium. This is but further proof that asphalt binder represents an entirely impermeable barrier to aqueous media.

Table 5

Assessment of S–S procedure for salt by TCLP test of individual asphalt-coated test specimens

Asphalt content in solidified salt [%]	Conductivity [mS/m]	pH	Pb [mg/dm^3]	Ba [mg/dm^3]	Cr [mg/dm^3]
5	37.9	3.00	< 0.05	< 0.5	< 0.05
10	38.0	3.01	< 0.05	< 0.5	< 0.05
15	37.8	3.01	< 0.05	< 0.5	< 0.05
20	38.3	3.01	< 0.05	< 0.5	< 0.05
30	38.5	3.02	< 0.05	< 0.5	< 0.05
Extraction fluid	38.0	3.00	< 0.05	< 0.5	< 0.05

< – limit of detection of AAS method.

Table 6

Assessment of S–S procedure for ash by TCLP test of individual asphalt-coated test specimens

Asphalt content in solidified ash [%]	Conductivity [mS/m]	pH	Pb [mg/dm^3]	Ba [mg/dm^3]
5	38.0	3.01	< 0.05	< 0.5
10	37.8	3.01	< 0.05	< 0.5
15	38.1	3.01	< 0.05	< 0.5
20	38.3	3.02	< 0.05	< 0.5
30	38.2	3.01	< 0.05	< 0.5
Extraction fluid	38.1	3.00	< 0.05	< 0.5

< – limit of detection of AAS method.

3.3. ECOTOXICOLOGICAL ASSESSMENT OF S–S PROCEDURE

Efficiency of the presented S–S procedure was also tested by evaluating leachates of untreated wastes and of test specimens of stabilized wastes in a limited set of biological toxicity tests (see experimental part). The observed parameters were growth inhibition of bacteria *Pseudomonas putida* and inhibition of root elongation of such higher plants as for instance lettuce (*Lactuca sativa*) and white mustard (*Sinapis alba*). The salt proved to be considerably toxic, while toxicity of tested ash, to plant seeds in particular, was rather low. Following S–S, toxicity of both wastes was reduced to such extent that no significant inhibition was recorded in any of the tests, not even for maximal possible contents of leachates in test media. All is quite evident from table 7. Results of ecotoxicological assessment prove excellent efficiency of the S–S procedure developed.

Table 7

Percentage contents (v/v) of leachates in the testing medium producing 50% inhibition of the observed parameter (IC_{50})

	Salt [%]	Stabilized salt [%]	Ash [%]	Stabilized ash [%]
Pseudomonas putida	0.25	LT	13	LT
Lactuca sativa	10	LT	90	LT
Sinapis alba	14	LT	LT	LT

LT – low toxicity; determined toxicity was so low that a 50% inhibition was not attained even with maximum possible leachate content in the medium (80% for test with *Pseudomonas putida*, 100% for tests with *Lactuca sativa* and *Sinapis alba*); tabulated values are means of 3 results for *Pseudomonas putida* test and 2 results for higher plant tests.

3.4. VOLUME BALANCE OF S–S PROCEDURE DEVELOPED

From our works dealing with S–S of salt and ash with molten asphalt [3], [4] it followed that a significant reduction in volume of stabilized waste was brought about by this treatment, as compared with untreated waste. Similar results have now also been obtained when performing a volume balance of the S–S procedure carried out by means of asphalt emulsions. For instance, mixtures containing 10% of asphalt have a relative volume of stabilized salt attaining approx. 40% of the initial volume of untreated salt, and the corresponding value for stabilized ash is about 65%. S–S with asphalt emulsions obviously brings about a reduction in volume of stabilized waste analogous to that produced by S–S with molten asphalt.

4. CONCLUSIONS

Comparing leachability results of stabilized salt, stabilized ash and blank sample, it may be stated that they are essentially the same and that the leachability is low. It signifies that almost nothing is leached out of wastes thus stabilized and that stabilization is satisfactory. Moreover, equal leachability results substantiate the universal applicability of the S–S procedure developed, and ecotoxicological assessment also brings very favourable results.

Preparing the asphalt coat, which is done with test specimens by rapid setting emulsion spraying on and is quite simple, might cause certain trouble on a technical scale when disposing waste in a landfill. We imagine, however, that creating bodies of stabilized waste is not at all necessary (as opposed to laboratory tests). Solidified waste (mixed blend of waste + slow setting anionic emulsion, see the figure) could be dumped in an asphalt "tomb" built in the landfill. After filling, this "tomb" could be sealed with the rapid setting anionic emulsion. Both operations, i.e. building the asphalt "tomb" in landfill as well as its sealing, could be accomplished employing currently used highway engineering technology [11].

As follows from the results obtained, a mere 10% content of asphalt binder is sufficient for solidification itself (sufficiently coating waste particles with asphalt binder and producing a mix of plastic consistence). For building up the asphalt "tomb" and sealing it after its filling with solidified waste, the required quantity of asphalt emulsion – related to a volume unit of waste – naturally depends on "tomb" size (the greater the dimensions of a common body, the smaller the surface-area to volume ratio). Considering the size of an asphalt "tomb" in a real landfill, consumption of asphalt emulsion should accordingly be relatively low.

The crucial issue of any S–S technology is inevitably that of long-term stability of stabilized waste deposited in a landfill. We are convinced that with a view to the exceptional chemical and biological resistance of the asphalt mentioned above, the presented S–S procedure with asphalt emulsions will also meet this requirement.

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[11] Ibid., p. 53.

EMULSJE ASFALTOWE W STABILIZACJI–ZESTALANIU SOLI I POPIOŁU Z PIECA DO SPOPIELANIA ODPADÓW

Opracowano metodę stabilizacji–zestalania soli i popiołu z pieca do spopielania odpadów za pomocą wodnych emulsji asfaltowych. Metoda ta polega na mieszaniu wymienionych odpadów z anionową, powoli zestalającą się emulsją, dzięki czemu cząsteczki odpadów zostają częściowo pokryte asfaltem. Utworzona w ten sposób ciastowata mieszanina jest następnie pokrywana asfaltem wskutek spryskiwania jej anionową, wolno zestalającą się emulsją. Nieprzepuszczalna warstwa asfaltu stanowi wtórną barierę immobilizacyjną efektywnie zapobiegającą wypłukiwaniu zanieczyszczeń przez roztwory wodne. Testy wypłukiwania, którym poddano próbki stabilizowanej soli, stabilizowanego popiołu, a także pokryte asfaltem szklane ciało (ślepa próba), wykazały bardzo niskie wartości oznaczonych parametrów. Co więcej, wartości tych parametrów zarówno w przypadku odpadów, jak i ślepej próby są takie same, a więc przekonująco świadczą o efektywności i uniwersalności opracowanej procedury. Testy ekotoksyczności wykazały, że toksyczność obu stabilizowanych odpadów jest rzeczywiście mała w przeciwieństwie do bardzo dużej nieoczyszczonych odpadów.