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CHARACTERIZATION AND STABILIZATION OF WASTE DUSTS FROM SHREDDED AUTOMOBILES INDUSTRIES

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Abstract

Until recently, disposal to landfill has been the most convenient way to deal with the increasing amount of residues the shredding industries produce. But the shortage of such disposal sites and the risk that liquid drained from these waste dusts may pollute ground water have increased the environmental pressures to find more effective solutions. The present study is an alternative approach that suggests identifying waste dusts characteristics and selecting an appropriate binder for hazardous materials to reduce the amount of contaminants (mainly lead) that were leaking into the soil. Investigations on the characteristics of automobiles waste dusts show that these materials are composed mainly of cottons and sponge like substances, plastics, rubber, glasses and gravel, metals, and electric wires. Besides, the percentage in weight of organic (inflammable) materials is about 70% and the lead contamination, which has not a ionic but a particulate nature, is particularly remarkable in cottons and sponge like materials. Binding additives such as K-20 and sodium carbonate were not effective but the addition of 5 % of cement (in weight of the investigated sample) followed by a 3-minute stirring and a 4-hour storage could drastically reduce the run off of lead below the maximum authorized level. No addition of water was necessary in this method.

Keywords: waste dusts characteristics, lead contamination, biding additives, cement

Introduction

For more than four decades, except for the oil shock periods and the end of the so-called "bulb economy", the automobile industry has been the driving force of the Japanese economic growth. Presently, a constant increase in the annual production of automobiles (about 2 millions/year) still fortifies this trend (Koga et al.,

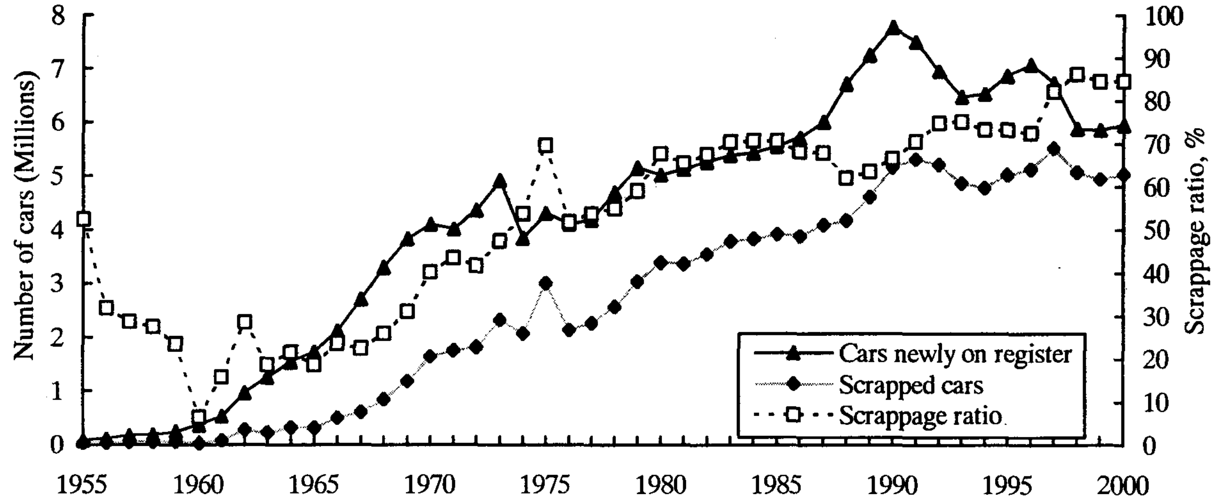

Figure 1: Annual variation in the scrappage ratio and number of cars in Japan

1997). A similar tendency is observed in the automobiles shredding industry where the number of cars scrapped annually, with regard to the number of cars newly on register, has gone up steadily in last decade to reach a scrapping rate of 84.5 % in 2000. This means that actually, four vehicles are scrapped for five ones newly on register (Mori et al., 1999). This process generates a huge amount of residues (waste dusts), generally taken away to landfill sites; A costly operation which never used to be considered excessive for the environment, with the shortage of such disposal sites and in order to avoid ground water contamination, the Japanese Environmental Agency has toughened the requirements for land filling operations: annual increases in landfill tax charges, reduction of the acceptable level of toxic substances (heavy metals contaminants) leaking from industrial waste dusts, etc. In 1996, the acceptable level of leakage has been reduced from 3.0 mg/l to 0.3 mg/l in the case of lead and from 1.5 mg/l to 0.3 mg/l for arsenic. To fit these new requirements and achieve a complete management, storage, and re-use of shredded automobiles residues, many environmentally friendly projects have been initiated. The present study is an alternative approach (intermediate solution) aimed at characterizing waste dusts, identifying the nature of lead contamination, and selecting an effective binder additive for hazardous materials that would help reducing or getting rid of lead contamination in liquid drained off from land filling sites where are dumped regularly about 2000 tons of waste dusts produced monthly at Kyushu Metal Industry Co., Ltd..

Sample preparation and procedures

About 3 tons of waste dusts collected from two shredded automobiles plants were subdivided into samples of 30-50 kg weight through coning and quartering. These samples were hand screened using sieves of 70 mm, 30 mm, and 10 mm aperture. Then, followed a thorough hand picking operation to classify materials contained in these fractions into six categories: cotton and sponge like materials, plastics, rubber, glasses and gravel, metals, and electric wires. For each classified fraction and category of materials, tests on lead contamination were carried out based on Japan Environment Agency's notification N°13. Accordingly, materials were ground to 0.5-5.0 mm and mixed with distilled water to make a solution containing about 10% of solids. Afterwards, the mixture was scattered to form a layer of 4-5 cm depth and shaken for 6 hours on a plate vibrating at 200 rpm. The filtrate, passing through a 1 μm glass fiber filter was collected and analyzed with accuracy in an atomic adsorption spectrophotometer to have an estimate of the amount of lead in the liquid drained from land filling sites of waste dusts.

The nature of lead dissemination was clarified using a 0.1 μm membrane filter made of cellulose nitrate in addition to the required 1 μm glass fiber filter (Mori et al., 1997).

In order to identify and select binder additives that would stabilize the leakage of toxic contaminants from waste dusts, highly contaminated composite samples were prepared mixing materials finer than 45mm with waste engine oil and air tumblers underflow in the proportion 39:10:1. These samples were stirred at 40 rpm either in a pug mill (length - 400 mm, width - 340 mm, diameter of the impact rotor - 300 mm) or in a drum mixer (length - 360 mm, diameter – 290 mm). Then, a stabilizing reagent (cement, carbonate sodium, or reagent K-20) was added through a sieve to discard agglomerated particles. Some water was sprinkled over to increase the sample moisture. The rotation of the mixing device was increased to 80 rpm for 3-5 minutes. Finally, about 200g of materials were collected to determine the runoff of lead in the investigated samples (Mori et al., 1999). The reagent K-20, mainly composed of potassium silicate, sodium borate, and glycerin, is used in a diluted form with cement to treat lead contaminated soil in USA.

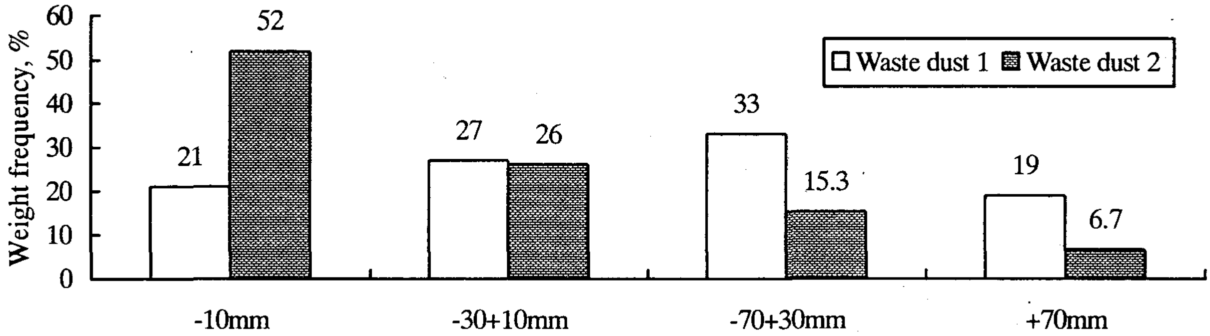

Figure2: Results of the screen analysis of waste dusts 1 and 2

Experimental results and discussion

Size distribution analysis and materials composition of waste dusts

The results of the screen analysis plotted in Figure 2 show that particles are quite regularly distributed in all fractions of waste dusts 1 while fine particles (about 52 % in weight of fraction finer than 10 mm) prevail in waste dusts 2. Nevertheless, the weight ratio of fraction –30+10 mm is almost the same for both samples. That makes this fraction of waste dusts an ideal target for material composition analysis. As reported in Figure 3, waste dusts are mainly composed of burnable substances such as cotton and sponge-like materials, plastics and rubber that come for 82.1% for waste dusts 1 and 67.9% for waste dusts 2 respectively. Besides, metals (steel, aluminum, copper, stainless) represent from 55.3% to 71 % of incombustible substances; that is about 6.7% to 22.8 % in weight of potentially recoverable materials lost in waste dusts.

Tests on lead contamination

For each size fraction and category of materials, the amount of lead that could leak from waste dusts disposed in landfill sites (Figures 4, 5) was evaluated at Technos Environment Co., Ltd (Kitakyushu, Japan) in compliance with Japan Environment Agency's notification N°13. As illustrated, the highest values of leakage were recorded for cotton and sponge-like materials in fractions –30+10mm for waste dusts 1 and –70+5mm for waste dusts 2. That is to say, binding lead in these categories and fractions of materials would reduce the leakage of toxic contaminants from shredded automobiles residues and make the latter fit environment requirements.

Nature of lead contamination

In addition to the 1 μm glass fiber filter required by the notification N°13, some tests were carried out with a 0.1 μm membrane filter made of cellulose nitrate to see whether the lead contamination was of chemical (ionic) or physical nature. For a contamination of ionic nature, the value of the lead leakage should be the same

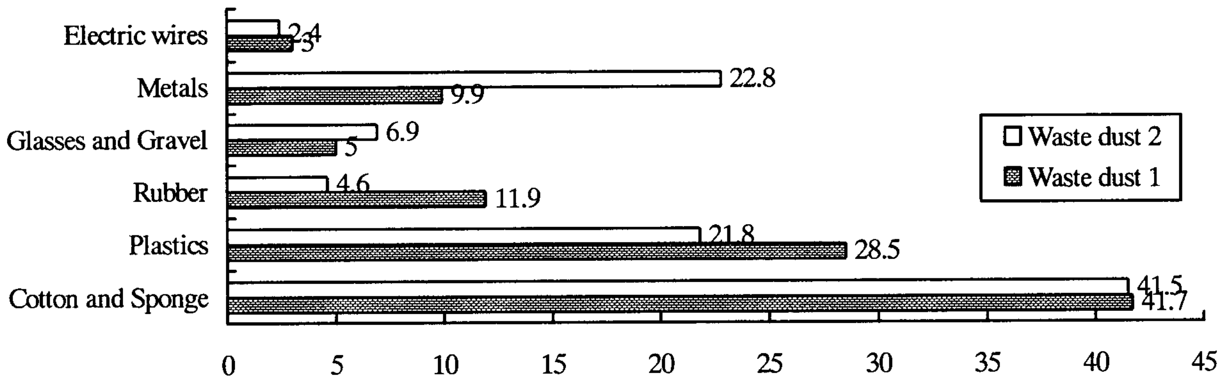

Figure 3: Material composition (%) of waste dusts (fraction -30+10 mm).

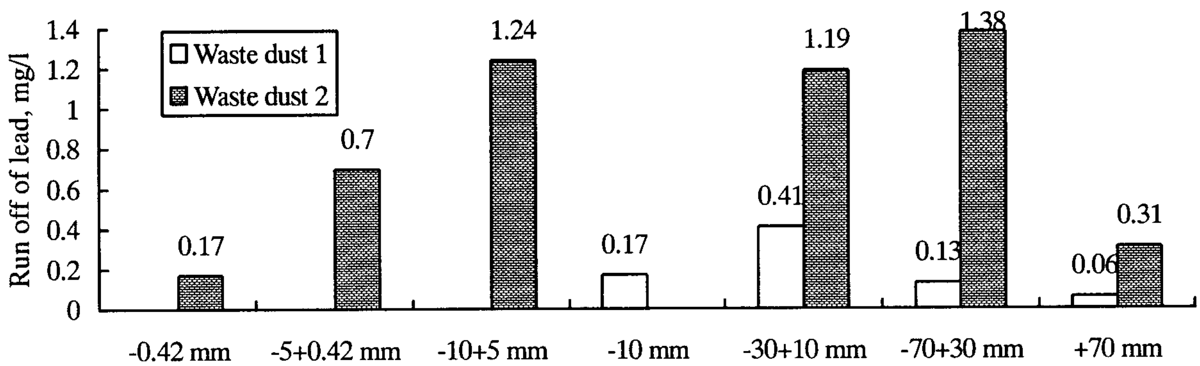

Figure 4: Leakage of heavy metals (lead) from different fractions of waste dusts.

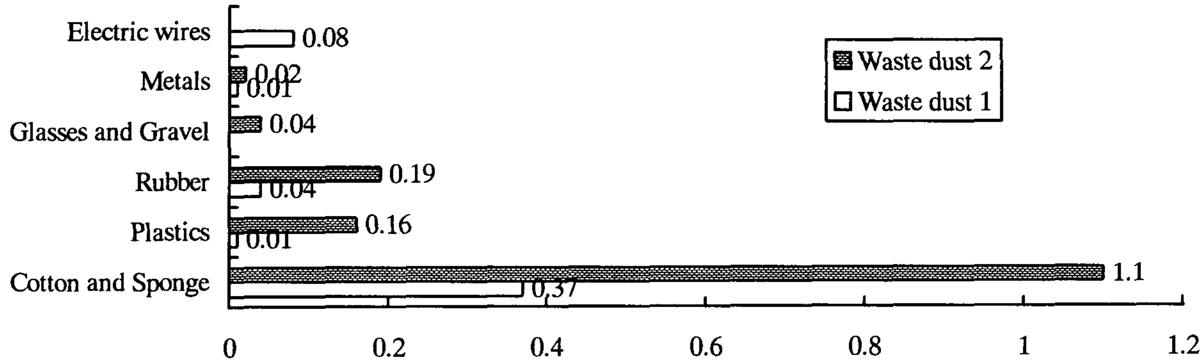

Figure 5: Leakage of heavy metals (lead, mg/l) from waste dusts components.

Tabel I Runoff of lead for different types of filters

Fractions	-70+30mm	-30+10mm	-10+5mm
Type of filters	Runoff of lead, mg/l		
Filters of 1 μ mØ	1.38	1.19	1.24
Filters of 0.1 μ mØ	0.03	0.02	<0.01

regardless of the size of filters otherwise, and that was the case, the contamination should be considered of physical nature. In our case, data reported in Table I indicate that the runoff of lead depends on the type of filters used for the solid-liquid separation. Therefore, we assume that lead contaminants are particles in the range from 0.1 to 1.0 μm finely disseminated in cotton and sponge-like materials, or stuck on.

Tests on lead stabilization

Required amount of additives

In this series of tests, 2000 g of composite samples with a lead leakage value of 1.63 mg/l were stirred for 3-5 minutes in a highly efficient mixing equipment (the pug mill), stored for 48 hours, and mixed with 1420 g of water. As reported in Table II, the minimum amounts of additives that reduced the leakage of lead below the environmentally acceptable level were 200 g for cement, 20 g for sodium carbonate and 3.6 g for reagent K-20 respectively. However, reagent K-20 was discarded from further investigations because its simultaneous use with cement did not affect the runoff of lead significantly. Besides, a mixture of sodium carbonate and reagent K-20 was not envisaged for economical reasons.

Influence of the moisture content on lead leakage

Tests were carried out at constant weight of stabilizing additive, using a composite sample with an initial lead leakage value of about 1.31 mg/l. The results of these tests, as reported in Table III, indicate that an addition of water affects the runoff of lead when sodium carbonate is used as stabilizing reagent. On the contrary, this effect is more difficult to appreciate in the case of cement because the runoff of lead remains below the environment prescript. Surely, the moisture content of the composite sample (about 15 %) was high enough to ease the binding of finely disseminated particles of lead with cement (5-10 % in weight of the investigated sample) and their agglomeration.

Optimal storage time and mixing efficiency

Composite samples with an initial leakage of lead of about 10.0 mg/l were mixed with cement for 3 minutes and stored for 0, 4, and 24 hours respectively. At the end of the storage time, the leakage of lead was evaluated

Table II : Effect of various stabilizing additives on the leakage of lead

Tests	1	2	3	4	5	6	7
Cement, g	200	300	0	0	200	300	400
Na2CO3	0	0	20	40	0	0	0
K-20, g	0	0	0	0	3.6	3.6	3.6
Leakage, mg/l	0.02	<0.01	0.03	0.11	0.01	0.02	<0.01

Table Ⅲ : Influence of water addtion on the stabilization of lead

Tests	1	2	3	4	5	6	7	8	9	10	11
Cement, g	200	200	200	200	100	100	100	100	0	0	0
Na2CO3	0	0	0	0	0	0	0	0	20	10	20
Water, g	1200	800	400	0	600	400	200	0	700	350	0
Leakage, mg/l	<0.01	<0.01	0.01	<0.01	0.04	<0.01	<0.01	<0.01	9.99	2.48	5.67

according to the Japan Environment Agency's notification N°13. As reported in Table Ⅳ, the minimal runoff of lead (0.09 mg/l) was found for a 4 hour-storage of samples while a longer storage time (24 hours) did affect the binding of lead. This was certainly due to the increasing dehydration of samples.

Tests with a drum mixer: Influence of the sample preparation on the lead leakage

Although the pug mill is a highly efficient mixer, its exploitation costs in a large scale may turn the leakage of lead into an expensive operation. Therefore, a less energy consuming equipment such as a drum mixer was designed to carry out experiences as follows:

- Mixing directly in a drum mixer the required amount of all materials (waste dusts, air tumbler overflow, engine oil, and cement as stabilizing binding additive): Table Ⅴa;
- Spreading a stabilizing binder additive over a composite sample made of waste dusts, air tumbler overflow, and engine oil stirred up in a pug mill and mixing the product in a drum mixer: Table Ⅴb.

As reported in Table Ⅴa, and certainly because of the poor stirring efficiency of the drum mixer, adding up to 10% of cement (in weight of the investigated sample) did not reduce the leakage of lead below the environmentally acceptable level. Nevertheless, Table Ⅴb indicates a considerable decrease in the leakage of lead when materials are well mixed. Comparing these results to the ones obtained with a pug mill (Table Ⅵ), a method was established to stabilize the runoff of lead definitely: dispersion of cement on waste dusts, addition of water, stirring in a drum mixer for 3 minutes, and storage for 4 hours.

Industrial application

The above suggested method was experimented at the shredding plant of Kyushu Metal Industry Co., Ltd. in 1997, with a drum mixer (length: 3.0 m, diameter: 2.3 m) settled at the discharge point of waste dusts. The rotation of the drum mixer was set up at 6 rpm so that the residence time of materials in the mixer was reduced to 45 seconds. Below these values, the drum mixer was overloaded and its efficiency decreased considerably. A rotary feeder was provided at the bottom of the silo with a capacity of about 30 tons built over the waste dusts discharging line to ensure a regular spread of cement.

Tabel Ⅳ Influence of the storage time on the leakage of lead (mg/l)

Tests	Test 1	Test 2	Test 3	Test 4
Cement, g	0	100	100	100
Time, h	0	0	4	24
Leakage, mg/l	10	0.23	0.09	0.16

Table Ⅴ Influence of sample preparation on the leakage of lead (mg/l)

Ⅴa : Direct mixing of waste components and cement in a drum mixer

Cement, g	0	12.5	25	50	100
Leakage	3.62	2.37	0.82	0.50	0.65

Ⅴb : Stirring a pre-made composite sample in a drum mixer

Cement, g	0	50	100	150
Leakage	3.62	0.11	0.06	0.05

Table Ⅵ Influence of the type of mixing equipment on t leakage of lead

Cement, %		0	5	10	15
Leakage, mg/l	Pug mill	3.64	0.05	0.04	0.05
	Drum mixer	3.62	0.11	0.06	0.05

Tabel VII Leakage of lead (mg/l) at the shredding plant of Kyushu Metal Industry Co., Ltd.

Sampling time (1997)		January, 30		January, 31		February, 4	
		A.M.	P.M.	A.M.	P.M.	A.M.	P.M.
Leakage, mg/l	Before	0.08	0.67	0.02	1.79	0.26	0.36
	After	0.06	0.16	0.03	0.12	0.17	0.02

This feeder rotated at 30 rpm and the addition of cement was 8.5 % of treated waste dusts. As for water, it was added in less than 3 % in weight of treated waste dusts to preserve a certain moisture to waste dusts. Table VII reports on the results of a three (3) day-running test carried out after launching the unit.

Conclusion

As a part of an environmentally friendly research project for a complete management, storage, and re-use of shredded automobiles residues, the characteristics of waste dusts have been investigated and an alternative method have been established to reduce the runoff of lead in the liquid drained from waste dusts disposal sites. The study reveals that about 30% of these waste dusts are non-burnable and still re-usable materials: metals (steel, aluminum, copper,...), glass and gravel, and electric wires. The other 70% are burnable substances such as cotton and sponge like materials, rubber, and plastics. From this second category of materials, the runoff of particulate lead is generally important, especially in the fraction -70+5 mm of cotton and sponge like materials. A method has been established that suggests using cement as a binding additive to reduce and stabilize the leakage of lead from waste dusts disposal sites. The method involves: spreading cement (lead stabilizing reagent) on waste dusts, sprinkling water over this product to increase its moisture, mixing the pre-wetted materials in a drum mixer for 1 to 3 minutes, and storing them for 4 hours before their disposal to land filling sites. For an effective stabilization of lead within environmental norms, the minimal proportion of cement and waste dusts was 1:20 and the addition of water, if necessary, was made to preserve a certain level of moisture. Therefore, using cement as binding reagent for lead stabilization is a potential operation that could make shredded automobiles waste dusts fit today's environmental requirement in regards to the leakage of lead.

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