ALEX CENDRE INC.

INSTITUT NATIONAL DE LA RECHERCHE SCIENTIFIQUE - INRS-EAU

DECONTAMINATION OF FLY ASH FROM MUNICIPAL WASTE INCINERATORS

SCIENTIFIC SUMMARY

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MANAGEMENT PERSPECTIVE

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INTRODUCTION

The incineration of municipal waste produces two types of ash: bottom ash, which is generally inert and doesn't constitute a danger to the environment, and fly ash. Fly ash, which comes from the purification of gas produced from combustion of waste, is usually considered as a hazardous waste. This dangerous characteristic comes from its high lead, cadmium and mercury content. These metals are leachable during the application of leaching tests of different legislation, which gives fly ash the technical characteristic of being a hazardous waste. It should be noted that fly ash is composed of boiler ash, electrostatic precipitator ash and also used lime.

The combustion of urban waste from incinerators produces important quantities of ash which represent 20 to 35% of the initial mass of the waste. In general, 10 to 20% is fly ash and the rest is essentially bottom ash. In North America alone, there are over 325 municipal waste incinerators. The combustion of waste generates over 1.5 millions tons of fly ash annually. The most common methods of waste management for fly ash is chemical stabilization, vitrification and sanitary landfilling.

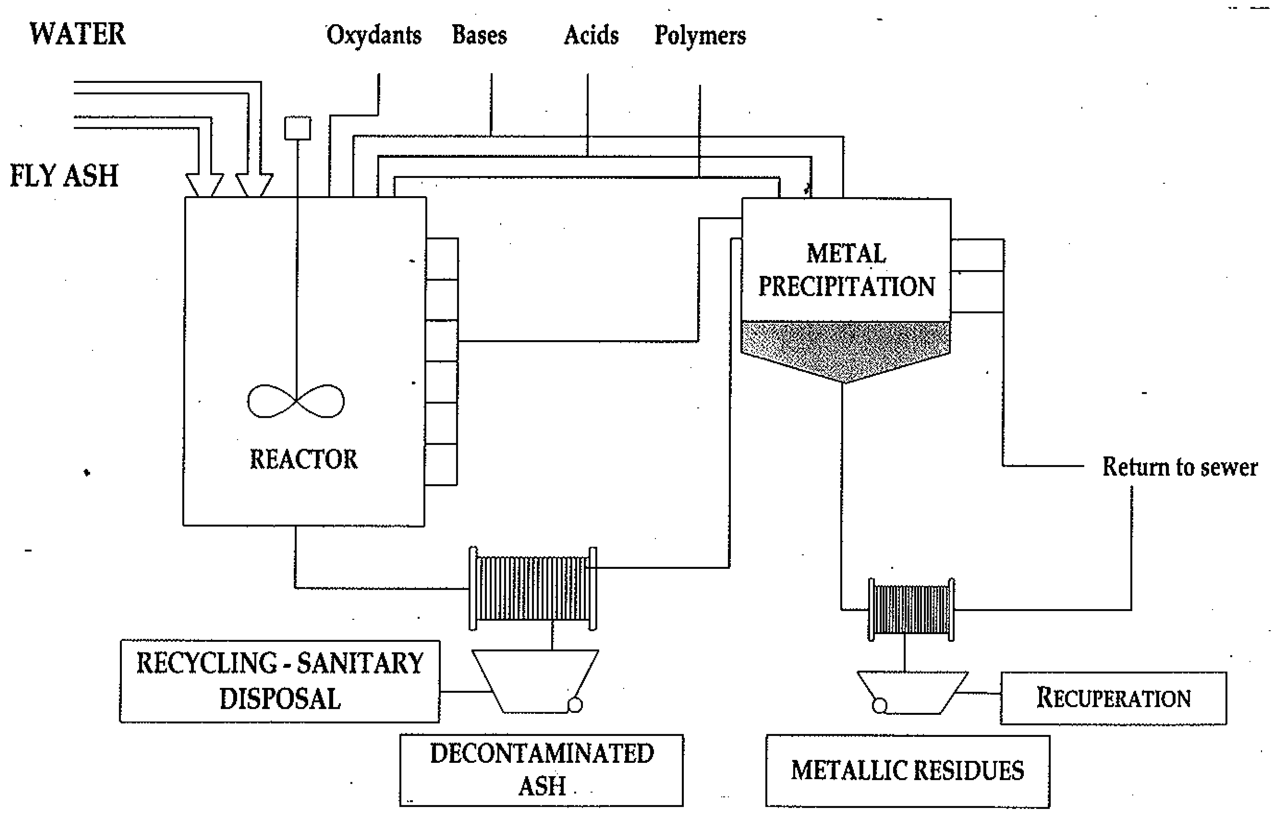
The present report is a follow up to the demonstration at the pilot scale of the decontamination process of fly ash from municipal waste incinerators. Thus, this is the final report which includes the results acquired from April 1st to the 31st of December 1996. This project was the next logical step to the research project which was developed at the National Institute of Scientific Research (INRS-Eau) in 1991. From March 1993 to March 1995, the process was developed in a laboratory during a project financed by Research and Development Funds of Environmental Technologies from the Quebec Ministry of the Environment. Partnership for the present project is between: Environment Canada, Alex Cendre inc., INRS-Eau, the Quebec Urban Community and the Quebec Ministry of the Environment.

The main objective of this demonstration project was to establish an environmental and economical process to decontaminate fly ash. More precisely, the objectives of the treatment were to render the fly ash non toxic and in conformity to the governmental regulations. Also, this treatment must permit the recycling of treated fly ash and the recuperation of extracted metals.

DESCRIPTION OF THE TECHNOLOGY

The description of the fly ash decontamination technology is presented schematically in figure 1. The proposed process consists of the chemical solubilization of metals contained in fly ash. First, fly ash is transported into a reactor and is subjected to the decontamination treatment. This decontamination consists of alkaline baths and acidic baths and uses the oxidant characteristic of certain chemical products. Following this treatment, fly ash is sent to a filtration unit; the filtered fly ash is decontaminated and may be reused. The liquids from the baths are directed towards a metal precipitation unit. This precipitation is carried out by using the principal of the solubility product (K_{ps}). The metal precipitate obtained is filtered and is collected by the metallurgical industry.

Figure 1: Global sketch of the fly ash decontamination process



TESTS DESCRIPTION AND RESULTS OBTAINED

The present report is a synthesis of all the results obtained during the demonstration. This report presents a global view of the results obtained from this process: the results from the TCLP leaching test before and after treatment, those concerning the filtration of the treated fly ash, metal precipitation via the metallic residue production and finally the quality of the final effluent.

During the technological demonstration, about thirteen tons of fly ash were treated. Over thirty decontamination tests were realized from this fly ash. These tests were carried out in a pilot plant owned by INRS-Eau. This plant was equipped with a reactor of 4 000 liters, a press-filter to dehydrate the treated ash. It also contained two sedimentation tanks for metal precipitation and a press-filter for the filtration of metallic residue. A number of other equipment like pumps, pH controllers, mixers and different stockage basins were part of this plant which is contained in a 12 by 60 feet mobile unit. Two sheds of 10 by 15 feet were also installed temporarily during the demonstration period.

Fly ash is constituted of boiler ash, electrostatic precipitator residue and used lime. These categories represent different types of fly ash sampled from distinct areas of the incinerator. When it is a question of mixtures, it refers to a combination of determined proportions of fly ash.

TCLP leaching tests on non-treated fly ash

In practically every case, non-treated boiler ash surpassed the norm for cadmium. It contained from 0.70 to 10.1 mg/L of cadmium as compared to the norm of 0.5 mg/L.

As for the lead, non-treated boiler ash rarely surpassed the norm. For the electrostatic precipitator residue, it surpassed the acceptable levels for both lead and cadmium. For lead, the levels which were superior to the norm (5.0 mg/L) mainly varied from 5.16 mg/L to 32.3 mg/L. For cadmium, the levels surpassed were even greater varying from 11.0 to 30.4 mg/L in comparison to the norm of 0.5 mg/L in Quebec. Used lime surpassed the norms for lead and cadmium on less occasions. However, in most cases its mercury content surpassed the norm of Quebec (0.10mg/L) with values varying from 0.26 to 0.45 mg/L. All samples were found to be within the norm for the following elements: arsenic, selenium, silver, boron, barium and fluorine. For mixtures #1, #2 and #3, only the cadmium was problematic with surpassing varying from 2.28 mg/L to 13.0 mg/L.

In order to verify the toxic potential following atmospheric precipitations or sanitary landfilling of fly ash, a simple test was performed only as an indication. This test, the neutral test with water, consisted of a leaching test with tap water (50 g of solid in 1 liter of water). This simulates a neutral water flow on solid waste. Even if it isn't regulated, it is of scientific interest to demonstrate that which happens with contaminants when in contact with water. This simulation allows a verification of certain metals that may leach towards the receptive area. This test permitted to observe that the pH of the water extract was alkaline and varied from 10.31 to 12.09. With these pH values, lead may partially solubilize (up to 30 mg Pb/L) and this is what is observed for boiler ash and mixture #1. As for the other metals, they remain solid and therefore are not solubilized, or very small amount is, and it may be found in the extract. An instantaneous test with water showed a solubilization of lead up to 200 mg/L for mixture #1 at 20% total solids.

TCLP leaching tests on fly ash after treatment

During each test, the TCLP leaching tests were done on treated fly ash. Even if the results are not presented, the levels for silver, barium, boron and fluorine were all within the norms. During the demonstration phase of the process, two principal series of tests were realized. The first series of tests were done from a mixture of fly ash while the second was done from used lime only.

From the results obtained, we observed that the treatment performed on mixture #1 respected the TCLP norms for the different metals analyzed. In fact, the lead concentration varied from 0.00 to 0.02 mg/L where as for cadmium they ranged from 0.01 to 0.08 mg/L; the norms are 5 mg/L for lead and 0.5 mg/L for cadmium. However, the following test showed the norms being surpassed for lead and cadmium and an optimization had to be made. In fact, the electrostatic precipitators were renovated and put into operation in the month of June; this fact caused a significant increase in the levels of lead and cadmium. As a result, a readjustment was made to the process and thus brings us to a new mixture, that is mixture #3. The results obtained during the TCLP leaching tests showed the norms being respected with concentrations of 2.34 to 3.23 mg/L for lead and 0.27 to 0.41 mg/L for cadmium.

The results which we obtained for the TCLP leaching tests for used lime only were also very positive. From these results, the proposed treatment allows the norms to be respected for lead, cadmium and mercury. In fact, the concentration obtained for lead varies from 0.37 to 3.15 mg/L, for cadmium varies from 0.02 to 0.12 mg/L and for mercury is under 0.06 mg/L.

Neutral leaching tests with water on treated fly ash

First of all, the pH of fly ash after treatment is greatly reduced from 12.5 to neutrality. Soluble lead in water is thus submitted to a great reduction in the order of about 10 mg/L to practically no leaching. This fact demonstrates how available lead is removed by this treatment by leaching in water. For the water test over a 24-hour period, the availability of mixture #1 goes from 25 mg Pb/L to 0.03 mg Pb/L after treatment, that is a reduction in availability of 99.9%. The water test is compared to an instantaneous water test (about 1 hour). The reduction of lead instantaneously available in water is 99.8%.

Percentage of metal removal by the treatment

Very high levels of lead and cadmium were reached; these concentrations of over 800 mg Cd/L and about 10 000 mg Pb/L were observed in certain samples of electrostatic precipitator residue. The amount of lead and cadmium in used lime is a whole lot smaller than that of electrostatic precipitator residue and it approaches the levels of boiler ash. Electrostatic precipitator residue contains a very high level of zinc.

The percentage removed indicates at what level the developed process removes and does not stabilize the metals in the matrix. The processes that were put to the test with mixture #1 removed on average about 89.6% of its cadmium (with values varying from 77.5 to 94.1%). For zinc, the average removal is in the order of 72.5%. As for lead, the average observed is 26.7%. For mixture #2, once again a high efficiency removal average is observed for cadmium (95,4%), zinc (85.6%) and less efficient for lead (31.2%). The removal rates presented for mixture #3 are 28.8% for lead and 94.6% for cadmium. The complete treatment on used lime permitted to remove 59.1% of lead, 84.2% of cadmium and 62.2% of zinc.

Fly ash filtration after treatment

The observations of the results show that it is possible with the test's operational conditions to obtain a *cake* having total solids average of 44.3% with a range varying from 34.1% to 55.0% total solids. The filtrate is rather limpid with an average suspended solid count of 17.2 mg/L. This limpidity is also visible in the rate of particles captured approaching 100%. The filtration rate of the press-filter is relatively high (16.8 kg/(m^2.h) to 21.2 kg/(m^2.h) and stable according to the type of fly ash used. As a result, the data demonstrate the efficiency of the filtration system.

The precipitation of solubilized metals during the fly ash treatment

The average production of metallic residue is in the order of about 14.1% for the treatment of mixture #1. In other words, every ton of fly ash treated produces approximately 141 kg of metallic residue. For used lime, two types of tests were carried out. The first test consisted of a combination of phases and produced 8.8% of metallic residue whereas the second test consisted of one phase and produce 0.56% of metallic residue. From a qualitative point of view, twenty-six analysis were done during the project on each fraction and on different mixtures of fly ash. The principal elements found in the metallic residue were aluminum, calcium, iron, sulfur and zinc. This last element represents in fact a source of zinc capable of being recuperated. It is interesting to note that over 10% of zinc in metallic residue was attained on three different occasions. The lead level in metallic residue varies from 2 401 to 5 115 mg/kg. The highest level attained for cadmium was 1 951 mg/kg from the used lime metallic residue. Calcium is the major element precipitated and represents 12.2% to 25.3%. The sulfate anion is quite present because it varies from 3.1% to 14.3%.

The final effluent of the fly ash treatment process

The precipitation of metals from the effluent demonstrated that a precipitation at pH 9.0 instead of pH 8.0 permitted to reduce the concentration of cadmium from 0.99 mg/L to 0.32 mg/L (norm at the Quebec Urban Community is 2.0 mg Cd/L). The effluents are very limpid and don't surpass any norms.

Mass assessment on the principal metals for all tests carried out

The assessment reveals interesting information. First of all, a total of 12 289 kg (12.3 tons) of fly ash were treated at the pilot plant. This treated fly ash represents 8 347 kg dry, that is 68% of its original dry mass. From this 1 377 kg of dry metallic residue was produced with 465 250 liters or 465.3 m^3 of effluent. In order to verify the appropriateness of the assessment, the sum of the metallic residue of effluent must equal the quantities of metal in this fly ash before treatment. The results obtained showed that the assessment was quite acceptable for lead (1.08), cadmium (0.93), zinc (1.02), copper (1.07) and nickel (1.02). This kind of precision is quite surprising for this type of mass assessment, taking into consideration the quantity of operations carried out. For the other elements, the assessments vary from 1.27 (calcium) and 1.18 (chrome) to 0.84 (aluminum).

ENVIRONMENTAL ADVANTAGES

Incinerator fly ash from municipal waste is considered a hazardous waste that must actually be submitted to a stabilization treatment prior to being landfill. The stabilization treatment consists of isolating this fly ash in a cement matrix before burial in a very high security site. In time this matrix erodes, allowing the metal content to become leachable and this constitutes a danger for the environment.

The decontamination process developed by Alex Cendre inc. and INRS-Eau (Alex Cendre process) aims to offer managers of municipal waste incinerators around the world a final and durable solution for fly ash. The Alex Cendre process decontaminates the fly ash by extracting the toxic fraction (lead, cadmium and mercury) and therefore rendering the decontaminated ash totally inoffensive and favorable to being reused. The reuse of decontaminated ash has a very high potential with the cement industry, thus avoiding sanitary landfilling. The high concentration of certain metals contained in the toxic fraction (metallic residue) may justify its recuperation in the metallurgical industry.

The liquid effluents produced during the operation of the Alex Cendre process are all in conformity to regulations with sewage discharge and represent no danger to the environment. Even if the atmospheric emissions are minor, they may be treated by the gas purification system present at the incinerator.

The principal environmental advantage to the Alex Cendre process is it capacity to make hazardous material into recoverable material. Also, with the recycling of solids, the liquid effluents respecting the norms and an appropriate air treatment, the operation of this process does not constitute a risk for the air, water and soil quality.

COSTS EVALUATION FOR THE TREATMENT

With the goal of evaluating the treatment costs, the parameters representing the most common incinerators in Europe and North America were used. The treatment costs include the burying and installation of equipment, the chemical products, the man-power, electricity and maintenance of equipment, the management of decontaminated ash and metallic residue. It should be noted that the treatment costs take into consideration the fact that fly ash decontamination is operated and installed at the incinerator, therefore limiting the costs of ash manipulation. So the space needed to install the equipment represents an area of 100 to 150 square meters.

The necessary equipment to commercially exploit the process exists on the market. As a result, no major equipment fabrication is needed and only some minor modification must be made. The operation of the decontamination process requires certain chemical products. These products are available in large quantities in the industrial environment and aren't subject to important price fluctuations. The man-power required for the commercial phase is two people per shift. Once the system is in place and running, the operation will require an environmental technician and an operator. The energetic needs to this process are limited to electricity to function the mixers, pumps and compressors. Maintenance was taken into consideration as a percentage of equipment costs.

Presently, decontaminated ash is managed by being sent to a standard sanitary landfill site. Nonetheless, the procedures to recycle ash are possible. In fact, the re-emergence of the cement industry seems to be a very good potential. So if a recycling process was used, this would significantly reduce treatment costs.

As for the metallic residue, it contains high metal concentration which surpasses the leaching norms of the Quebec Ministry of the Environment. Under these circumstances, the management of these residues is done by a stabilization system and by landfilling, as recommended by Stablex Ltd. Nevertheless, this metallic residue, with its metals content may become an interesting source for the metallurgical industry. Even though small quantities of metallic residues are produced, a recycling process would also have a positive effect on reducing treatment costs.

When considering these treatment hypotheses, the exploitation cost for the Alex Cendre decontamination process is inferior to 150$/tons of ash. Optimization of this process and recycling processes of decontaminated ash and its metallic residue may allow a substantial reduction in treatment costs.

CONCLUSION

The management of incinerator fly ash from municipal waste is an international problem. The heavy content of fly ash in lead, cadmium and mercury makes it a hazardous waste.

The company Alex Cendre inc. and the National Institute of Scientific Research (INRS-Eau) have developed a technology that permits the chemical solubilization of metals contained in fly ash and render it reusable. In the scope of this technological demonstration project, the use of a pilot plant with a capacity of 300 kg/day had permitted thirteen tons of fly ash to be treated.

Two principal series of decontamination tests were realized during the demonstration phase of the process. The first series of tests were done from a mixture of fly ash while the second was done only from used lime.

Operating the treatment on an ash mixture permitted the environmental norms to be respected by using the TCLP (Toxicity Characteristic Leaching Procedure), for the metal analysis of lead, cadmium and mercury. The results obtained during the TCLP leaching tests for used lime only also proved to be positive because it attained the norms for the main problematic metals. The removal percentages for these metals indicate how far the developed process removes metals instead of stabilizing them in the matrix.

The decontamination process of incinerator fly ash by chemical solubilization allows the fixed norms for metal leaching to be attained and it is worthwhile both economically and environmentally. In fact, this ash treatment produces little in terms of atmospheric emissions and no toxic liquid effluent. This process also permits the reuse of decontaminated ash and the recycling of metallic residue. On the economic front, the Alex Cendre process has a treatment cost of less than 150$/ton of fly ash, which signifies an important cost reduction as compared to other present management methods. Also, the optimizations foreseen for the process will permit to considerably reduce treatment costs.

In light of the results obtained during this demonstration phase, it now appears to be the right moment for an industrial application of the Alex Cendre process.