MOBILE ASBESTOS DECONTAMINATION BY MICROWAVE HYBRID HEATING

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ABSTRACT

Within the European project "New Safe and Cost Effective Techniques Against Asbestos Risks" different methods for decontamination of asbestos in asbestos containing wastes, abbreviated as ACW from building industry were investigated. A mobile asbestos decontamination unit was developed, aiming at the complete disintegration of asbestos fibres on-site. The process is based on a chemo-thermal treatment. Disintegration of fibres is achieved by addition of chemical reactants at temperatures of 300 to 500 °C. Heating is performed by a combination of microwave and infra-red heating devices. Microscopic and phase analysis show a complete destruction of asbestos fibres.

1 INTRODUCTION

Asbestos is the generic name given to a class of natural, fibrous silicates. The international ban of asbestos started during the 1980ies, e.g. in Germany 1980, and in the United States 1983. The need for disposal of asbestos containing materials is growing, since the waste stream from the extensive use of such materials in the 1960s and 1970s in industrial and domestic infrastructures is significantly increased, because asbestos containing products are reaching the end of life time. A cost effective, safe and reliable disposal should include the complete disintegration of asbestos fibres. Usually, a wide range of concentrations and mixtures of different asbestos phases is present in ACW. Destruction of asbestos fibres difficult, because of their excellent thermal and chemical resistance [1,2], and the heterogeneous material mixture.

Traditional asbestos abatement is organized by onsite stripping work and subsequent transport and landfilling. A mobile process would decontaminate the hazardous waste onsite and significantly reduce the need for hazardous waste transport. As shown in figure 1, complete disintegration of asbestos fibres into non-hazardous phases can be achieved either by heat treatment, by chemical additives, or a combination of both.

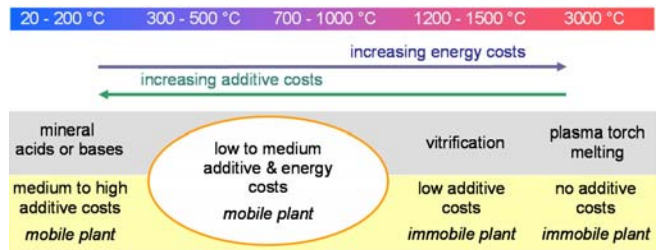


Figure 1: Concepts of a asbestos decontamination processes with different energy and additive demands.

High temperature processes like plasma arc treatment [3] or melting/ vitrification processes [4, 5] require high amounts of energy and substantial investment cost, therefore are not the preferred technologies for cost effectiveness. High temperature processing plants are immobile, therefore ACW have to be transported from the stripping site to the processing plant. Chemical treatment [6, 7] or mechanical destruction by grinding [8] are alternatives, however, full disintegration is not easy to achieve by such methods.

In ACW the fibres are usually embedded in an organic or inorganic matrix, a thermal or chemical impact on asbestos fibres is therefore limited. Supporting additives must first penetrate the matrix material to expose the asbestos fibres to chemical disintegration.

The present study therefore investigates the disintegration of various ACW upon combined chemo-thermal treatment, in contact with alkali melts under microwave radiation in a laboratory scale reactor. The results were used for the development of a pilot plant, utilised for testing of different ACW under on-site conditions within a special testing facility.

Most ACW originate from construction materials and consist of carbonates, sulphates and silicates. In alkali melts, like caustic soda, these substances are dissolved easily.

Hence, asbestos fibres are released from the surrounding matrix and become susceptible to the chemical attack of the melt, which by adjusting the process temperature leads to full disintegration of the siliceous asbestos fibres, according to the following reactions:

$CaCO_3\ (s) + 2\ NaOH\ (l) \rightarrow Na_2CO_3\ (s) + Ca(OH)_2\ (s)$

$CaSO_4\ (s) + 2\ NaOH\ (l) \rightarrow Na_2SO_4\ (s) + Ca(OH)_2\ (s)$

$SiO_2\ (s) + 2\ NaOH\ (l) \rightarrow Na_2SiO_3\ (s) + H_2O\ (g)$

The melting point of caustic soda is 320 °C, enabling an operation of a mobile processing unit at moderate temperatures. The process generates low emissions due to absorption of gaseous compounds like CO_2 or SO_2 in the melt.

2 EXPERIMENTAL

A glove-box equipped with means to handle asbestos materials safely at lab-scale conditions was build.

The box provides a working compartment with a modified domestic microwave oven and two material locks with self-closing sliding doors, which separate the asbestos-contaminated working area from the laboratory environment.

The inner lock has a water shower to clean any material taken to the outside. Inside the working compartment a slightly reduced pressure is applied. An air cleaning unit prevents airborne fibres to be released. During experiments the composition of the exhaust gas is examined by a gas analyser (see Figure 2).

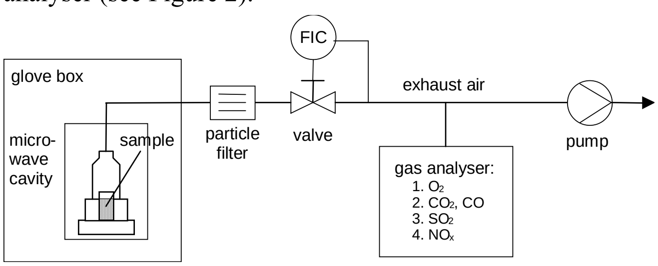


Figure 2: Experimental set-up of laboratory equipment.

Asbestos sample (typically 20 to 50 g) and caustic soda are filled into 100 ml quartz crucibles, which provide acceptable resistance to high temperatures and corrosion. The crucible is insulated by a microwave transparent material and covered by a glass hood. After microwave treatment the melt is cooled down and dissolved in water. After several washing steps the solid residues are further separated by sedimentation. The dried and sealed samples are analysed by SEM, EDX and XRD.

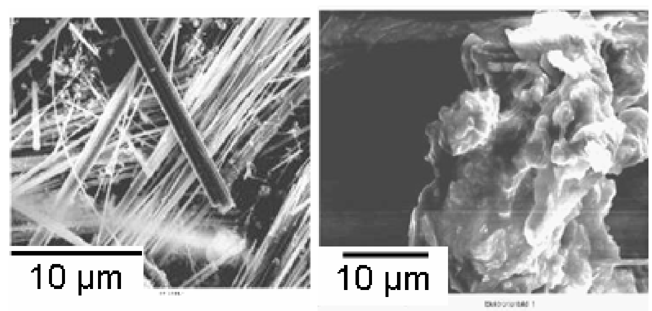
3 RESULTS

A minimum ratio of 3:1 of NaOH to ACM was found to be reasonable for treatment of ACW with different matrix materials like, e.g., gypsum, cement or lime. The process is easy to control. NaOH is melting under microwave radiation rapidly.

Because the NaOH-melt absorbs even more readily microwave energy than the solid NaOH, the microwave power level can be reduced to compensate heat losses and to keep the temperature constant as soon as a melt pool has formed. However, it is observed that microwave penetration into liquid caustic soda melt is limited to few centimetres.

After heat treatment the product is dissolved in water in order to separate the solid residues of the ACW from the caustic melt.

It is shown that caustic soda effectively destroys any asbestos fibres at either 450 °C/ 30 minutes or 400°C/ 45 minutes at lab-scale (Figure 3). The product consists chemically of the same elements like asbestos fibres, i.e. silicon, carbon, oxygen and different metals like Mg or Fe, but is free of sodium. As gaseous by-product mainly water vapour is released, with minor amounts of SO_2 or NO_x detected in the exhaust gas by IR-measurements. It is therefore assumed, that substantial amounts of CO_2 and other volatile oxides are directly absorbed or reacting in the caustic soda melt.



a) untreated b) treated

Figure 3: SEM analysis of sprayed asbestos coating a) untreated and b) treated in caustic soda melt, 45 min. at 400°C.

3.1 SCALE-UP

For scale-up of the process direct microwave heating of ACW collected on-site in steel drums is chosen. It suits well the demands of a robust on-site system, the steel drum serves as re-usable or one-way containment for collected ACW and as process vessel for the chemo-thermal treatment.

Microwave drum heating was tested with 70 and 200 litre drums on “artificial” ACW made from wet sand, rock wool, expanded perlite and a fibrous dummy material. As heat source a single 2.45 GHz, 2 kW magnetron was installed on top of the drum. The scale-up experiments demonstrate, that the microwave field is focussed along the axis of the drum, causing hot zones in the centre of the barrel. A more homogeneous microwave field distribution inside the drum was achieved by a triple arrangement of magnetrons (result of project partner Plazmatronika, Poland, see figure 4).

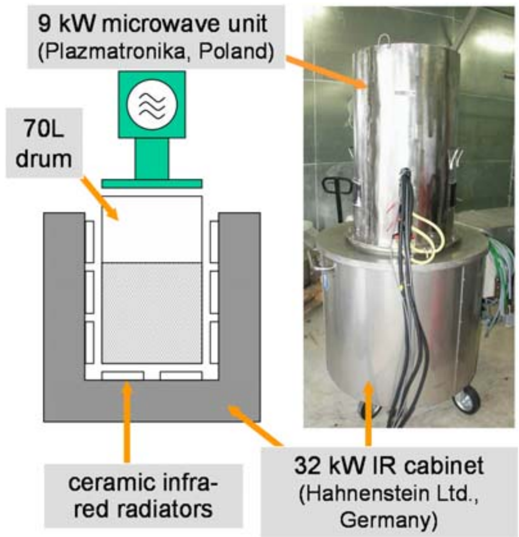


Figure 4: Design of mobile, hybrid-heated prototype unit.

The most important limitation when heating caustic soda by microwave absorption comes from the reduction of microwave penetration depth in the melt. Therefore, heat loss to the exterior has been compensated by application of infra-red radiators as additional heat source to provide hybrid heating. The pilot plant underwent tests for disintegration of ACW on a kilogram scale. The infra-red power is 32 kW, the microwave power is 9 kW.

3.2 PILOT PLANT TEST

The pilot plant test is performed at an experimental waste treatment area (see Figure 5).

Figure 5: Operation of prototype unit at experimental waste centre (CMS, France).

Several tests are carried out on sprayed asbestos coating (80-90% asbestos) and gypsum based plaster (10-15% asbestos). Both ACW typically contain a lot of moisture due to wetting procedures during removal. The volume of the drums is 70 litres. Because of the low density of sprayed asbestos the amount of ACW is limited to 6 kg plus 25 kg caustic soda, and 10 kg of gypsum plaster with 40 kg of caustic soda, respectively. The treatment takes 2-4 hours, to reach 450 - 500°C followed by a dwell time of 45 minutes. Afterwards the drums are removed from the heating station and cooled down. Both ACW yield a homogeneous product. As concluded from cross-checked analysis a complete destruction of asbestos fibres is achieved.

A comparative test with conventional heating only reveals significantly different results. Two different layers are formed during treatment in the drum: a red-coloured, porous upper layer, and a greyish-white layer with a dense crystalline structure at the bottom.

4. DISCUSSION AND CONCLUSION

Alkali melts are able to dissolve asbestos minerals efficiently into non-fibrous compounds, independently of matrix materials. The caustic soda process requires moderate temperatures in the range of 400 to 500°C. Apparently microwave radiation causes convection streams that keep the melt in movement, even if microwave penetration is significantly reduced during melt formation. The average process time at pilot scale is 3 hours. Post-processing, i.e. dissolution in water, solid-liquid separation and drying, is necessary to obtain an inert and disposable product. Phase analysis and optical microscopy in designated liquid media of the raw product and the solid residue show a complete destruction of asbestos fibres. The solid residue is sodium free, i.e. all of the caustic soda is removed by the water treatment of the product. The recovery and re-use of caustic soda is feasible, and operation costs could be reduced by 70% to 0.75 €/kg ACW. The pilot plant tests demonstrated the efficiency of the hybrid heating system to achieve homogeneous treatment. Based on the presented results the development of an industrial process could be designed like illustrated in Figure 10.

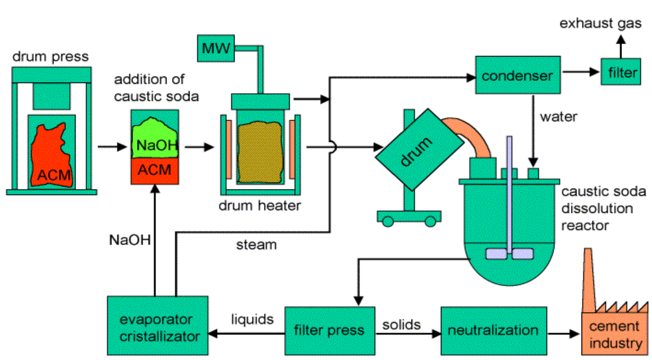


Figure 10: Development of mobile, industrial-scale process.

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