LANDFILLING OF WASTE INCINERATION RESIDUES BY STABILIZATION-SOLIDIFICATION

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REZUMAT. Incinerarea deşeurilor menajere se practică de mult timp, fiind una din principalele soluţii sustenabile a managementului integrat al deşeuriolor. Pe plan mondial, protecţia mediului înconjurător este din ce în ce mai severă ceea ce impune construirea unor incineratoare pentru deşeuri menajere cu emisii tot mai scăzute. În ultimele decenii s-au făcut eforturi semnificative pentru atingerea acestui obiectiv. În urma procesului de incinerare rezultă o cantitate semnificativă de zgură şi cenuşă precum şi reziduuri provenite de la staţia de tratare a gazelor de ardere. Cea mai mare parte a acestor reziduuri sunt depozitate în haldă. Depozitarea în haldă ridică problemele legate contaminarea pâzei de apă freatice prin fenomenul de levigare. Pentru rezolvarea acestor probleme există mai multe metode de gestionare a cenuşii cum ar fi sinterizare, vitrificare sau stabilizarea/solidificarea. Depozitarea în haldă a zgurii şi cenuşii provenite de la termocentralele pe cărbune trebuie să rezolve aceleaşi probleme legate de fenomenul de levigare. Pentru minimizarea fenomenului de levigare a acestor depozite a fost dezvoltată tehnologia şlamului dens ca metodă de stabilizare/solidificare a reziduului depozitat. Având în vedere acest aspect, lucrarea prezinta ca noutate posibilitatea de combinare a celor două tipuri de reziduuri prin aplicarea tehnologiei de şlam dens, în scopul creării unei noi metode de depozitare în haldă.

Cuvinte cheie: incinerarea reziduurilor menajere, stabilizare/solidificare, depozitare.

ABSTRACT. Municipal solid waste incineration (MSWI), following a long history, remains today the main suitable solution for waste management. Environmental issue is becoming more and more severe all over the world and result in a strong demand for environmentally friendly waste incineration plants. A large effort directed towards this goal has been devoted in the last few decades. As a result of the incineration process we need to handle the resulted residues as raw and fly ash, and flue gas treatment by-products. Most part of this kind of residues ends in landfilling disposal. One of the major problems arise from landfilling is the contamination of the ground waters with harmful substances that can be transmitted by leaching. To solve this problem there were developed alternative options for the management of fly ash, such as sintering, vitrification or stabilization/solidification. Landfill solid residues disposal of fired coal power plants have to deal with the same risks regarding the leaching. Suitable solution to minimize disposal leaching was developed, and presently the dense slurry technology was developed as a stabilization/solidification technology. Based on this aspect, it would be possible to combine these two types of residues with dense slurry technology, to create new type of landfilling methodology.

Keywords: waste incineration residues, stabilization/solidification, landfilling.

1. INTRODUCTION

Presently, in Romania, a huge part of the municipal solid waste (MSW) ends in landfilling disposal that are conceived as open or even with ecologic concept. Waste itself, and its management, are themselves a significant environmental issue. The thermal treatment of waste may therefore be seen as a response to the environmental threats posed by poorly or unmanaged waste streams [1].

Target of waste incineration is to provide for an overall reduction in the environmental impact that might otherwise arise from the waste. Depending on the composition of the material incinerated and on the operating conditions, smaller amounts of CO, HCl, HF, HBr, HI, NO_x, SO_2, VOCs, PCDD/F, PCBs and heavy metal compounds (among others) are formed or remain. These substances are transferred from the input waste to both the flue-gas and the fly ash it contains. In municipal waste incinerators, bottom ash is approximately 10 % by volume and approximately 20 to 30 % by weight of the solid waste input. Fly ash quantities are much lower, generally only a few per cent of input [1].

Most quantity of municipal waste incineration (MSWI) residues is ending in landfill disposals, which are connected with environmental pollution through leaching phenomenon.

Regarding the environmental issues caused by landfilling of huge amounts of solid residues from coal combustion, a dense slurry technology (DST) was developed. DST presumes to create a homogenous mixture between the solid residues and water in a controlled environment with the aim to activate the cementing reactions of the elements containing in the coal ash. The final product of the process is the “ash rock” that modifies the pattern of the landfilled material which leads to minimize the leaching phenomenon through final disposal [2].

Implementing DST towards the MSWI residues is consequently of great interest in the context of new and environmentally friendly using the pozzolanic activity of the fly ash as a binder with properties to improve the characteristics of conventional landfilling disposals. Thus the environmental pollution is avoided and the risk of contamination is reduced.

2. LANDFILLING BY STABILIZATION-SOLIDIFICATION

2.1. Landfilling disposal goal

One objective of landfilling of waste, including MSWI residues, is to remove from general circulation materials and products that are no longer useful in any respect. It is preferable to do this in a manner that ultimately returns the basic constituents of the waste to the ecological cycle, possibly after they have undergone chemical and/or physical reactions and transformations.

A second and equally important objective of waste disposal is to ensure that the waste does not cause any unacceptable short- or long-term impact on the environment or on human health. Disposal methods must ensure that this is accomplished in a sustainable manner, i.e. without excessive and/or prolonged maintenance or operation requirements and without a prolonged need for aftercare [1, 3].

Yet, the major environmental concerns in relation to the short-and long-term impact of landfilling of MSWI residues are connected with the risk of leaching and subsequent release of potentially harmful substances, particularly inorganic salts and metals/trace elements, into the environment.

As incineration residues are produced by high-temperature processes, they are thermodynamically unstable under ambient conditions. This renders incineration residues highly reactive, especially under wet conditions. This means that they change their mineralogical and physico-chemical characteristics as well as their leaching behavior as long as thermodynamic equilibrium conditions with the surrounding environment are attained. The specific environmental conditions influence and change the leaching behavior and contaminant release from such materials during utilization or final land disposal. To assess the discharge behavior of a specific waste, it is necessary to take the specific conditions (scenarios) into account. To arrive at a conclusion, the following methodology should be applied (ENV 12920):

– formulate the task and the sought-after solution,
– specify the scenario,
– evaluate the waste characteristics,
– determine the influence of the scenario conditions on the variation of waste characteristics over time, as well as on their environmental behavior
– model the environmental behavior of the waste
– validate the model by calibration with the results from laboratory tests and field experiments and by comparing it to natural analogues.

Such a methodology will also help identify the most appropriate mitigating measures to be undertaken before, during or after utilization or final land disposal.

The EU Landfill Directive (LFD) distinguishes technically between three main classes of landfills (landfills for inert waste, landfills for non-hazardous waste and landfills for hazardous waste), but only in terms of the contamination potential of the waste and the environmental protection measures required at each class of landfill. The LFD does not include any landfill strategy or guideline on the design and operation of landfills aiming at the minimization of the period during which active aftercare will be necessary [1, 3].

2.2. Leaching production

The potential environmental impact of leaching includes contamination of soil, groundwater and surface water bodies. Leaching can be defined as the dissolution of a soluble constituent from a solid phase into a solvent. Leaching occurs as a consequence of the chemical reactions taking place at the scale of the individual waste particles as well as of the contaminant transport processes via the fluid moving through the solid particles.

As far as MSWI residues disposal is concerned (see Fig. 1), the transport medium of pollutants is mainly represented by water, so that the overall water balance will determine the actual amount of water reaching the application site.

The application site itself then modifies the water infiltration pattern as a result of the physical and hydrological characteristics of the material. Thus, the discharge pattern also depends on the pore type, pore distribution, homogeneity, permeability and field capacity of the material as well as on the presence of preferential flow paths.

Water balance models can also be used to analyze the effect of different vegetation/covering scenarios on leachate generation.

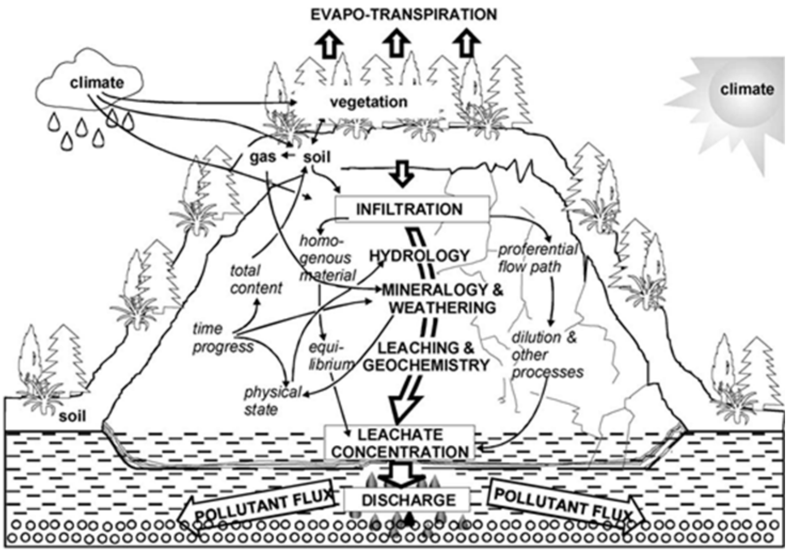

Fig.1. Schematic layout of leaching production on a landfill disposal [3].

Together vegetation and physical barriers (top cover, liners) reduce the amount of leachate from the landfill but cannot completely prevent leachate formation over a long time scale. Some physical factors also affect the percolation pattern (advection, diffusion) and hence the modes of contact between leachate and waste, which can be caused by leachate flowing around the waste, leachate flowing through the waste or by a combination of the two [3]. Dense slurry technology is meant to reduce the leachate flowing through landfill disposal materials, and is reducing the aftercare period of the disposal. By cementing process that end with the formation of the ash rock, the dust emissions of the disposal are eliminated.

2.3. Solidification through dense slurry technology

The core of DST is the hydraulic mixing device, where takes place the intense mixing of the solid residues and water. Basically the mixing device consists of vessel and two recirculating pumps. An industrial mixing device is depicted in Figure 2.

Mixing process it develops in three phase as follow:

– in first phase take place the formation of the two phase mixture, between solid residues and water on the mixing head;

– on second phase the formed mixture is over mixed in the mixing tank, where the homogenizations occurs;

– the third phase takes place on the recirculating pumps, where is considered that the chemical reactions are kick started.

The most important phase is the third one where the pozzolanic elements contained in the fly ash are activated. The mineral structure of the fly ash is crushed by centrifugal driven force inducted by the impeller of the pump, and the water penetrates the mineral structure of fly ash and so the chemical reactions of cementing are activated.

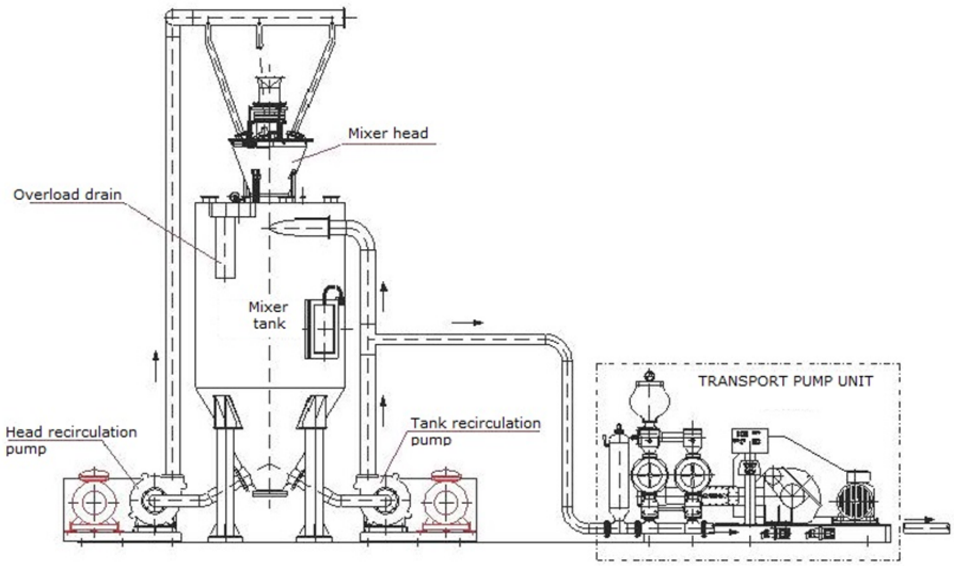

Fig. 2. Industrial hydraulic mixer [2].

For a proper functionality of the hydraulic mixer, it is necessary to maintain the mixture on continuously recirculation speed, otherwise the clogging occurs. The recirculation speed is influenced by the mixing ratio between solids particle and water, size of the particle and viscosity of the new formed fluid.

When high percentages of fined-sized solid particles (of less than 100 μm) are mixed with water, they usually form slurries, which do not behave like Newtonian fluids and in which the solids usually do not settle. There are various types of non-Newtonian fluids but in our case we deal only with a group known as Bingham fluids. A Bingham fluid could be described as a Newtonian fluid with an additional parameter, namely yield stress τ0. This material behaves like a jelly when stationary and like a fluid when moving [4].

3. RESULTS AND DISCUSSIONS

Cementing reactions of coal fly ash are developing upon the pozzolanic activity of siliceous and aluminous compounds. Flue gas treatment plant residues are calcium based (lime) products that reacts with pozzolanic compounds and develops different types of lime bearing phase like calcium silicate, calcium aluminate, calcium aluminosilicate that are subsequently hydrated in the presence of water from different hydrates. These hydrates are responsible for development of strength in ash rock as new created compound [5].

The cementing reactions develop in DST are strong influenced by:

– intense mixing of the solid residues with a closer quantity of water to solid mass, which dissolving the calcium (CaO) and magnesium (MgO) oxides. The resulted solution partially enables the surface of the ash particles.

– the calcium hydroxide (CaOH) that has been formed is reacting with the minerals dissolved in slurry, and with the silicate dioxide (SiO2) and aluminum oxide (Al_2O_3) having as a result the formation of the calcium hydrates and/or calcium aluminate known in the cementing process.

– the presence of the reducing substances as sulfates and sulphurs enable a lower value of the pH and the massive precipitation of calcium carbonate resulting the calcium and aluminum sulphate which is participate also to the cementing reaction of the dense slurry.

The main chemical reactions characteristic for cementing chemical process are [6]:

– generation of calcium and sulfate ions (fast reactions):

$$CaO + H_2O \rightarrow Ca(OH)_2 \quad (1)$$

$$Ca^{2+} + SO_4^{2-} + 2H_2O \leftrightarrow CaSO_4 \cdot 2H_2O_{(s)} \quad (2)$$

– ash rock formation (at the beginning is a fast reaction):

$$\begin{aligned} &6Ca^{2+} + 3SO_4^{2-} + 2Al(OH)_3 + 31H_2O \leftrightarrow \\ &\leftrightarrow 3CaO \cdot 3CaSO_4 \cdot Al_2O_3 \cdot 31H_2O_{(s)} + 6H^+ \end{aligned} \quad (3)$$

– formation of calcium silicate hydrates (slow reaction):

$$\begin{aligned} &xCa^{2+} + 2xOH^- + SiO_2 + nH_2O \rightarrow \\ &\rightarrow Ca_xSiO_{2+x} \cdot (n+x)H_2O_{(s)} \end{aligned} \quad (4)$$

On cementing process arise new undissolved minerals compounds. New formed mineral crystals are gradually deposited by joining to others particles in the slurry mass encompassing them. In landfilling deposit, the new formed compounds are solidified by cementation reactions, and so are created the “ash rock” that encapsulates the undisolved elements in slurry [2].

4. CONCLUSIONS

Landfilling of the MSWI solids residues still remains and issue to be solved for the future. Integration of these residues into dense slurry technology can be seen as a future possibility came to minimize the leaching of landfill deposits.

Dense slurry technology has proven its efficiency as environmental friendly; therefore it was implemented in several fired coal power plants worldwide. Considering that most of coal power plants are in proximity of big urban settlements, so the quantities of the municipal solid waste are in large quantities.

From the environmentally point of view of the landfilling disposal for the solid waste incinerations residues it can be seen like a future solution the possibility to integrate them into dense slurry technology that is used for the treatment fired coal incineration solid residues.

The idea of encapsulations of MSWI solids residues into ash rock can be seen as a real possibility to develop for the future.

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