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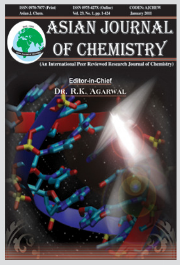

Heavy Metal Analysis and Stabilization of Medical Waste Incineration Ash

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Incineration processes are widely used for the treatment of medical wastes all over the world. In Turkey, there are several incineration plants for medical wastes in some big cities. In Istanbul, there is an incineration plant that treats 13,000 tons of medical wastes annually. Incineration of medical waste itself is not enough to remove all the contaminants. From the literatural review, it is clear that sometimes the remaining ash may still contain genotoxic threats as well as metals and heavy metal elements. The presence of these heavy metals has been examined in the bottom ash of the medical waste incineration plant in Istanbul. The aim of this research is to reduce the toxic effects of the remaining heavy metal contamination from the bottom ash by a stabilization process. Perlite, zeolite and bentonite were used as the stabilizing material. Different concentrations were tested. Perlite was not successful for most of the elements. On the other hand, zeolite and bentonite gave quite good solutions for most of the heavy metal removals. The optimum concentration was found after a series of tests, in order to decrease or remove the heavy metal contamination.

Key Words: Medical waste, Bottom ash, Leachate, Heavy metal analysis, Stabilization.

INTRODUCTION

As the population increases all over the world, the amount of the waste also increases tremendously, heightening the need for ideal management in order to overcome the adverse effects of the pollution caused by any type of waste. Not only the municipal wastes, but also the treatment of industrial, hazardous and medical wastes needs far more care and investigation. There are several methods for waste treatment. One of the most used treatment methods for medical wastes is the incineration process[1]. In Turkey there are several incineration plants, most of them are used for medical waste treatment. Istanbul is one the pioneer cities that has a good waste management system in Turkey.

For all types of wastes produced by health care facilities such as general hospitals, medical centers, medical laboratories or animal hospitals, the term "medical wastes" is used instead of the term "hospital wastes". Infectious wastes have been described as "biohazardous," "health-services hazardous," "pathological," "biological" and "hazardous infectious"[2].

The laws and regulations emphasize the principles of treatment in detail for every type of solid waste in Turkey[3]. According to the regulation (Number: R.G.25883, Date: 22.07.2005) on waste management, the municipalities should take care of all types of wastes. Istanbul Metropolitan Municipality has a special Enterprise Company for waste management, called ISTAC and medical wastes from all types of hospitals, clinics, medical institutes, laboratories, *etc*., are collected by them[4].

There are two modern sanitary landfill sites, one medical waste incineration plant, one compost plant, two electricity generation plants from landfill gas, one RDF plant, *etc.*[5]. As the medical wastes are pathologically contaminated, they have the risk of infection, for that reason special care should be taken. Annually 13,000 tons of medical wastes are collected in Istanbul from 230 medical institutions (39,000 beds in total) with 20 specially-equipped and licensed trucks and brought to the incineration plant[6].

The incineration plant is based next to the modern sanitary landfill site, at the suburban site of Istanbul which is called as Kemerburgaz, Odayeri Province. From the incineration process, ash is generated. The bottom ash from the primary incineration stage and the fly ash from the secondary incineration process are collected and deposited in the special lots in Kemerburgaz Landfill Site after treating them with lime and active carbon. As it is a sanitary landfill site, it has the impermeable layer with mineral barrier (clay layer) and synthetic liner (HDPE-geomembrane) sheet[7]. Besides this, these special lots, which have special, thickened, impermeable layers, are only for depositing the incineration ash and no other wastes are deposited on them.

In this study, the bottom ash generated at Kemerburgaz Incineration Plant, which is located in Kemerburgaz-Istanbul, is used. Although incineration is one of the most effective refuse-disposal methods for achieving 70 % reduction in mass, the amount of residue remaining to be disposed of after incineration is substantial. More than 90 % (by mass) of incinerator residue consists of bottom ash, the slag-like material which is dumped from the grate after combustion[8]. On the other hand, heavy metal contamination still remains in the ash, even though the pathogenic contamination is eliminated.

About 6 tons of bottom ash is produced daily in this plant[7]. The characteristics of the ash may change according to the incineration time and process. If the characteristics of the ash can be defined properly, the stabilization process might be more effective.

The bottom ash samples are randomly collected and transported to Fatih University Main Campus and analyzed in the laboratories of the Department of Environmental Engineering. As the stabilizer materials, perlite, zeolite and bentonite are used and distilled water is used as the leaching solution. Each of the stabilizer materials is applied to the medical waste incineration bottom ash with different concentrations and the effects of them are monitored for each case.

The metal and heavy metal contamination is checked with this research, by investigating the following elements; Cd, Co, Cr, Cu, Fe, Mn, Ni and Pb. The metal and heavy metal analysis are conducted by forming leachate from the bottom ash. After the analysis, suitable additives for stabilization to decrease the toxic effects of the heavy metals within the leachate are tested.

Fig. 1. Experiment device prepared in the laboratory according to ASTM D 4874-95

EXPERIMENTAL

The aim of this study is to detect the heavy metal pollution by analyzing the bottom ash of medical waste incineration plants. The stabilization study is also conducted on the analyzed ash in order to prevent the pollution. After the stabilization, the possibility of using this bottom ash for different purposes is also discussed.

As a first step of the study, the medical waste incineration ash is converted to liquid (leachate). This is done according to the standard method ASTM D4874-95, "standard test method for leaching solid waste in a column apparatus"[9]. Leachate is the liquid that contains most of the diluted and suspended components of the solid waste (ash). In the sanitary landfill site, leachate is first formed by the microbial activities of the solid waste and then, precipitation and storm water increases the amount of leachate when they percolate into the layers of the landfill site. In this study, this phenomena is modeled in the laboratory by using the most used apparatus; ASTM D 4874-95 as shown in Fig. 1. The peristaltic pump that is connected to the column has a capacity of 80 RPM pressure.

A leak proof cell/column is constructed (Fig. 2) and filled with "medical waste incineration bottom ash" and the pump is connected to this column. Distilled water is used as the experiment solution by pumping to the column with the help of the peristaltic pump in order to form leachate during the experiment. This process is very close to the system employed in the nature[10]. The most important parameter in this system is time. Pressure is used to fasten the process.

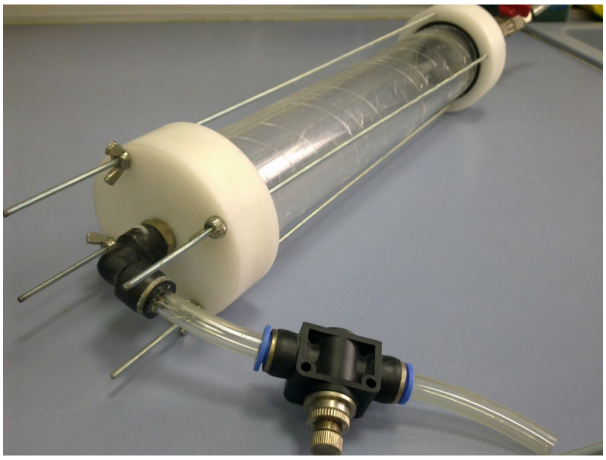


Fig. 2. Leachate column

After obtaining the leachate from the bottom ash in the laboratory, the analysis of the ash is started by using the obtained leachate, in the sense of metal and heavy metal contamination. According to the contamination level, a stabilization study will be conducted by first deciding the best material with the best concentration for it. The effects of different stabilizing materials, such as perlite, zeolite and bentonite, are tested, as well as the amount. The amount of the material mixed with the ash (concentration) effects the stabilization, solidification or purification process.

The analyses are conducted in the laboratory of the Department of Environmental Engineering, Fatih University by using the GFAAS device modeled "Varian FS230 Graphite Furnace Atomic Absorption Spectrophotometer" and the following parameters are measured with an acetylene/air flame in the absorption spectrophotometer device; cadmium, cobalt, chrome, copper, ferrous, manganese, nickel and lead (Cd, Co, Cr, Cu, Fe, Mn, Ni and Pb). Calibration is held at least three times for each element with standard solution.

The ash is mixed with different stabilization materials such as perlite, zeolite and bentonite. The same experimental process is performed again to figure out the changes in the concentration level of the elements. The stabilization materials are mixed with the ash in different ratios. Each experiment is recorded to find the best formula.

During the 1970s, natural zeolite was shown to preferentially remove heavy metals such as Sr and Cs from wastewater and this property made zeolite and similar additives (such as perlite and bentonite) the preferred adsorbents for wastewater treatment systems.

Zeolites are promising additives that stabilize wastes to ashes with their advantageous features: They have a high level of ion exchange capacity. They have absorptive properties. They have a porous structure. They act as molecular sieves, promoting dehydration. They have rehydration capabilities and a low density. They contain silica compounds.

The major advantages of the use of zeolites are their low prices and the fact that there are widespread deposits of them all over the world. So, for many reasons, additives like zeolite, perlite and bentonite are promising, especially for the removal of heavy metals and to control the leachate in the incineration ash.

RESULTS AND DISCUSSION

First of all, a leachate column was filled with pure ash and a leaching solution was applied to the column with the help of a pump. Distilled water was used as the liquid leaching solution and the leachate was generated. This sample was called a K (ash) sample. Later on, stabilizing material and ash were mixed using different ratios and tested. Perlite, zeolite and bentonite were used as the stabilizing material.

Stabilization is the permanent physical and chemical alteration of ash to enhance its physical properties. Stabilization can increase the shear strength of the ash and/or control the shrink-swell properties. Stabilization can be achieved with a variety of chemical additives including lime, fly ash, portland cement, perlite, zeolite and bentonite. Proper design and testing is an important component of any stabilization project. This allows for the establishment of design criteria as well as the determination of the proper chemical additive and admixture rate to be used to achieve the desired engineering properties.

Stabilization alters hazardous wastes to more physically and chemically stable forms, resulting in better environmental acceptance. Physical stabilization refers to the process of solidification and improves engineering properties, such as bearing capacity, trafficability and permeability of stabilized waste forms. Chemical stabilization is the alteration of the contaminants' chemical form so that leachability is eliminated or substantially reduced[11].

Stabilized MSW fly ash mixtures can be practically applied to road embankments and/or river dikes with cover soil in order to avoid the need for additional leachate from MSW mixtures[12].

Firstly, perlite was used as the stabilizing material. The particle size analysis was done using the standard sieves (Fig. 3). Different mixture rates (concentrations) of ash and perlite were tested for stabilization (PL1, PL2, PL3 samples). Metal and heavy metal contamination, monitored by the GFAAS for these samples, are shown in Table-1.

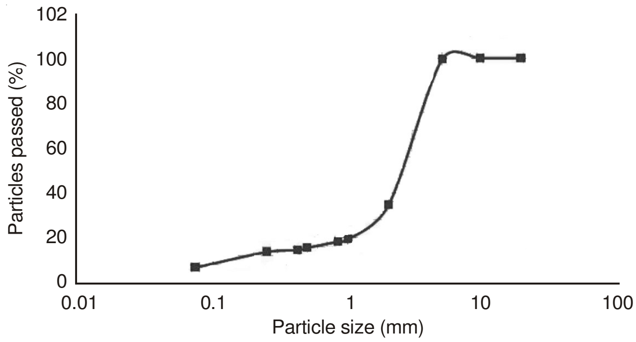


Fig. 3. Particle size analysis of perlite

In Table-1, the K (ash) results and PL1 results should be compared firstly. PL1 means the first leachate generated by ash and perlite. With perlite stabilization, copper remediation was done perfectly. The remediation for iron, manganese, nickel and lead was minor and for some other elements, there was almost no remediation. The contamination and remediation results for each element have been plotted on the graphs and shown in Fig. 4. The graph in Fig. 4 shows the result for each parameter from pure ash to different concentrations of the stabilizing material.

As the perlite did not provide a satisfactory solution for all elements, a new stabilizing material, zeolite, was tested. The particle-size analysis of the zeolite is shown in Fig. 5. Different mixture rates of ash and zeolite was tested for stabilization. The mixture rates of 5, 9, 17 and 23 % of zeolite mixtures were tested.

The results of the measured metal and heavy metal contents are shown in Table-2. When they are plotted to graphs, the total results can be seen in Fig. 6. Compared to perlite, zeolite provided good results for remediation. Specifically, a

TABLE-1
RESULTS OF THE HEAVY METAL REMOVAL FOR THE ASH TREATED WITH PERLITE

mg/kg	Conc. (%)*	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb
K (Ash)	0	0.21	0.91	0.16	1.55	1.61	0.56	0.79	1.65
PL1	10	0.22	0.91	1.10	0.23	1.53	0.21	0.74	1.57
PL2	17	0.24	0.96	0.95	0.33	1.28	0.26	0.78	1.32
PL3	20	0.25	1.04	0.84	0.24	1.39	0.27	0.88	1.56

*Concentration: The amount (%) of stabilizing material added to the ash.

TABLE-2.
RESULTS OF THE HEAVY METAL REMOVAL FOR THE ASH TREATED WITH ZEOLITE

mg/kg	Conc. (%)*	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb
K (Ash)	0	0.21	0.91	0.16	1.55	1.61	0.56	0.79	1.65
Z1	5	0.15	0.88	0.17	2.17	1.22	0.21	0.96	1.69
Z2	9	0.16	0.85	0.16	3.45	1.07	0.20	0.96	0.99
Z3	17	0.13	0.60	0.14	0.52	0.95	0.18	0.47	0.54
Z4	23	0.11	0.48	0.15	0.30	0.64	0.19	0.43	0.67

*Concentration: The amount (%) of stabilizing material added to the ash.

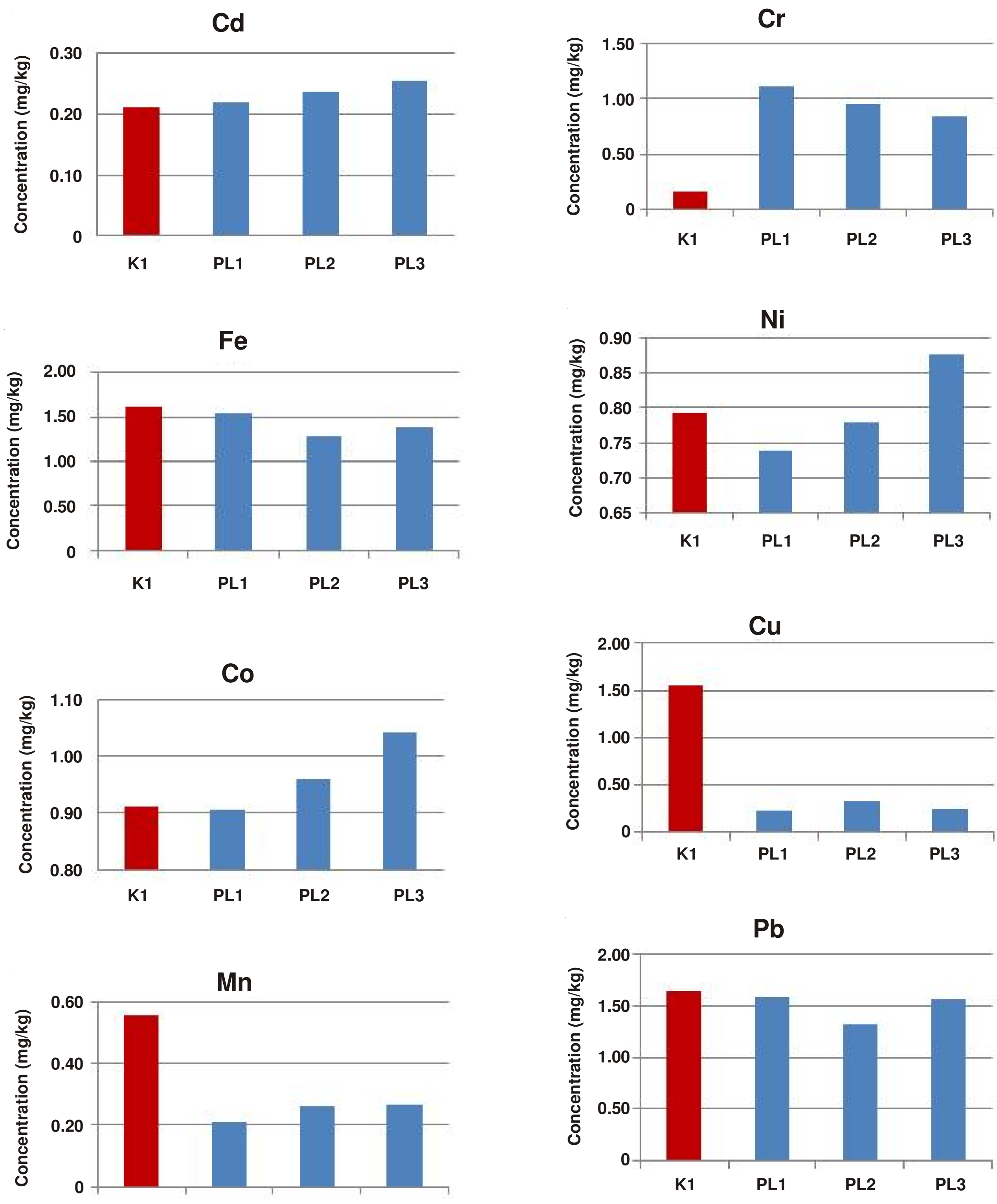


Fig. 4. Results of the heavy metal removal with perlite

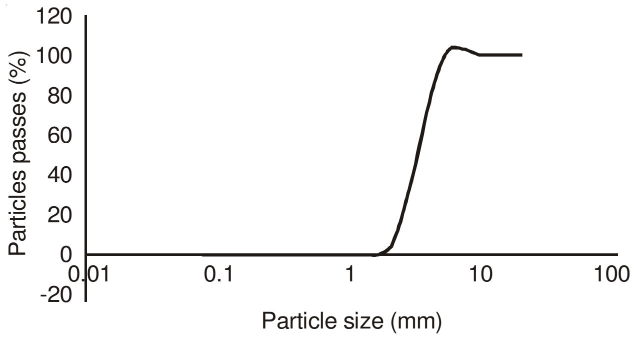
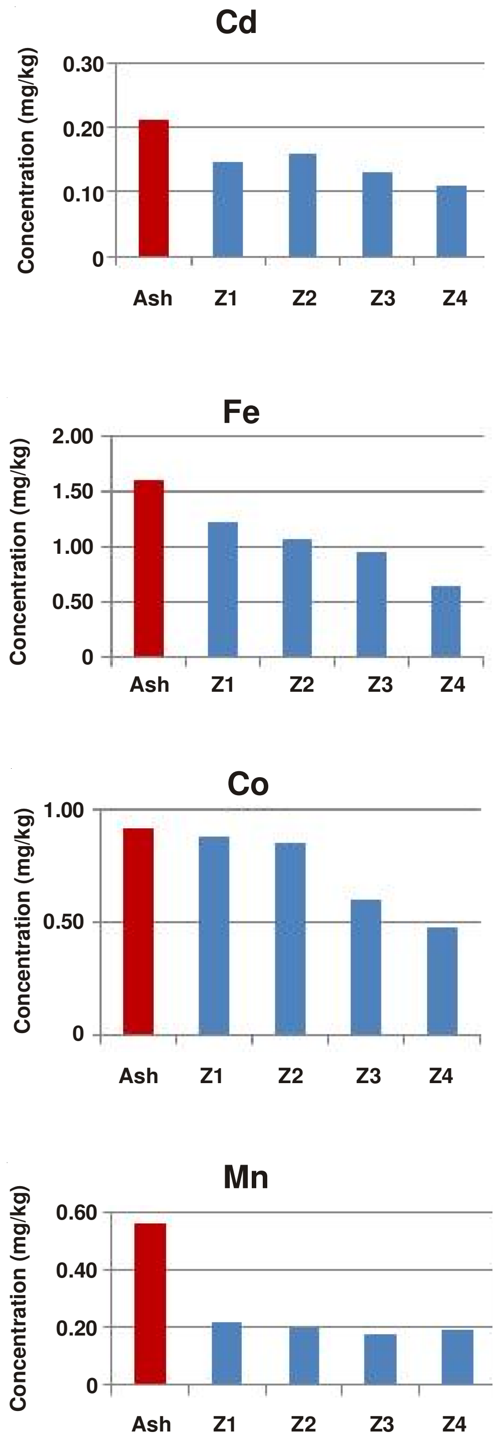


Fig. 5. Particle size analysis of zeolite



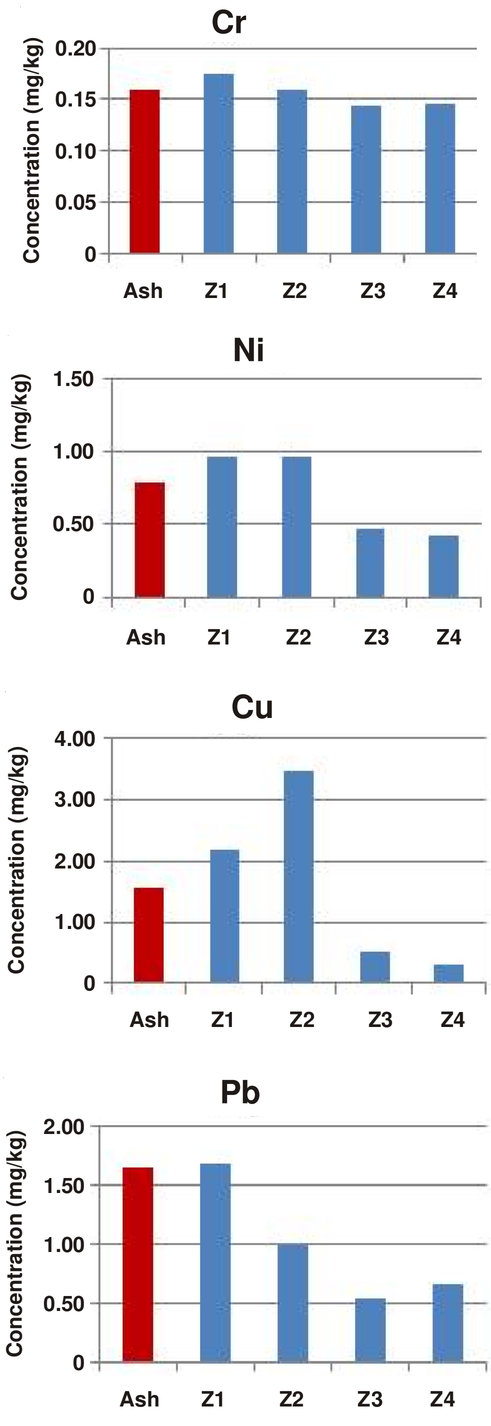


Fig. 6. Results of the heavy metal removal with zeolite

17 % ratio mixture produced good results for cadmium, chrome, manganese and lead. However, 23 % of the mixture could remediate cobalt, iron, nickel and copper.

A new stabilizing material, bentonite, was also tested for the same incineration ash. The particle-size analysis of bentonite is shown in Fig. 7. The same procedure was repeated for the bentonite which was added to medical waste bottom ash. The results of the leachate of this new product are shown in Table-3. Bentonite also created a good stabilization solution, as shown in Fig. 8.

In this research, an experimental device was designed according to EPA standards and constructed. The system showed

TABLE-3
RESULTS OF THE HEAVY METAL REMOVAL FOR THE ASH TREATED WITH BENTONITE

mg/kg	Conc. (%)*	Cd	Co	Cr	Cu	Fe	Mn	Ni	Pb
K (Ash)	0	0.21	0.91	0.16	1.55	1.61	0.56	0.79	1.65
BN1	15	0.12	0.38	0.07	0.09	0.38	0.47	0.39	1.14
BN2	20	0.05	0.14	0.06	0.07	0.13	0.31	0.15	0.48
BN3	25	0.03	0.07	0.04	0.05	0.06	0.26	0.09	0.36
BN4	30	0.01	0.01	0.01	0.03	0.01	0.13	0.01	0.11

*Concentration: The amount (%) of stabilizing material added to the ash.

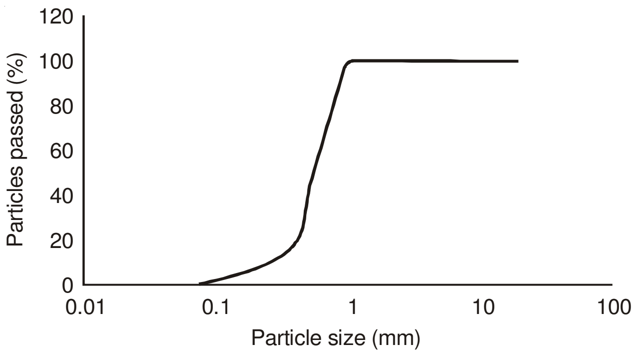
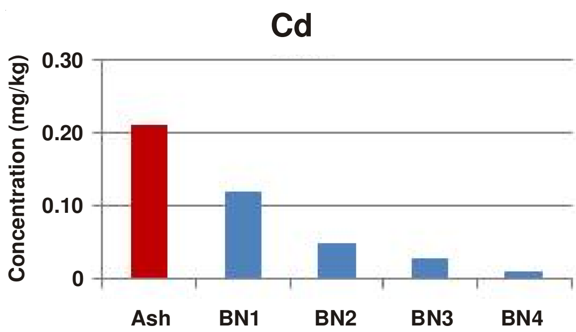
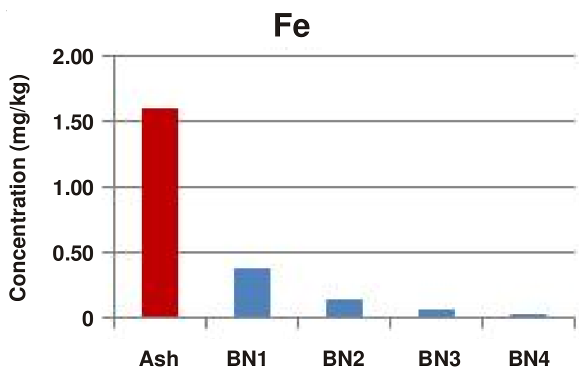
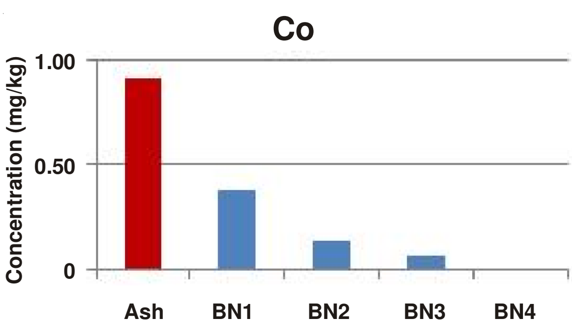
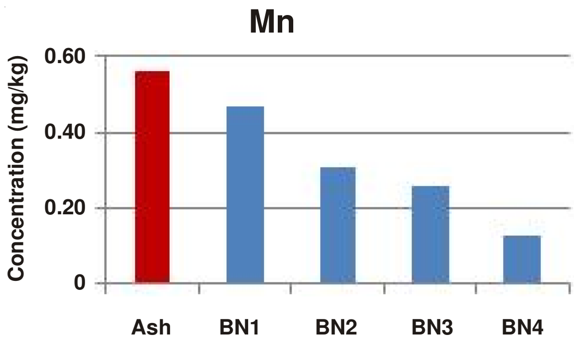


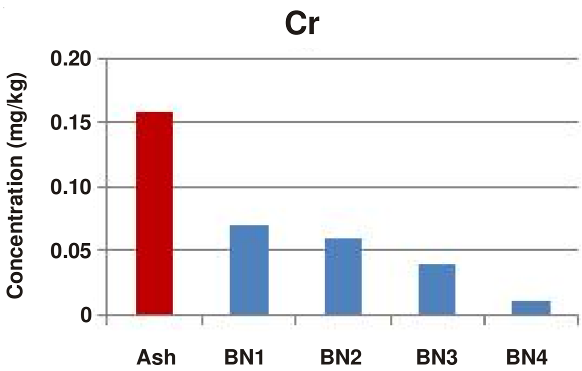
Fig. 7. Particle size analysis of bentonite

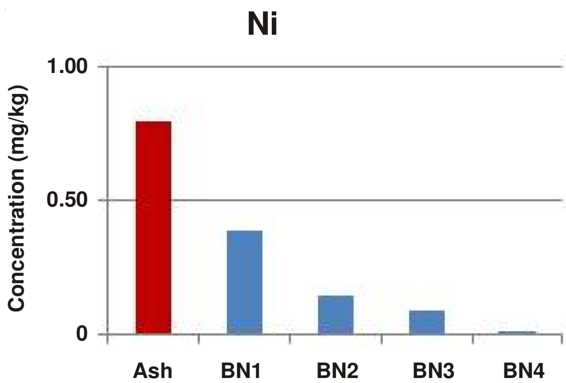


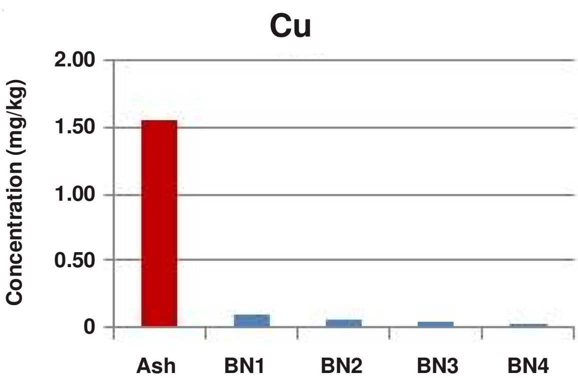












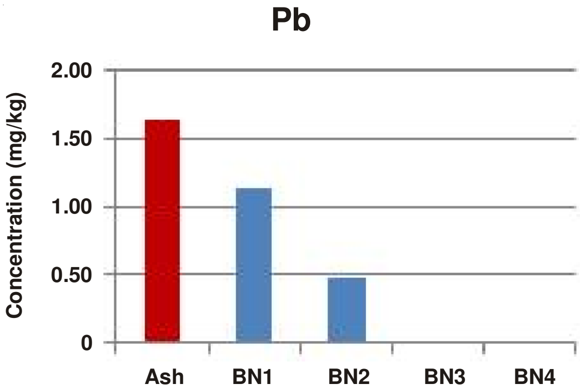


Fig. 8. Results of the heavy metal removal with bentonite

great flexibility in adapting to different operating conditions, allowing the study of the influence of different variables with the aim of residual ash treatment. To deal with the wastes and especially hazardous ones, it is very important to find a permanent solution so that the waste will not cause any health threats in the future to the public and the environment. Finding a solution to reduce the amount, volume and cost of these wastes has also become a great challenge of waste management. Even small amounts of waste still cause problems, in part because the amount of waste generated in Istanbul is always increasing and for that reason, new spaces for landfill area are needed. The lack of space and the increasing cost of the land in Istanbul could make it almost impossible to find a place for the direct deposit of wastes in the near future. For this reason, pre-treatment, treatment and alternative treatment techniques will become very important. On the other hand, many new facilities will be constructed in Turkey in the near future. This kind of research can be a good guide for the new plans and investments.

By incinerating the medical wastes, volume reduction is also achieved. However, even with a small amount, the waste still exists as ash. This ash may contain many toxins, including metal and heavy metal contaminants. When they are deposited in the land without pre-treatment, the threat to nature and the public health still remains. Although an impermeable sheet and clay barrier exists at the landfill site, the contamination may accidentally spread to nature and may reach the surface or ground water. For that reason, the ash should not be deposited directly into the ground. This can only be achieved by finding new areas for ash to be used.

The stabilization studies showed that perlite is a good stabilizer for copper. If there is a specific intent to reduce only the copper contamination, perlite can be used. However, for iron, manganese, nickel and lead, the stabilization effect is very little and for the resting elements, there is almost no effect. For that reason, zeolite and bentonite were tested as new stabilization materials. After the analysis was completed, it was understood that both provide good stabilization effects for almost all of the elements.

It is a fact that zeolite and bentonite are effective for removing many metal and heavy metal elements from the ash. Although more research is needed to make this stabilizer a marketable product, at least the wastes can be mixed with zeolite or bentonite before depositing them into the ground. This simple process will be a great support to and have a beneficial impact on nature. It seems that the most effective ratio for zeolite is between 17 and 23 %. For bentonite, any ratio above 20 % produces quite a good stabilization effect on the ash for the removal of metal and heavy metal contamination. Perlite, however, can only be used for copper removal. If the stabilization process using these materials can be executed with exact ratios, the ash could be safely used as construction or fill material for road repair and construction. With application methods such as these, the ash will not need to continue to be deposited in landfill areas. Furthermore, if the contamination is reduced or removed, special precautions will no longer need to be taken, resulting in a great reduction in waste volume and associated costs for waste management.

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