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Medical Waste Incineration Ash Waste: Impact on Environmental Health and Its Potential to be Used for Paving Blocks

Siti Rachmawati [1,4], Syafrudin[1,2]✉, Budiyono[1,3]
[1]Department of Doctoral Environmental Science, Faculty of Postgraduate, Diponegoro University, Indonesia
[2]Department of Environmental Engineering, Faculty of Engineering, Universitas Diponegoro, Indonesia
[3]Department of Chemical Engineering, Faculty of Engineering, Universitas Diponegoro, Indonesia
[4]Department of Environmental Science, Faculty of Mathematics and Natural Science, Universitas Sebelas Maret, Indonesia

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Abstract

Medical waste has increased in recent years due to the COVID-19 pandemic, followed by the ash from burning medical waste processing using incinerators. The objective of this study is to determine the impact of using medical waste incineration ashes on health and the environment, as well as the potential for using solidification techniques to make the ash into paving blocks. The research took time from 2022 to March 2023. The ash was obtained from a medical waste processing facility in Surakarta, Indonesia's Central Java. The test object was created using seven combinations of ash, sand, and cement with a water-cement ratio of 0.5 and cured for 28 days. The optimum compressive strength condition was determined as the basis for the composition of medical waste incineration ash as a mixture of paving block raw materials, which was then tested for the content of heavy metal compounds using the SNI 8808: 2019 method. According to research, the ash from medical waste incineration contains heavy metal compounds such as Pb, Ni, Cu, and Cd and potentially be used as a mortar mixture. Six of the seven mortar compositions, with the addition of incineration medical waste ash, met the compressive strength requirements of SNI 03-0691-1996 for category D paving blocks to be used in parks and other places.

Introduction

Bottom ash is waste from the incineration of medical waste, which will continue to increase in quantity during the COVID-19 virus pandemic. The rate of spread of the COVID-19 virus has led to an increase in the number of patients in several areas. Medical waste has been increasing in the last three years. The WHO (2020), then declared it a pandemic on March 11, 2020 (Morfi, 2020). Medical waste is generated from activities related to health care (hospitals, health centers, clinics, and clinical laboratories). Personal protective equipment (masks, aprons, medical gloves), syringes, ampoules, expired medicines, contaminated body fluids, infusion tubes, and other items (Rahman et al., 2020).

Several hospitals with types A, B, and C are known to have not implemented B3 waste management efforts properly (Damayanty et al., 2022), and besides that, several elementary schools also did not provide efforts to manage consumable mask waste during the pandemic (Widowati et al., 2022). Medical waste is waste that contains heavy metals and dioxins so that it has the impact of contaminating soil and water and is detrimental to health if heavy metals reach the food chain and have the potential as a medium for disease transportation (Dehghanifard & Dehghani, 2018; USEPA 1996). Incineration is a waste treatment method widely used by hospitals, one of which is in Indonesia. Medical waste is included in the category of hazardous and toxic waste handled

✉ Correspondence Address:
Department of Doctoral Environmental Science, Faculty of Postgraduate, Diponegoro University, Indonesia
Email: udin_syaf@yahoo.com

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following applicable Government Regulations, as well as the treatment of the ash produced. Bottom ash, which contains heavy metal compounds, is the primary material produced in the incineration process (Filipponi et al., 2003). Gidarakos et al., (2009) explained that the resulting ash waste is treated according to regulations. Good and correct management of ash can reduce the potential for environmental pollution.

Several studies have used medical incinerator ash, both bottom ash and fly ash, as an engineering material where the addition of 15-25% ash produces concrete strength (Mehvish Bilal, et al., 2022), as a raw material for geopolymer (Tzanakos et al., 2014), building construction materials as fine aggregate (Md Anamul et al., 2012), as a substitute for the solidification technique is one that used to process incineration residue to make the chemical compound content more balance and to prevent heavy metal leaching (Jorge Mendoza et al, 2017). Utilization of ash from incineration medical waste needs to be carried out with the requirement of passing a predetermined quality standard test to reduce environmental pollution (Rachmawati et al., 2022). This study describes bottom ash as a raw material in the combustion of COVID-19 waste as paving blocks. Paving blocks are one of the most commonly used media in road pavement today (Hutagaol & Butar-Butar, 2016). Paving blocks are becoming more popular due to their ease of installation, low maintenance costs, and aesthetic appeal. Because the absorption of water through the installation of paving blocks can maintain groundwater balance (Dehghanifard & Dehghani, 2018), the use of paving blocks supports the go green concept declared nationally/internationally.

Based on the research carried out, the use of burning ash can be used as a mixture of glass recycling and geopolymer. We concluded that the more ash used in a mixture of bricks and building materials, the lower the compressive strength. It is necessary to research on the use of ashes from health facilities not intended for construction. Utilization is carried out through the use of a solidification technique by combining various compositions of bottom ash from the combustion of COVID-19 waste with sand and cement. Bottom ash from incinerated COVID-19 waste is intended to replace sand. Bottom ash with a higher composition is expected to have higher compressive strength, resulting in better bottom ash utilization. Although many studies on the use of bottom ash from medical waste incineration have used solidification techniques, no studies have been conducted on the use of ash from health facilities to make paving blocks not intended for buildings.

Method

The medical waste processing facility's bottom ash from the incineration process came from Central Java, Indonesia. Screening was performed to obtain ash free of waste not burned completely, such as vials, wire, and others. The research took time from 2022 to March 2023. The compressive strength test was performed at the Material Laboratory, Faculty of Engineering, Sebelas Maret University, Surakarta, and the TCLP test was performed at the Islamic University of Indonesia's Environmental Quality Laboratory. The compressive strength object was made in the form of a mortar measuring 50 mm x 50 mm x 50 mm using the SNI 03-6825-2002 method. For 9 samples, the test object was made with 7 variations of the composition of medical waste ash, sand, and cement with a water-cement ratio of 0.5. After a 28-day curing period, the compressive strength test was performed. A Universal Testing Machine was used to perform the compressive strength test. The compressive strength value of mortar is obtained using the formula:

$$fc' = \frac{F}{A}$$

Description:

fc' = Compressive strength (mPa)

F = Maximum load (N)

A = Surface area (mm2)

Analysis of the compressive strength of paving blocks refers to the requirements of SNI 03-0691-1996 concrete brick (Paving block). Optimum conditions are determined as the basis for the composition of medical waste incineration ash as a mixture of paving block raw materials. Toxicity Characteristic Leaching Procedure (TCLP) testing using the SNI 8808:

2019, concerning the TCLP-A and TCLP-B quality standards in Government Regulation Number 22 of 2021 in attachment X. The extraction procedure used a Rotary Agitator. The extraction results were then analyzed with Inductively Coupled Plasma (ICP) to determine the total amount of Nickel (Ni), Cadmium (Cd), Copper (Cu), and Lead (Pb). The TCLP test was designed to determine if heavy metal compounds in ash.

Results and Discussions

Ashes from medical waste incineration are included in the list of Hazardous and Toxic Wastes with general specific sources from the source of waste from incinerator facilities for the type of activity of health care facilities. The use of B3 waste must be carried out by the waste producer or passed on to a third party. Mandatory criteria for utilizing B3 waste in paving blocks are having a total metal oxide content for SiO2+Al2O3+F2O3+CaO > 50% and having a loss of ignition (LoI) of less than 10% (Ministry of Environment Regulation No. 18 of 2020).

The chemical properties of the ash incineration from medical waste were mostly CaO, Cl, Al2O3, Fe2O3, and SiO2 (Akyıldız et al., 2017). CaO compounds have the largest composition in ash from combusted medical waste (Miao et al., 2022; Patel & Devatha, 2019). Ca compounds contributed the most to ash-combusted medical waste because many types of waste were burned, including face masks, protective clothing, and glasses made of polypropylene (Pechyen & Ummartyotin, 2017). Figure 1 shows the ashes from medical waste incineration that fell to the bottom during the incineration treatment. While Figure 2 shows the results of ash filtering from burning medical waste that fell to the bottom during the incineration treatment.

Figure 1. Medical Waste Incineration Ash (1) and Incineration Ash After Filtering (2)

Table 1. Content in the Ashes of Medical Waste Incineration

Heavy metal compounds parameters	Content of heavy metal compounds in the ash (mg/l)	TCLP A pada PP 22 Tahun 2021 (mg/l)	TCLP B pada PP 22 Tahun 2021 (mg/l)
Lead (Pb)	0,32	3	0,5
Nickel (Ni)	0,20	21	3,5
Copper (Cu)	0,28	60	10
Cadmium (Cd)	0,08	0,9	0,15

Source: Primary Data, 2023

The content of heavy metals in residues of medical waste incineration is in the form of, Argentum (Ag), Arsen (As), Barium (Ba), Bismut (Bi), Copper (Cu), Cadmium (Cd), Crom (Cr), Polycyclic Aromatic Hydrocarbons (PAH) Nickel (Ni), Titanium (Ti), Antimon (Sb), Timah (Sn), Lead (Pb), dan Seng (Zn) which are effect harmful to environment (Lo & Liao, 2007; Rozumová et al., 2015; Xie & Zhu, 2012). According to Table 1, the content of heavy metal compounds Pb, Ni, Cu, and Cd in the ashes from burning medical waste is still below the TCLP A and B quality standards set by PP 22 of 2021, so it can be concluded that the ashes from burning medical waste have the potential to be utilized. The heavy metal content of the incineration residue is affected by the type of waste burned. Except for radioactive waste, medical waste that is burned at medical waste processing facilities is in the form of syringes, body tissue waste, contaminated gauze or wipes, infusion hoses, food contaminated with COVID-19 patients, plastic medical waste wrapping, and so on.

Solidification converts hazardous and toxic waste into a form acceptable to the environment to be disposed of in landfills or used for construction purposes. The solidification technique is a method that requires a binder that aims to bind harmful and toxic compounds in ash. Cement is often used as a binder in the compaction (Gumadita et al., 2017). Improper management of medical waste ashes can cause soil and water pollution and affect the health of the environment and surrounding communities. Miao et al., (2022) stated that Pb and Cu compounds tended to increase in bottom ash during the combustion process using an incinerator, whereas most of Cd was in fly ash and the rest remained in bottom ash.

Pb metal compounds affect the health development of children due to accidental ingestion of contaminated soil (Lanphear et al., 2005; Kabata et al., 2007). Pb compounds have the potential to be carcinogenic and are included in Group 2B based on reports from the International Agency for Research on Cancer (IARC, 2012). So exposure to Pb is considered harmful even if the Pb content in the blood is less than 5 µg dL− 1 (Forsyth et al., 2019). Based on the International Agency for Research on Cancer, (2012) Cd and Ni compounds are included as carcinogenic agents (Group 1).

Excessive exposure to copper metal compounds affects human health, including gastrointestinal, cardiovascular, respiratory, and neurological disorders (Jorge Mendoza et al., 2017). Excessive intake is due to the condition of plants exposed to Cu metal compounds, which are consumed by humans as a result, affecting their health. Human health is at risk due to exposure to heavy metals in plants, soil, and water (Yang et al., 2018).

The compressive strength test of the mortar was carried out after 28 days of soaking with a mixture of 600 kg/m3 cement and 300 kg/m3 water. Based on Table 1, the average compressive strength was calculated by taking the average compressive strength from 9 specimens for each sample. The average maximum compressive strength was 14.5 Mpa in sample 2, with a composition of 50% ash and 50% sand. The average minimum compressive strength is 5.2 mPa in sample 5, with 80% ash and 20% sand. Table 2 demonstrates the results of the mortar compressive strength test for medical waste incineration ashes.

Table 2. Compressive Strength Test Results for Medical Waste Incineration Ashes

Composition	Average Compressive Strength (mPa)	Standard Deviation
Sample 1 (40% ash, 60% sand)	13,9	1,95
Sample 2 (50% ash, 50% sand)	14,5	1,60
Sample 3 (60% ash, 40% sand)	10,9	1,99
Sample 4 (70% ash, 30% sand)	7,4	1,94
Sample 5 (80% ash, 20% sand)	5,2	1,55
Sample 6 (90% ash, 10% sand)	10,2	1,99
Sample 7 (100% ash, 0% sand)	10,1	1,41

Source: Primary Data, 2023

Mortar strength increases with increasing soaking time, and the compressive strength will show the expected strength after 28 days of soaking (Jorge Mendoza et al., 2017). The slow hydration process was responsible for the development of mortar strength at 28 days (Mughnie, 2010). When cement comes into contact with water, it goes through a hydration process, the strength of the sample will increase as the sample ages until the hydration process no longer occurs (Jorge Mendoza et al., 2017). Figure 3 shows the regression results for the relationship between the average compressive strength value and the addition of medical waste ash to sand in the mortar based on the results of the data analysis above and by using the Trendline facility in Microsoft Excel.

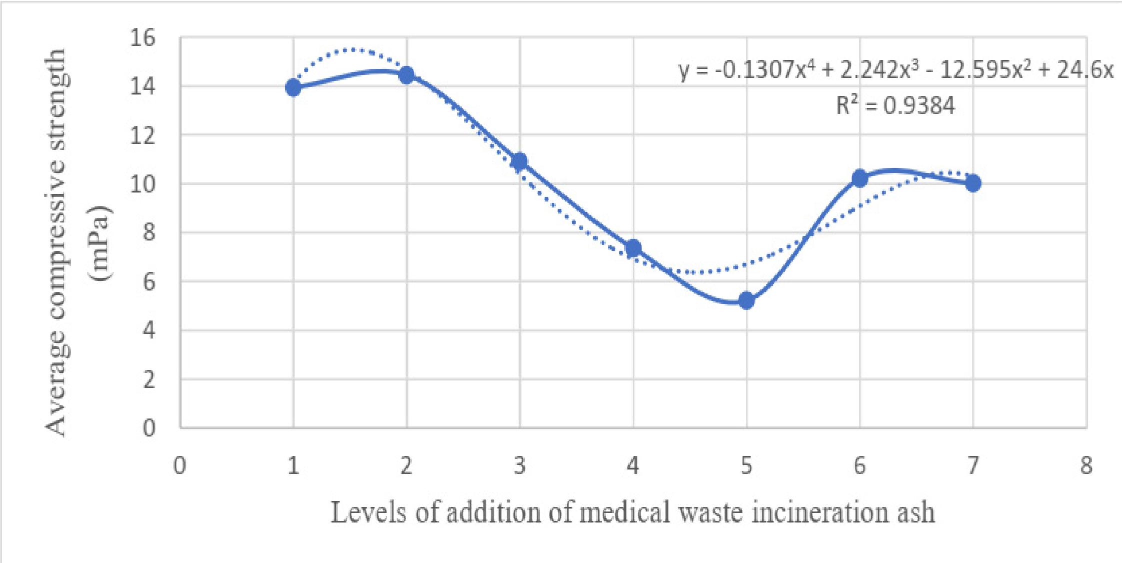

Figure 3. Graph of Regression Analysis of the Relationship Between Levels of Addition of Medical Waste Incineration Ash and Average Mortar Compressive Strength

According to the results of the regression analysis, the optimal addition of medical waste incineration ash content was 93.84%, resulting in a compressive strength value of 14.5 mPa. According to the results of this analysis, adding ash at a certain level increases the compressive strength value, but after passing the optimum limit, the compressive strength value decreases. It demonstrates that the ashes produced by incinerating medical waste contain silica, which can act as a binder. Bottom ash had an 8.21% Si content based on the XRF test (Ferdinand, 2013). Akyıldız et al.,(2017) explained that the chemical contained in the incineration ash medical waste including CaO, Cl, Al2O3, Fe2O3, and SiO2 of 7.963%.

Using waste from landfills as much as 30% replacing fine aggregate (sand) with a 1:3 mixture composition ratio using type I Portland cement in the manufacture of paving blocks can provide a compressive strength of 17.19 mPa (M. Aminul & Hoque, 2014). Whereas in this study, the composition of 50% medical waste incineration ash replaced fine aggregate (sand) producing a maximum compressive strength of 14.5 MPa. The difference in the type of ash used and the amount of composition used as a mixture gives a difference in the compressive strength results. The properties of cement as a binder will work optimally to bind all the mortar particles when the addition of ash from incinerated medical waste is small. However, if the amount of ash added exceeds the optimum level, the compressive strength will be decreased because the volume of cement and water is not added along with the ash. It causes the binding properties of cement and water to work improperly. Based on Figure 3, there are six of the seven mortar compositions with the addition of medical waste incineration ash meet the compressive strength requirements of SNI 03-0691-1996 with the quality of category D paving blocks used for parks and other places. Figure 3 displays that the best conditions are 50% ash and 50% sand, with a standard deviation of 1.60.

Conclusion

Based on the results, we concluded that the ashes from incinerated medical waste contain heavy metal compounds Pb, Ni, Cu, and Cd below the determined quality standards and can potentially be used as a mixture for making mortar. Six of the seven mortar compositions meet the compressive strength requirements of SNI 03-0691-1996 with the quality of category D paving blocks for parks and other places with the addition of incinerated medical waste.

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