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PERFORMANCE OF MEDICAL WASTE ASH AS A PAVING BLOCK: IMPACTS TO AIR QUALITY AND HEAVY METALS IN PRODUCT

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Abstract: In compliance with regulation of the Republic of Indonesia 22 of 2021, hazardous and toxic waste (B3) producers are obligated to use B3 waste. The purpose of this research is to assess the influence of using ash from incinerated medical waste on air quality and to identify the concentration of heavy metals in paving block products such that its use is ecologically and environmentally benign. Air quality is measured as dust present in it using the Gravimetry technique while noise was measured using a Sound Level Meter. The Toxicity Characteristic Leaching Procedure (TCLP) was used to determine the level of lead Pb, nickel (Ni), copper (Cu), and cadmium (Cd) compounds in the product. The usage of medical waste ash had an influence on the environment with respect to air quality in the form of dust with a value that exceeds the prescribed quality standard threshold, but noise values on the environment and health can be tolerated. Ash from the burning of medical waste has the potential to be used as paving blocks with a soaking period of between seven and 14 days, with metal levels of Ni, Cu, and Cd well below the quality limits imposed by the government. Unlike the heavy metal compound Pb, above the TCLP B (0.5 mg/l). Medical waste ash has the potential to be used as paving blocks with the addition of a pozzolanic composition so that it can bind the maximum amount to heavy metals.

Keywords: Dust, noise, ash medical waste, paving block.

Introduction

One of the processes used in the treatment of solid waste generated by healthcare facility operations (hospitals, health centres, clinics, and so on) that fulfils thermal standards is the incineration process. Burning with an incinerator is a common thermal process. The negative impact of incinerator combustion results in harmful air pollutants and ash from combustion, including fly ash and bottom ash. Heavy metals in the ash can be hazardous to the environment (Rovira *et al.,* 2018; Ramadhansyah *et al*., 2021). Up to 95% of medical waste is burnt in an incinerator to produce fly ash and bottom ash (Miao *et al*., 2022). Most of the ash produced by health facilities is handed over to third parties for landfilling (Rachmawati *et al*., 2022b). Because of the significant metal level in ash, there has been limited general application, whereas rules allow for the use of B3 waste under certain conditions.

Given the features of ash, including poisonous hazardous elements, the influence on the process of using medical waste ash must be examined. Soil contamination due to heavy metals occurs at a distance of 60 m from the medical waste incineration site (Adama *et al*., 2016). Fly ash and bottom ash generated during the combustion process must be carefully managed by existing regulations to avoid potential repercussions on the environment and human health (Gidarakos *et al*., 2009; Liu *et al*., 2018).

The usage of hazardous and toxic waste is indicated in government regulation Number 22 of 2021 concerning the Implementation and Protection of the Environment, which specifies that manufacturers of B3 waste must use B3 waste (Pemerintah Republik Indonesia, 2021). Medical waste ash is hazardous and toxic waste material, and several studies have been carried out on its utilisation such as being used for glass recycling (Papamarkou *et al*., 2018b), used to be a geopolymer with geopolymerisation technique (Tzanakos *et al*., 2014), also as an aggregate and mixture on the highway (Azni *et al*., 2005) as well in brick mix (Gumadita *et al*., 2017), as paving blocks (Rachmawati *et al*., 2023). Targeted treatment of combustion residues can reduce toxicity levels and improve technical quality (Kuo *et al*., 2015). There needs to be more research on the environmental impact of turning medical waste ash into goods.

Solidification is a common approach for controlling heavy metals in combustion or incineration ashes (Assi *et al*., 2020). The composition of 90% of Portland cement has the best results (Sobiecka *et al*., 2014). The paving block is one of the media that is said to promote the green idea since it can preserve groundwater balance in terms of water absorption in its installation (Hutagaol & Butar-Butar, 2016; Basuki *et al.,* 2019). Previous research on incorporating bottom ash from municipal trash incineration into a making of paving units found less heavy metals being leached, and the quality criteria still needed to be reached (Kuo *et al*., 2015). In this study, it is suggested to use medical waste ash as a raw material mixture for paving blocks and to assess the environmental effects of these activities.

The use of ash from the combustion of medical waste influences environmental quality, including air and water quality. One of the hazards that might impair air quality is dust and noise. Dust has the potential to be employed as a raw ingredient in paving block mixtures during the filtering process of combustion ash. The lungs are the primary target of air pollution. Asthma, bronchitis, and pneumonia are examples of lung illnesses (WHO, 2016). The particle size of medical combustion ash can create air pollution (Miao *et al*., 2022). As printing press equipment is powered by a diesel engine, noise is possible throughout the paving block manufacturing process. The noise can affect worker's health, especially their sense of hearing (Fisika *et al.*, 2021). Noise involves irregular vibrations and is associated with irritation; annoyance is a response that arises when exposed to noise (Michaud *et al.*, 2005).

Soaking paving blocks in water aids the cement, ash, and sand bonding process, resulting in optimum compressive strength. Soaking water is released into water bodies after use, it is one of the variables that influence the environment and the surrounding community. Heavy metal compounds found in paving stones were investigated to see if the solidification process was working properly. The purpose of this study is (1) to investigate the influence of employing medical waste incineration ashes on dust and noise, as well as the number of heavy metal compounds such as lead (Pb), nickel (Ni), copper (Cu), and cadmium (Cd) in paving blocks and (2) to establish whether or not the usage is possible and ecologically harmless.

Materials and Methods

Samples of Medical Waste Incineration Ash

Ash from burning medical waste were received from medical waste processors in Sukoharjo, Central Java, Indonesia. The ash used was that which falls to the lowermost end of the incinerator during combustion and is often called bottom ash. The waste burned was infectious and included wastewater treatment plant sludge, and food contaminated with COVID-19. The bottom ash used for the paving block mixture was filtered before use. Filtering was carried out to obtain ash that was not mixed in with objects that were not completely burned.

Place and Time of Study

The study was carried out at s medical waste incinerator site in Weru Village, Baki District, Sukoharjo Regency, Central Java, Indonesia. The sample area is geographically located at -7. Latitude is 6064929, and longitude 110.7837011.

TSP Dust (Total Suspended Particulate)

TSP dust was measured using a High-Volume Air Sampler (HVAS) by SNI 7119-3:2017, which describes how to test for completely suspended particles using a gravimetric technique. TSP dust was measured throughout the process of creating the paving stones from medical waste ash, from the filtration to the creation of the paving blocks. TSP dust measurements were carried out at sampling points for bottom ash filtering activities and use of medical waste ash. The determination of the location of the sampling point was adjusted based on the density of worker activity in the utilisation process. There were two sampling points at eight hours and 24 hours with one repetition, namely in the ash filtering area and during the paving block production process. TSP samples were taken using the grab sampling technique, instantaneous measurements with the consideration that this method is one of the standard methods and is in accordance with the characteristics of the research area. The concentration of TSP in the test sample was determined using (SNI 7119-3:2017):

$$C = \frac{(W_2 - W_1) \times 10^6}{V_{std}} \quad (1)$$

The following formula was used to calculate the volume of air test samples in standard circumstances (V_{std}) (SNI 7119-3:2017):

$$V_{std} = \frac{\sum_{s=1}^{n} Q_s}{n} \times t \quad (2)$$

Calculation of the flow rate correction at standard conditions (QS) used the following formula (SNI 7119-3:2017):

$$Q_s = Q_0 \times \left[\frac{T_s \times P_0}{T_0 \times P_s}\right]^{\frac{1}{2}} \quad (3)$$

Noise

The noise was measured using a Sound Level Meter with the determination of measurement points adjusted to SNI 8427:2017. Noise mapping used the ArcGis 10.3 application to describe the pattern of noise distribution in an area with a total of 88 points presented in Figure 1. The point determination was carried out to determine the distribution of noise produced in the process of utilising ash from burning medical waste into paving blocks. The location point for collecting data from the production process was up to a distance of 500 m from the location. The research location was chosen based on the medical waste ash utilisation area and its surroundings, which are densely populated areas. This is based on the Decree of the Minister of the Head of the Environmental Control Agency Number 205 of 1996 concerning Technical Guidelines for Controlling Air Pollution from Non-Stationary Sources, which requires a minimum of two sampling points for pollutant sources. Noise measurements were taken after 10 minutes for six repetitions at one measurement point. Environmental noise measurements are adjusted according to the Regulation of the Minister of Manpower of the Republic of Indonesia No. 5 of 2018, where the noise threshold value (NAB) is 85 dBA. The noise measurement time was carried out three times at one point, which is considered to represent the time such as taking data at 07:00, namely in the morning, taking data at 10:00, namely the afternoon, and taking data at 15:00, which representing the evening. Noise measurements were then calculated using the average formula—average noise (Leq) (SNI 8427:2017).

$$Leq = 10 \log \frac{1}{n} \left(10^{\frac{L1}{10}} + 10^{\frac{L2}{10}} + 10^{\frac{L3}{10}} + \cdots \right) dBA \quad (4)$$

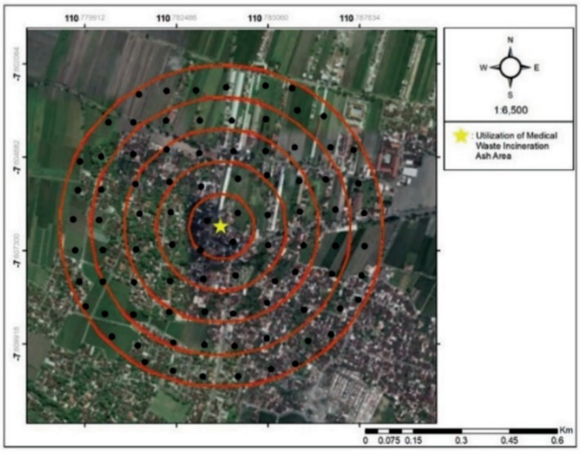

Figure 1: Noise collection point

The Content of Heavy Metal Compounds in Paving Blocks

The tests for the content of heavy metal compounds in paving blocks with immersion periods of seven days, 14 days, 21 days, and 28 days were conducted at the Environmental Quality Laboratory at the Islamic University of Indonesia with the Toxicity Characteristic Leaching Procedure (TCLP) using the SNI 8808:2019 method. Requirements adjusted to the TCLP-A and TCLP-B quality standards in Government Regulation Number 22 of 2021 in Appendix X. The extraction procedure was carried out with a Rotary Agitator. The results of this extraction were then analysed using Inductively Coupled Plasma (ICP) to determine the total amount of metal nickel (Ni), cadmium (Cd), copper (Cu), and lead (Pb).

Results and Discussion

Air Quality [TSP Dust (Total Suspended Particulate)]

Paving blocks were made by first filtering the bottom ash to get ash for mixed raw materials and removing syringes that had not been entirely burned up in the incinerator. The next step was to make paving blocks by first combining sand and cement and then printing them with a press machine. Figure 2 (a) depicts the total suspended particle dust formed throughout the filtering operation for eight hours, with a TSP level of 1,380.504 µg/Nm^3. The total suspended particulate dust generated in the paving block printing process for eight hours is presented in Figure 2 (b) with a TSP content of 482.017 µg/Nm^3. Based on the results of the analytical tests presented in Table 1, it was revealed that the TSP

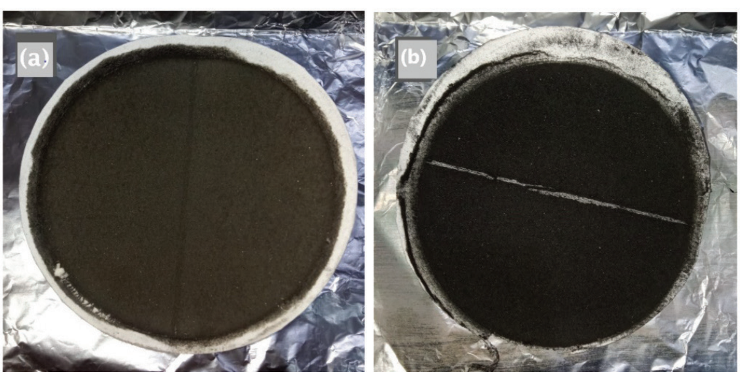

Figure 2: Dust filter (a) dust filtering, and (b) use of ash as paving blocks

Table 1: TSP dust measurement results

Measurement Location	TSP Concentration for 8 Hours (µg/Nm^3)	TSP Concentration for 24 Hours (µg/Nm^3)
Medical waste ash screening location	1380.504	1145.320
Location of the utilisation of medical waste ashes into paving blocks	482.017	399.900

levels exceeded the threshold values that had been determined based on (Pemerintah Republik Indonesia, 2021) about Implementation of Environmental Protection and Management, namely the Threshold Value (NAV) of the TSP parameter of 230 µg/Nm^3.

TSP particles are hazardous to human health if exposed over an extended period. Given the composition of the medical waste ash, the existence of TSP pollution in the ambient air in the medical waste ash utilisation area can potentially to be hazardous to the health of employees and the surrounding community. The content of heavy metal compounds in medical waste ash after incineration were found in the form of Polycyclic Aromatic Hydrocarbons (PAH), silver (Ag), arsenic (As), Barium (Ba), Bismuth (Bi), copper (Cu), cadmium (Cd), chromium (Cr), nickel (Ni), titanium (Ti), antimony (Sb), tin (Sn), lead (Pb), and zinc (Zn) (Zhao *et al*., 2009; Xie & Zhu, 2012; Rozumová *et al.*, 2015). This is consistent with the test findings for heavy metal compounds comprising Pb, Ni, Cu, and Cd in medical waste incineration ashes, which are provided in Table 2. The ash employed as a raw material had a heavy metal compound content.

Total Suspended Particulate (TSP) dust is a solid in the air with a particle size of > 10 µm. The size of the particulates determines how big the impact will be if they are inhaled by people or pollute the environment. The size of particulates varies; some measuring < 10 µm are called PM10, and particulates measuring < 2.5 µm are called PM 2.5 (Putra *et al*., 2022). When dust enters the respiratory system, it produces symptoms such as coughing, shortness of breath, and poor mucociliary transport (Indriyani *et al*., 2017). Total Suspended Particulate (TSP) dust is one of the risk agents that can enter the human body by inhalation or respiration. Several studies have found a relationship between long-term dust exposure and reduced lung function (Suryadi *et al*., 2022). Control can be carried out by implementing working hours, namely four hours of work followed by rest, which aims to provide time to breathe fresh air after being exposed to dust while working (Susihono & Gede Adiatmika, 2020).

Air Quality Noise

Noise is produced by the diesel engine, which serves as an electrical supply in the press machine for printing paving blocks. Based on Figure 3, it is known that the distribution of noise is created during the process of converting medical waste ash into paving blocks. Noise maps assist the community in identifying and preventing noise, which improves the quality of life (Tang *et al*., 2022). Figure 3 depicts the range of airwave propagation that transfers sounds originating from noise sources. The cause of noise in medical waste ash use was diesel engines and transportation surrounding the utilisation region. 88 points with a radius of 500 m from the medical waste ash use region were measured. The maximum noise level was between 76.18 and 80.98 dBA.

According to the interviews conducted, people within a radius of 100 m of the direction of utilisation felt bothered by the noise created by the diesel engine. However, inhabitants within a radius greater than 100 m did not hear the noise arising from utilisation operations. The location for converting medical waste ash into paving blocks was close to a major road, resulting in a rather broad pattern of sound wave dispersion. The noise threshold value is within

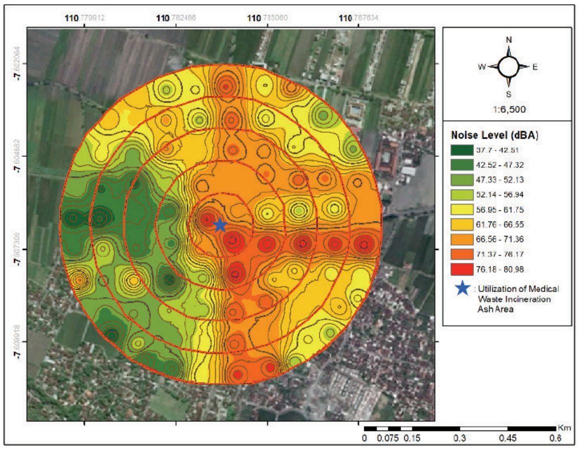

Figure 3: Contour noise

the limits set by the Minister of Manpower of the Republic of Indonesia Regulation Number 5 of 2018 concerning Occupational Health and Safety in the Work Environment is 85 dBA. Thus, it was determined that the noise value at the point of the usage site was still below the quality level.

Noise is produced by a vibrating sound source. The vibrations emitted by the sound source affect the air molecules surrounding it. The vibrations that occur in air molecules cause mechanical energy propagation waves to form in the air medium with a longitudinal propagation pattern. Sound or noise is produced by propagating waves in the air (Septio *et al*., 2020). This pattern of sound dispersion might cause performance issues as well as emotional ease (Parningotan & Mulyanto, 2020), hearing loss and sleep disturbances (Baffoe *et al*., 2022), stress, psychological effects (Essers *et al*., 2022), and health problems when exposed for a long time (Rachmawati *et al*., 2022a). Mitigation efforts need to be made to reduce noise by using hearing protection equipment for workers in locations that have noise sources (Stone & Moro, 2022).

The Content of Heavy Metal Compounds in Paving Blocks

Paving block products created from the ashes of medical waste following incineration were made under preset ideal circumstances and had a composition of 50% ash and 50% sand for a cure duration of 28 days. Bottom ash was used as a raw material combination and was filtered to separate sharp pieces that had not been entirely burned up. The quantity of heavy metals in the ashes of medical waste incineration before consumption, namely the metal Pb, exceeded the quality criteria stated in Government Regulation Number 21 of 2022. Table 2 shows the concentration of heavy metal compounds Pb, Ni, Cu, and Cd.

The high Pb concentration was attributable to the type of waste that was incinerated; the type of determined the number of heavy metal compounds in the resultant ash or residue. Pb and Cu compounds are made from types of medical equipment waste, Cd is formed from drugs and photographic materials, and Ni is related to types of steel medical equipment waste (Zhao *et al*., 2008).

The TCLP test on paving blocks utilising a mixture of medical waste incineration ash as a raw material with a soaking duration of seven, 14, 21, and 28 days revealed a decrease in the concentration of metal compounds as compared to the ash before it was processed into products. The heavy metal components Pb, Ni, Cu, and Cd in the product remained below the TCLP A and B quality criteria established by PP 22 of 2021. This is supported by research by

Table 2: The content of heavy metal compounds in the bottom ash of medical waste incineration

Heavy Metal Compounds Parameters	Content of Heavy Metal Compounds in the Ash (mg/l)	TCLP A in PP 22 Year 2021	TCLP B in PP 22 Year 2021
Lead (Pb)	3.34	3	0.5
Nickel (Ni)	0.64	21	3.5
Copper (Cu)	14.8	60	10
Cadmium (Cd)	2.39	0,9	0.15

Table 3: The content of heavy metal compound in paving blocks

Parameters of Heavy Metal Compounds	Paving Blocks 7 Days of Soaking Time (mg/l)	Paving Blocks 14 Days of Soaking Time (mg/l)	Paving Blocks 21 Days of Soaking Time (mg/l)	Paving Blocks 28 Days of Soaking Time (mg/l)
Lead (Pb)	0.75	0.72	0.81	0.78
Nickel (Ni)	0.4	0.38	0.36	0.4
Copper (Cu)	2.82	3.12	2.57	2.33
Cadmium (Cd)	0.07	0.07	0.09	0.95

(Tzanakos *et al*., 2014), arguing that the use of ash from medical waste incineration in the form of bottom ash and fly ash to become geopolymer indicates a decrease in heavy metals during the geopolymerisation process. In contrast to (Papamarkou *et al*., 2018b), the concentration of Pb and Cl metals in the use of ash to recycle glass is very high. This is because the ash used is fly ash where the content of heavy metal compounds is higher than that of bottom ash. Vitrification using bottom ash of incineration of medical waste shows concentrations of heavy metals far below predetermined standards (Papamarkou *et al*., 2018a).

Heavy metal leaching is influenced by the formation of ettringite, calcite, and thermonatrite and the pH of the environment (Patel & Devatha, 2019). The formation of ettringite is proven by the percentage of free lime (CaO), aluminium oxide (Al_2O_3), anhydrite ($CaSO_4$), and silicon dioxide (SiO_2) contained in the ash. The chemical properties contained in some combustion ash include CaO (38.5%), Cl (30.75%), Al_2O_3 (6.9%), Fe_2O_3 (1.097%), and SiO_2 (7.963%) (Akyıldız *et al*., 2017). The ash produced by the incineration of medical waste has a high calcium concentration (Wang *et al.*, 2022).

Figure 4 shows that the heavy metal compound Pb during seven days soaking period decreased by 77.5%, followed by 14 days soaking period with a 78.4% decrease while 21 days soaking period decreased by 75.7%, followed by a soaking period of 28 days of 76.6%. The maximum reduction occurred during the soaking period of seven to 14 days, entering 21 days Pb metal compounds experienced an increase. The content of Pb compounds in paving blocks during soaking periods of seven and 14 days was above TCLP B (0.5 mg/l) in PP 22 of 2021. Pb metal compounds in medical waste incineration ashes were very high and exceed the TCLP A quality standard (3 mg/l), TCLP B (0.5 mg/l) in PP 22 of 2021 but after being used as paving blocks, the Pb content decreased with evidence of a decrease in the range of between 75% and 78%.

Ni metal compounds decreased in the seven days soaking period of 37.5%, the 14 days soaking period reached a decrease of 40.6% while in the 21 days period, it decreased only by 43.7%, followed by 28 days immersion period of 37.5%. The content of Ni compounds in paving blocks during the soaking period of seven to 28 days was still below the quality standards for TCLP A (21 mg/l) and TCLP B (3.5 mg/l) in

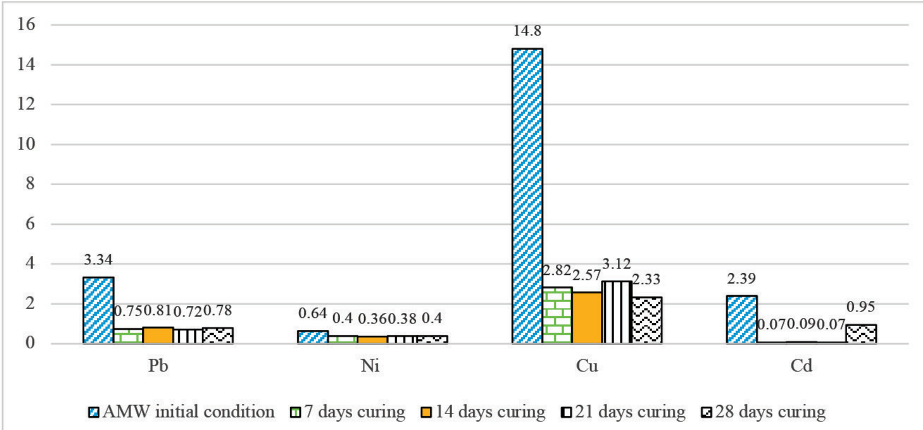

Figure 4: Reduction of heavy metal compounds in paving blocks

Regulation of the Republic of Indonesia 22 of 2021. This was due to the content of burning ash compounds. Medical waste before utilisation was still below the quality standard so after the product was made the solidification process became more effective.

Cu metal compounds decreased during the 7 days immersion period by 80.9%, but the 14 days soaking period experienced a decrease of 78.9% while there were periods of 21 days and 28 days which experienced a significant decrease of 82.6%, followed by 84.3%. The content of Cu compounds in paving blocks during the soaking period of seven to 28 days was still below the quality standards for TCLP A (60 mg/l) and TCLP B (10 mg/l) in Regulation of the Republic of Indonesia 22 of 2021.

Cd heavy metal compounds in the seven days soaking period can decrease by 97.1% while in the 14 days soaking period, it can reduce by 97.1%, in 21 days soaking period, it decreased by 96.2%, followed by the 28 days soaking period of 60.3%. The maximum decrease occurred during the soaking period of seven to 21 days, entering 28 days the content of Cd metal compounds increased. The content of Cd compounds in paving blocks during the seven and 21 days soaking periods was still below the quality standards for TCLP A (0.9 mg/l) and TCLP B (0.15 mg/l) in Regulation of the Republic of Indonesia 22 of 2021.

This is in accordance with previous research that ash from incineration of medical waste is used as a mixture for bricks with a composition of 10% to 30% ash, which results in the immobilisation of pollutant compounds below the specified quality standards (Gumadita *et al.*, 2017). The compaction of fly ash from medical waste into geopolymer shows a decrease in heavy metal concentrations (Tzanakos *et al.,* 2014). The compaction process of bottom ash and incinerator fly can reduce the content of dangerous and toxic heavy metal compounds (Suryawan *et al.*, 2019).

Bottom ash may be used for combustion with correct management, one of which is using solidification processes to bind and stabilise the concentration of heavy metals in the ash (Quina *et al.*, 2008; Zhou *et al.*, 2017). The bottom ash resulting from medical waste incineration has a finer particle size (Miao *et al.*, 2022). Some studies suggest that finer ash particle sizes pose a higher potential environmental risk (Allawzi *et al.*, 2018). Cement-based solidification can reduce the mobilisation of heavy metals found in ash (Akyıldız *et al.*, 2017; Kaur *et al.*, 2019). Solidification or stabilisation techniques in ash management can control the immobilisation of heavy metals in the resulting product (B. Ren *et al.*, 2021). Management of medical waste from health service activities contaminated with COVID-19 must be carried out appropriately to reduce the risk of virus transmission for staff and the public (Hantoko *et al*., 2021) publications from the governments and multilateral organisations, and media reports were used to quantify the effect of the pandemic towards waste generation. A huge increase in the amount of used personal protective equipments (facemasks, gloves, and other protective stuffs, as well as risks to the environment) (Kathiravan *et al*., 2023).

Conclusions and Suggestions

Based on the findings of the research, it was found that the use of medical waste ash had an environmental impact in the form of dust with a value exceeding the specified quality standard threshold (> 230 µg/Nm^3). The noise produced during the utilisation process is still below the quality standard (85 dBa). Workers must use personal protective equipment during the utilisation process such as masks to prevent exposure to the dust produced and earmuff to prevent exposure to the noise.

Ashes from medical waste burning could be utilised as paving blocks with metal levels of Ni, Cu, and Cd much below the quality limits stipulated by Indonesian Government Regulation 22 of 2021. Unlike the heavy metal compound Pb, above the TCLP B quality standard (0.5 mg/l), it is necessary to add more than 50% pozzolanic substances to obtain maximum results and utilisation.

Further study is expected to assess the characteristics of additional heavy metal compounds such as Cr, Ba, Ti, Bi, and Zn, as well as analyse the products of medical waste ash combustion into paving block products in a sustainable and economically effective manner.

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Conflict of Interest Statement

The authors declare that they have no conflict of interest.

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