RESEARCH ARTICLE **Open Access**

Gema Lingkungan Kesehatan
Vol. 23, No. 1 (2025), pp 34-41
e-ISSN 2407-8948 p-ISSN 16933761
Doi: https://doi.org/10.36568/gelinkes.v23i1.218 *Journal Hompage: https://gelinkes.poltekkesdepkes-sby.ac.id/*

Effectiveness of Concrete Tiles Made from Medical Waste Incineration Residue Admixture

Anggreini Beta Citra Dewi[1*], Fathoni Firmansyah[1], Siti Rachmawati[2], Prabang Setyono[2], Jilan Ashila[2], Iwan Suryadi[3]

[1] Departement of Diploma IV Occupational Health and Safety. Stikes Mitra Husada Karanganyar, Indonesia
[2] Department of Environmental Science, Faculty of Mathematics and Natural Science, Universitas Sebelas Maret, Indonesia
[3] Department of Environmental Health, Poltekkes Kemenkes Makassar, Makassar, Indonesia

*Correspondence: bethacd5@gmail.com

ABSTRACT

Incineration is a widely used method for processing solid waste, involving a high-temperature combustion process that generates various residues, including bottom ash. Bottom ash is one of the residues that is produced. Bottom ash contains heavy metals that are harmful to the environment, one of which is nickel (Ni). This study aims to evaluate the concentration of Ni in medical waste incineration ash and concrete roof tiles produced using ash mixtures, while also assessing the impact of ash addition on the flexural strength and impermeability of these tiles. The Toxicity Characteristic Leaching Procedure (TCLP), following the Indonesian National Standard (SNI 7184.3:2011), was employed for heavy metal analysis. The test results on medical waste incineration ash showed that the Ni metal content was 0.33 mg/L, while the test results on concrete roof tiles varied 10%, 20%, and 30%, respectively, at 0.18 mg/L, 0.21 mg/L, and 0.39 mg/L. These values fall below the permissible threshold specified in Indonesian Government Regulation PP 22 of 2021. When testing the flexural strength of roof tiles with variations of 10%, 20%, and 30%, the results were 654 N, 1018 N, and 754 N. Based on these results, the flexural strength of concrete roof tiles is below the flexural strength standard in SNI 0096:2007. Water impermeability tests, however, showed no signs of water penetration across all variations, meeting the SNI 0096:2007 standard for water resistance.

Keywords: Incineration, Medical waste, Concrete roof tiles

INTRODUCTION

Waste management in Indonesia remains a significant challenge.Waste management in Indonesia is still a problem. According to data from the Ministry of Environment and Forestry in 2022, the amount of waste generation in Indonesia reached 21.1 million tons and around 7.2 million tons have not been managed properly. One type of waste that arises is medical waste, which can cause health and environmental problems. MB3 medical waste (B3) is generated from medical and health activities that contain hazardous components such as toxic chemicals, infectious substances, sharp objects, and unused medicines (Purwanti, 2018). Medical waste is considered as one of the chains of transmission of infectious diseases due to the presence of pathogenic bacteria attached (Suprihatin, 2018).

The emergence of the Covid-19 pandemic has increased the generation of medical waste. Good and safe medical waste management is essential to prevent environmental pollution and the spread of disease (Septiariva et al., 2022). Poor decisions in medical hazardous waste management can result in environmental pollution, the spread of disease, and even serious risks to medical personnel and the general public.

Government Regulation No. 22 of 2021 addresses the management of hazardous medical waste (B3) in Indonesia. One method outlined is incineration, a process that produces ash residues, including fly ash and bottom ash (Pungut et al., 2021).The management of hazardous and toxic (B3) medical waste in Indonesia is regulated in Government Regulation Number 22 of 2021. One method that can be used for medical waste management is incineration, which is the burning of waste at high temperatures. The residue from the combustion process can be in the form of ash as well as gas or particulates (Darmawan et al., 2022). The ash residue is also known as FABA (Fly ash and bottom ash) (Pungut et al., 2021). Fly ash is a fine solid waste that flies away, while bottom ash is a solid waste at the bottom of the furnace (Suryawan et al., 2019). However, the ash residue from the incineration process is still an environmental problem. At present, fly ash and bottom ash are still one of the environmental problems in Indonesia, because the amount of production is quite abundant, while the utilization and processing have not been maximized. The handling of ash from inseneration in Indonesia is only by dumping it on open land or landfill (Asof et al., 2022).

Incinerated bottom ash contains heavy metals that can pollute the environment and interfere with health. Examples of heavy metals contained in bottom ash include Pb, Cd, Cu, Cr, Ni, and others (Miao et al., 2022). Based on research by Allawzi et al. (2018), in medical waste, heavy metal Ni has the potential to be contained in medical devices such as syringes, scalpels, and others. Ni heavy metal has a high level of toxicity and can cause health problems such as cancer and respiratory problems. Therefore, the utilization of incinerated bottom ash as a raw material for fine aggregates such as sand is carried out by the solidification method. In this study, the main objective was to determine the content of nickel (Ni) heavy metal in medical waste incineration bottom ash and the resulting concrete tiles.

Based on PP No. 22 of 2021, there are efforts to utilize B3 waste, including as raw materials, substitution of raw materials, substitution of energy sources, and other utilization in accordance with the development of science and technology. Bottom ash can be used as a substitute for fine aggregate raw materials such as sand (Rachmawati et al., 2023). The utilization of bottom ash is expected to reduce heavy metal contamination in medical waste and produce more durable concrete roof tiles. This research will also examine the effect of ash mixture variation in concrete roof tiles on their flexural strength and impermeability. Thus, this research aims to provide a better solution for medical waste management in Indonesia.

METHODS

The collection of medical waste incineration residues was carried out at Type C Hospitals in Surakarta City. The TCLP test was carried out at the Environmental Quality Laboratory FTSP Islamic University of Indonesia Yogyakarta, the flexural strength test was carried out at the Materials Laboratory of the Faculty of Engineering, Sebelas Maret University Surakarta. The manufacture of concrete tile samples was carried out at UD. Restu Adi, Papahan, Tasikmadu sub-district, Karanganyar district, Central Java.

This research was conducted by following the following steps: Bottom ash from the incinerator was sampled at UNS Hospital using the grab sampling method. Incinerator bottom ash sampling was conducted at UNS Hospital using the grab sampling method. After that, the available materials were weighed according to the planned variation composition of the test specimen mixture of 10%, 20%, and 30%. The mixture was poured into concrete tile molds and vibrated with a vibrating machine to ensure a smooth and even surface.Then, the mixture was put into a concrete tile mold and vibrated using a vibrating machine to maintain the flatness of the surface. Furthermore, using a press machine, the concrete tile mixture was pressed for 1 minute. The molded roof tiles were then turned over with the mold flat at the bottom and placed in storage for 28 days.

There were 3 stages of testing, including TCLP testing of bottom ash samples and concrete tile variation samples, water seepage resistance testing, and flexural strength testing. The heavy metal content of nickel (Ni) as well as the flexural strength and water seepage characteristics of the tile and bottom ash samples were analyzed.

The data used in this study consisted of primary data obtained from measurements and laboratory tests on medical waste incineration residues and concrete tile samples, and secondary data obtained from journal literature and previous research documents. The research design used is experimental research, and the results of the parameter analysis include the levels of heavy metal nickel (Ni) in medical waste incineration residues and concrete roof tiles made from residue mixtures, flexural strength of concrete roof tiles, and water seepage in concrete roof tiles.

Nickel (Ni) heavy metal parameters were tested using the TCLP test according to SNI 8808: 2019. Flexural strength is obtained to get the strength of the roof tile to withstand the load.

The water seepage test is carried out in accordance with SNI 0096: 2007 concerning concrete tile standards. Water seepage testing was carried out for 24 hours using a zinc box measuring 23 cm x 10 cm x 5 cm. The box is used as a water reservoir, which is placed on the top surface of the concrete tile. For the test, wax or plasticine is used to adhere the zinc box to the roof tiles to prevent water from escaping. Table 1 shows the bending load characteristics of roof tiles are minimal

Table 1
The bending load characteristics of roof tiles are minimal

High profile (mm)	Genteng interlok		Genteng non interlok
	Profile	Flat	
	20 ≥ t ≥ 5	t < 5	
Cover width (mm)	≥ 300	≥ 300	-
Bending load (N)	1400	1200	550

(Source: SNI 0096:2007)

Testing the flexural strength of concrete roof tiles was carried out at the UNS Civil Engineering Materials Laboratory. The tile samples were dried for 5 days, then soaked for 28 days. The roof tiles were 33 cm x 42 cm in size.

Data Analysis

Nickel (Ni) heavy metal parameters were tested using the TCLP test according to SNI 8808: 2019 adjusted to the threshold set in PP 22 of 2021 concerning the Implementation of Environmental Protection and Management.

Flexural strength is obtained to get the strength of the roof tile to withstand the load.

The heavy metal compound Ni was subjected to TCLP testing, and the results were compared using TCLP A and B quality standards in Government Regulation No. 22 of 2021 concerning Implementation of Environmental Protection and Management. The TCLP test is used to identify leaching in the content of heavy metal compounds in a waste.

The results obtained are calculated using the formula to obtain the flexural load characteristics. Furthermore, it is compared with the flexural load standard in SNI 0096: 2007 concerning concrete tile standards. The formula for flexural load characteristics is as follows:

$$Fc = F - 1.64 \times Sd$$

With:

$$Sd = \sqrt{\frac{\sum(Fi - F)^2}{n-1}}$$

Description:
Fc: characteristic bending load (N)
F: average bending load (N)
Fi: bending load of each test specimen (N)
Sd: standard deviation
n: number of test specimens

The water seepage test is carried out in accordance with SNI 0096: 2007 concerning concrete tile standards.

RESULTS AND DISCUSSION

Nickel (Ni) content in medical waste combustion residue

Hospitals are health care institutions that organize comprehensive individual health services that provide inpatient, outpatient, and emergency services. Aspects of health services provided include preventive, promotive, curative, and rehabilitative. Based on their service capabilities, hospitals are classified into 4 types of hospitals, namely type A, B, C, and D (Law No. 17 of 2023). These hospitals generate medical waste, such as syringes, clinical pathology waste, pharmaceutical toxic waste, and contaminated gauze, as well as non-medical waste, such as food packaging, used lamps, and used batteries. Incineration using incinerators is the method chosen by the hospital to treat the waste produced. Combustion residue is the impact given to the incineration process. Figure 1 shows the combustion residue of medical waste.

Figure 1. Medical waste incineration residue

Figure 2. Concrete tile made from a mixture of medical waste incineration residue

Toxicity tests were conducted on samples of bottom ash and concrete tiles. Tests on ash determine the content or amount of heavy metals involved and assess the level of safety for environmental health, considering that the additional material used is medical waste from burning in an incinerator. Ni heavy metal testing was conducted based on SNI 8808:2019. The following are the results of toxicity testing on ash and concrete tile samples.

Tabel 2
Ni Metal Content Test Results

No	Sample (mg/l)	Results (mg/l)	Quality Standard (PP.No.22/2021)	
			TCLP A (mg/l)	TCLP B (mg/l)
1	Ash	0.33	21	3.5
2	10%	0.18		
3	20%	0.21		
4	30%	0.39		

The test results showed that the nickel content in the ash was 0.33 mg/L, below the quality standard as stipulated in Government Regulation No. 22 of 2021. Nickel is a silvery-white transitional metal. It has no odor or taste. Sources of nickel include food processing, industrial waste, oil combustion, medical waste, and others. It is commonly used as a rust-resistant coating in industry. In medicine, nickel is used in tools such as syringes and scalpels. In the combustion process, nickel tends to collect in the bottom ash and a small part is released into the air. According to research by Chuai et al.

(2022), nickel concentrations in flue gas emissions range from 2.54 to 9.25 µg/m³. Based on research by Chuai et al. (2022), in flue gas emissions, nickel ranges from 2.54 - 9.25 µg/m3. While hospitals manage medical waste through incineration, improper stockpiling of ash can pose environmental risks.Hospitals treat medical waste by incineration, but improper ash stockpiling can harm the environment

Table 2 illustrates the nickel (Ni) heavy metal content in ash and concrete roof tiles with varying additions of 10% to 30% of bottom ash.Table 2 shows that the Ni heavy metal content in concrete roof tiles decreased compared to ash, although there was an increase in the 30% variation. The Ni metal content in the 10%, 20%, and 30% variations composition were 0.18 mg/L; 0.21 mg/L; and 0.39 mg/L, respectively. Compared to the quality standard, the concentration of Ni metal parameter in concrete roof tiles meets the quality standard. An increase in the concentration of heavy metal content in cement-based solidification products can be caused because the raw materials used such as cement, sand, and water may contain heavy metals on a small scale (Sulityowati, 2018). The content of heavy metal compounds that increases in products is due to the potential for heavy metal content contained in product mixtures such as cement, water, or sand on a limited scale (Sulityowati, 2018). Senyawa logam Ni (Nickel) dikaitkan dengan jenis limbah peralatan medis baja (L.Zhao, et al., 2008). This also occurred in the research of Dewiandratika et al. (2018), where the concentration of heavy metals such as Cu, Ag, Zn, and Ba increased after the solidification process due to the contribution of heavy metal content in Portland cement and sand used.

The decrease in heavy metal concentration in solidification with cement also occurred in the research of Anastasiadou et al. (2012), where the fly ash and bottom ash used were the result of medical waste incineration. The ratio of fly ash to cement used was 40%, 50%, 60%, and 70%, as well as the ratio of bottom ash to cement. TCLP test results on fly ash concrete samples for each variation were 0.0446 mg/l, 0.0546 mg/l, 0.0469 mg/l, and 0.0112 mg/l, respectively, with Ni metal content in fly ash before treatment of 0.0762 mg/l. In concrete samples of bottom ash, the results were 0.0932 mg/l, 0.0763 mg/l, 0.1071 mg/l, and 0.0973 mg/l, with Ni metal content in bottom ash before treatment of 0.0803 mg/l.

The increase in the concentration of Ni compounds in the product has increased in line with the increase in the composition of the use of ash resulting from the incineration of medical waste, which is used as a raw material mixture for concrete roof tiles. Heavy metal compounds are not only found in ash resulting from the incineration of medical waste; Ni can also be found in water. The heavy metal waste Ni is distributed more easily through water flows such as rainwater, groundwater, rivers (Abdolvand et al., 2014), and dug well water (Sari and Puspita, 2018). Tests were carried out on drinking water where it could be concluded that the content of Ni metal compounds met the requirements for drinking water quality (Rahmadhani & Utami, 2023). Adsorption events can lead to an increase in concentration. Heavy metals in the water have the potential to adsorb onto the paving blocks. Adsorption is the stage where compound components move from one phase to another by crossing several boundaries or moving substances from the solvent to the absorber (LaGrega et al., 2001).

The Solidification Method is a fairly effective hazardous and toxic waste management technique. Solidification aims to immobilize heavy metal contaminants in waste, one of which is the metal compound Ni (Ogawa et al., 2020). The B3 waste solidification process involves adding a binder or thickener to the B3 waste. This binding material functions to convert waste into a rigid solid object (Bui et al., 2017). Examples of binders that are often used include cement, soil, sand, or other special polymers used for the solidification process (Pérez-Villarejo et al., 2012).

Based on the research of Haque et al. (2014), it is stated that Ni heavy metal content decreases during the rainy season which indicates the potential for Ni metal migration from the landfill site to the surrounding lower elevations and to surface water bodies through rainwater runoff and leachate discharge. The possibility of Ni metal migration from the landfill site to nearby lower elevations and to surface water bodies through rainwater runoff and leachate discharge is indicated by the drop in Ni heavy metal content during the rainy season (Haque et al., 2014). Water polluted by heavy metals including Ni has the potential to cause skin allergies, headaches, vertigo, nausea, vomiting, and insomnia in humans as was the case in the study of Miaratiska & Azizah, (2015). The study explained the exposure of nickel contained in the liquid waste of the metal plating household industry to skin health problems of workers. As much as 70% of all workers sampled experienced skin health problems in the form of itching, reddish skin, and peeling skin. In addition, nickel accumulated in the long term in the human body can trigger cancer (Sonone et al., 2021). Soil fertility can also be disturbed due to the accumulation of Ni heavy metals (Zulaehah et al., 2020). Therefore, it is necessary to process the bottom ash of this medical waste incineration so that Ni heavy metal contamination can be minimized by the solidification method. In the research of Chaabane et al. (2014), Solidification/stabilization techniques are used to reduce Ni contamination from landfill waste to minimize hazardous waste, so in this study, solidification of bottom ash was carried out with cementation in the form of concrete tiles. Based on research by Wang et al. (2023), cement contains calcium silicate hydrate (C-S-H) and calcium hydroxide compounds that can bind Ni^{2+}. In the solidification process, Ni^{2+} reacts with calcium hydroxide ($Ca(OH)_2$) to form $Ni(OH)_2$. In addition to $Ni(OH)_2$, nickel can form nickel silicate ($Ni(SiO_4)$) which is more stable and difficult to dissolve, reducing the potential for nickel leaching into the environment.

Flexural Strength of Concrete Tile

Testing the flexural strength of concrete roof tiles was carried out at the UNS Civil Engineering Materials

Laboratory. The tile samples were dried for 5 days, then soaked for 28 days. The roof tiles were 33 cm x 42 cm in size. In the test, the pressing wood was shaped according to the tile profile and given rubber pads. The support distance was 22 cm. The roof tile was placed on the flexural strength testing machine with the center position at the center point of loading. The position of the flexural strength test is presented in Figure 2.

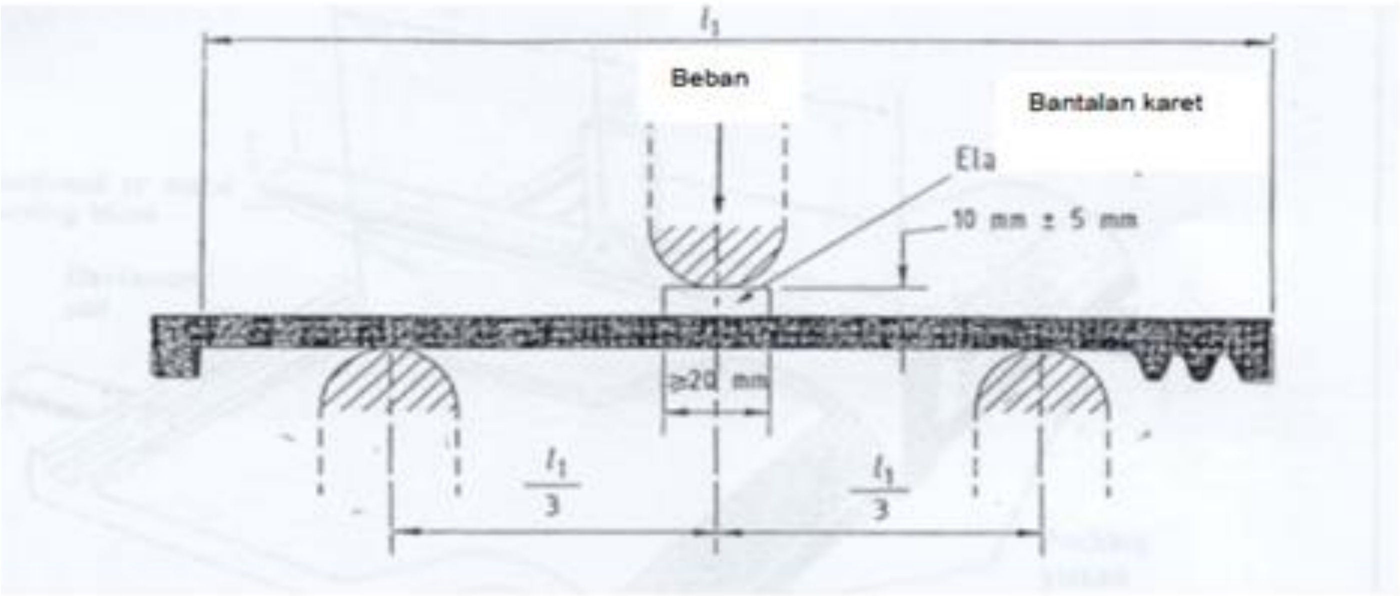

Figure 2. Illustration of flexural strength test position (Source: SNI 0096:2007)

Table 3
Flexural strength test results of concrete roof tiles

No.	Composition	Mean	Flexural Strength Characteristics
1.	0%	160 kg	1272 N
2.	10%	90 kg	654 N
3.	20%	110 kg	1018 N
4.	30%	100 kg	754 N

Table 3 shows the flexural strength of all samples. The test results show a decrease from 0% to 30%. The flexural strength characteristics of concrete roof tiles with a mixture of bottom ash do not meet the standards in SNI 0096:2007 (less than 1200 N), because there are differences in sand ratio between 0% and 30%. The use of medical waste combustion residue as a cement substitute in concrete roof tiles results in an increase in flexural strength, although it is still below the standard .

Table 3 shows the reduction in flexural strength in samples from 0% to 30% compared to sample 1 (control), which did not use ash as a mixture for concrete roof tiles. The flexural strength characteristics of concrete roof tiles mixed with bottom ash do not meet the standards in SNI 0096:2007 (less than 1200 N). Manual mixing in making concrete roof tiles has the potential for a mixture that is less even or homogeneous, thus affecting the resulting strength. A homogeneous mixture, enhanced by the addition of water and cement, is crucial for achieving good workability (Bunyamin et al., 2023).

This is due to the different sand ratio between 0% and 30%. Roof tile with 0% ash is a comparison that shows that the addition of bottom ash affects the strength of the roof tile to withstand the load. In the research of Zacoeb et al. (2013), basic ash was used to substitute cement in concrete roof tiles, the results of flexural strength characteristics at 0%-50% increased even though it was still below the roof tile flexural strength standard. The highest result was obtained at 40% composition which amounted to 857.88 N, while the lowest result of 792.57 N was obtained at 10% bottom ash composition. There are several factors that affect the flexural load of concrete roof tiles, such as raw materials, the manufacturing process, and others. The raw materials used in this study include cement, sand, bottom ash, and sufficient water. The particle size of the sand and bottom ash can influence the flexural strength of the concrete tiles. Coarser sand and ash will result in larger pores in the tiles, which not only affects water absorption but also the flexural strength of the tiles. This occurs because the bond between material particles becomes less compact. Bottom ash contains chemical compounds such as CaO, Al_2O_3, and SiO_2, which are similar to cement, although in smaller quantities, and there are other chemical compositions. The Si, Ca, and Al compounds play a role in the cement hardening process. During cement hydration, tricalcium silicate and tricalcium aluminate compounds are formed, which contribute to the reaction speed with water and the initial setting of the cement (Rani M. et al., 2017). The higher the amount of ash added, the more it affects the voids in the concrete. The use of other materials as substitutes for sand and cement also affects the flexural strength of concrete tiles, as seen in the study by Arkhanditya et al., (2024). In that study, glass powder waste was used as a sand substitute, and hydrated lime as a cement substitute. The optimal flexural strength result was achieved with a composition of 10% glass powder and 10% hydrated lime, reaching 1751.43 N. The physical and chemical properties of hydrated lime, which are almost the same as cement, help strengthen the bond between each material particle.

The flexural strength of concrete roof tiles is also influenced by the age since manufacture. Flexural strength will increase with the length of time since its manufacture. According to research (Gumadita et al., 2017), variations in drying time for 14 days, 21 days, and 28 days affect the flexural strength of concrete blocks, where the longer the drying time the flexural strength also increases, namely 105 kg/cm2, 135 kg/cm2, and 200 kg/cm2. The process of making concrete roof tiles can also affect the flexural strength. In the process of stirring the material is done manually by hand, allowing the mixing between materials to be less homogeneous or not well mixed. This allows the cement binding force to be less than perfect, so that the flexural strength of the concrete tile is not maximized.

Water Seepage Resistance (Impermeability)

Water seepage resistance in concrete roof tiles is a condition in which an object is said to be resistant to water seepage if the upper surface does not leak water. Water seepage testing is carried out for 24 hours, using a zinc box measuring 23 cm x 10 cm x 5 cm. The box was used as a water reservoir and placed on the top surface of the concrete tile. Night or plasticine is used as an adhesive between the zinc box and the roof tiles so that no water can escape from the gap during the test.

Table 4.
Results of Water Seepage Resistance Test

No.	Composition	Results
1.	10%	No water droplets
2.	20%	No water droplets
3.	30%	No water droplets

Table 4 shows that in the 10% to 30% variation there are no water droplets on the bottom surface of the roof tiles. The top surface of the tile looks wet, which means that water seeps into the tile. The mixture density in mixing concrete tile materials affects the resistance to water seepage (Sultan et al., 2018). According to Sholih's research (2023), bottom ash has a fairly high-water absorption characteristic with an average of 10.65%. This shows that the nature of incinerated bottom ash has the ability to absorb water which is quite high and if exposed to water the bottom ash will tend to shrink. The amount of ash added affects the ability of the concrete tile to retain water.

Water absorption is quite high with an average of 10.65%. This shows that incinerator bottom ash has a high-water absorption capacity and will shrink when exposed to water. The amount of ash added affects the ability of the concrete tile to retain water. According to SNI 0096:2007, concrete tiles are considered to pass the water seepage resistance test if no water droplets occur for a period of 24 hours. In this test, the tiles may become wet, but no water droplets are visible. The same concrete tile impermeability test results were obtained in the research of Zacoeb et al., (2013), where concrete tiles with bottom ash as a substitute for cement with a composition of 10-50% also meet the SNI 0096:2007 standard, namely no water droplets falling for 24 hours.

In the study (Solny et al., 2015), to improve water seepage resistance, a tile surface treatment was carried out in the form of surface coating using acrylic coating. Based on TCLP, flexural strength, and impermeability tests on concrete tile samples with a mixture of 10%, 20%, and 30% bottom ash, it was found that the most effective tile was the 20% composition. In this composition, the flexural strength obtained is closest to SNI standards and in terms of impermeability meets SNI standards. In addition, the Ni heavy metal content in this composition is still below the threshold in PP No. 22 of 2021.

CONCLUSSIONS

Ni levels in the bottom ash of each incinerated medical hazardous waste must be less than 3.5 mg/L according to PP 22 of 2021. The test result using AAS was 0.33 mg/L. In concrete roof tiles mixed with medical hazardous waste bottom ash, the Ni quality standard is also less than 3.5 mg/L. The AAS test results at 10%, 20%, and 30% variations were 0.18 mg/L, 0.21 mg/L, and 0.39 mg/L. Solidification effectively reduces heavy metal pollution. The addition of bottom ash affects the flexural strength of concrete roof tiles, with 10%, 20%, and 30% compositions still below the SNI 0096:2007 standard. The 20% composition has the most optimal result, although it does not meet the standard. Water seepage resistance meets the standard for all composition variations.

REFERENCES

Abdolvand S, Esfahani SK, Dmirchi S. 2014. Mercury (Hg) and Methyl Mercury (MMHg) Bioaccumulation in Three Fish Species (Sea Food) from Persian Gulf. *Toxicol. Environ. Health. Sci.* 6(3): 192-198. [Crossref], [Publisher]

Arkhanditya, D. A., Sigalingging, R., Hartono, H., & Setiabudi, B. (2024). Pengaruh Penambahan Limbah Serbuk Kaca dan Kapur Padam pada Pembuatan Genteng Beton Ramah Lingkungan. *Jurnal Sipil Dan Arsitektur*, 2(1), 48–56. [Crossref], [Publisher]

Asof, M., Arita, S., Andalia, W., & Naswir, M. (2022). Analysis of Characteristics, Potential and Utilization of Fly Ash and Bottom Ash PLTU

Fertilizer Industry. *Jurnal Teknik Kimia*, 28(1), 2721–4885. [Crossref], [Publisher]

Allawzi, M., Al-harahsheh, M., & Allaboun, H. (2018). Characterization and Leachability Propensity of Bottom Ash from Medical Waste Incineration. *Water, Air, and Soil Pollution*, *229*(5), 1–13. [Crossref], [Publisher]

Anastasiadou, K., Christopoulos, K., Mousios, E., & Gidarakos, E. (2012). Solidification/stabilization of fly and bottom ash from medical waste incineration facility. *Journal of Hazardous Materials*, 207–208, 165–170. [Crossref], [Publisher]

Bunyamin, B., Hady, M., Hendrifa, N., & Syakir, A. (2023). Analisis Kuat Tekan Beton Menggunakan Bahan Substitusi Serat Roving dan Cangkang Tiram. *Jurnal Serambi Engineering*, 8(3), 6104–6114. [Crossref], [Publisher]

Bui, P. T., Ogawa, Y., Nakarai, K., Kawai, K., & Sato, R. (2017). Internal curing of Class-F fly-ash concrete using high-volume roof-tile waste aggregate. *Materials and Structures/Materiaux et Constructions*, *50*(4), 1–12. [Crossref], [Publisher]

Chaabane, L., Moussaceb, K., & Ait-Mokhtar, A. (2014). Factors Affecting the Leaching of Heavy Metals (Ni12, Pb12, Cr13) Contained in Sludge Waste Stabilization/Solidification by Hydraulic Benders, Part I: Water/Cement and Waste/Cement Ratio in S/S Mortars. *Environmental Progress & Sustainable Energy*, 33(3), 676–680. [Crossref], [Publisher]

Chuai, X., Xiao, R., Chang, L., Wang, J., Yong, H., Jiang, R., Zhang, T., Tan, S., Zhao, Y., Xiong, Z., & Zhang, J. (2022). Fate and emission behavior of heavy metals during hazardous chemical waste incineration. *Journal of Hazardous Materials*, 431(February), 128656. [Crossref], [Publisher]

Darmawan, A. I., Mutiara Sari, M., Wayan, I., Suryawan, K., Studi, P., & Lingkungan, T. (2022). Upaya Pengelolaan Abu Hasil Pengolahan Limbah Medis dengan Stabilisasi/Solidfikasi di Indonesia: Sebuah Review. *Serambi Engineering*, *VII*(3), 3508–3515. [Crossref], [Publisher]

Dewiandratika, M., Sukandar, & El Akmam, M. T. (2018). Study on the leaching performance of chromium (Cr) and cadmium (Cd) from the utilization of solidified nickel slag as concrete floors. MATEC Web of Conferences, 147. [Crossref], [Publisher]

Gumadita, B. F., Bahri, S., & Yenie, E. (2017). Pemanfaatan Limbah Medis Padat Infeksius RSUD Arifin Achmad Pekanbaru Dengan Teknik Solidifikasi Sebagai Campuran Batako. *Jom F Teknik*, 1, 1–9. [Publisher]

Haque, M. A., Hoque, M. A., Saha, S., & Hadiuzzaman, M. (2014). Immobilization of heavy metals from paving block constructed with cement and sand-solid waste matrix. Asian *Journal of Applied Sciences*, 7(3), 150–157. [Crossref], [Publisher]

LaGrega, M.D., Buckingham, P.L., dan Evans, J.C. (2001). *Hazardous Waste Mangement.* Edisi ke-2. New York: McGraw Hill. Hal. 117, 196, 202, 478- 479. [Publisher]

Miao, J., Li, J., Wang, F., Xia, X., Deng, S., & Zhang, S. (2022). Characterization and evaluation of the leachability of bottom ash from a mobile emergency incinerator of COVID-19 medical waste: A case study in Huoshenshan Hospital, Wuhan, China. *Journal of Environmental Management*, *303*(November 2021). [Crossref], [Publisher]

Miaratiska, N., & Azizah, R. (2015). Hubungan Paparan Nikel Dengan Gangguan Kesehatan Kulit Pada Pekerja Industri Rumah Tangga Pelapisan Logam Di Kabupaten Sidoarjo Correlation Nickel Exposure and Worker Skin Health Disorders at Metal Plating Home Industry in Sidoarjo. Perspektif *Jurnal Kesehatan Lingkungan*, 1(72), 25–36. [Publisher]

Ogawa, Y., Bui, P. T., Kawai, K., & Sato, R. (2020). Effects of porous ceramic roof tile waste aggregate on strength development and carbonation resistance of steam-cured fly ash concrete. *Construction and Building Materials*, *236*, 117462. [Crossref], [Publisher]

Peraturan Pemerintah. 2021. Peraturan Pemerintah Republik Indonesia Nomor 22 Tahun 2021 tentang Penyelenggaraan Perlindungan dan Pengelolaan Lingkungan Hidup. Jakarta : Sekretariat Kabinet Republik Indonesia. [Publisher]

Pérez-Villarejo, L., Eliche-Quesada, D., Iglesias-Godino, F. J., Martínez-García, C., & Corpas-Iglesias, F. A. (2012). Recycling of ash from biomass incinerator in clay matrix to produce ceramic bricks. *Journal of Environmental Management*, *95*(SUPPL.), S349–S354. [Crossref], [Publisher]

Pungut, P., Al Kholif, M., & Sugianto, A. A. P. N.

(2021). Pengaruh Tekanan Blower pada Proses Pembakaran Sampah Medis Menggunakan Insinerator Statis terhadap Kualitas Abu. *Jurnal Serambi Engineering*, *7*(1), 2601–2606. [Crossref], [Publisher]

Purwanti, A. A. (2018). The Processing of Hazardous and Toxic Hospital Solid Waste in Dr. Soetomo Hospital Surabaya. Jurnal Kesehatan Lingkungan, 10(3), 291. [Crossref], [Publisher]

Rachmawati, S., Syafrudin, & Budiyono. (2023). Medical Waste Incineration Ash Waste: Impact on Environmental Health and Its Potential to be Used for Paving Blocks*. Jurnal Kesehatan Masyarakat*, 19(2), 312–318. [Crossref], [Publisher]

Rahmadhani, L. S., & Utami, M. (2023). Determination of Nickel (Ni) Metal Levels in Drinking Water at the Laboratory of Health and Medical Devices Testing in Central Java Province. *IJCR-Indonesian Journal of Chemical Research*, 8(2), 35–42. [Publisher]

Rani M., Y., Bhagawan, D., Saritha, P., Himabindu, V., & Reddy, V. V. (2017). Treatment of Hazardous Solid Waste Using Solidification and Stabilization Technique. *American Journal of Environmental Protection*, 6(4), 94. [Crossref], [Publisher]

Sari, & Puspita, L. (2018). Analisis Kandungan Nikel (Ni) pada Limbah Cair dan Air Sumur Gali serta Keluhan Kesehatan pada Masyarakat Sekitar Industri Logam (Studi di UD. Aji Batara Perkasa Mandiri (ABP) Desa Ngingas Kecamatan Waru). 1–102. [Publisher]

Septiariva, I. Y., Suryawan, I. W. K., Sarwono, A., & Ramadan, B. S. (2022). Municipal infectious waste during COVID-19 pandemic: trends, impacts, and management. *International Journal of Public Health Science*, *11*(2), 552–557. [Crossref], [Publisher]

Sholih, D. 2023. Analisis Kandungan Cr6+ dan Karakteristik Fisika pada Bottom Ash Hasil Insinerasi Limbah B3 di PT ARAH Environmental Indonesia. *Skripsi*. Surakarta, Universitas Sebelas Maret : Fakultas Matematika dan Ilmu Pengetahuan Alam.

Sonone, S. S., Jadhav, S., Sankhla, M. S., & Kumar, R. (2021). Water Contamination by Heavy Metals and their Toxic Effect on Aquaculture and Human Health through Food Chain. *Letters in Applied NanoBioScience*, *10*(2), 2148–2166. [Crossref], [Publisher]

Solny, T., Masilko, J., Švec, J., Kolarova, I., Kratochvil, J., Parizek, L., & ;Bednarek, J. (2015). Study of Surface Treatment of Freshly Fabricated Concrete Roof Tiles. *Advanced Materials Research*, 1124, 76–82. [Crossref], [Publisher]

Standar Nasional Indonesia. SNI 0096 : 2007 Genteng Beton. Jakarta : Badan Standarisasi Nasional.

Standar Nasional Indonesia. SNI 8808 : 2019 Prosedur Pelindian Karakteristik Beracun (Toxicity Characteristic Leaching Procedure). Jakarta : Badan Standarisasi Instrumen LHK.

Sultan, M. A., Imran, & Litiloly, F. (2018). Korelasi Porositas Beton Terhadap Kuat Tekan Rata-Rata. *Jurnal Teknologi Sipil*, *2*(2), 57–63. [Crossref], [Publisher]

Suprihatin, H. (2018). Efektifitas Incenerator Untuk Pembakaran Sampah Medis di RSUD Kota ABC. Dinamika Lingkungan Indonesia, 5(2), 76. [Crossref], [Publisher]

Suryawan, I. W. K., Prajati, G., & Afifah, A. S. (2019). Bottom and fly ash treatment of medical waste incinerator from community health centres with solidification/stabilization. *AIP Conference Proceedings*, *2114*(August). [Crossref], [Publisher]

Sulityowati, N. A. (2018). Kuat Tekan Dan Pelindian Logam Berat Paving Block dari Limbah Bahan Berbahaya Beracun Pengolahan Logam Terkait dengan Standar Nasional Indonesia. *Jurnal Permukiman*, 13(2), 69. [Crossref], [Publisher]

Wang, X., Ding, C., Long, H., Wu, Y., Jiang, F., Chang, R., Xue, S., Wu, J., & Cheng, K. (2023). A novel approach to treating nickel-containing electroplating sludge by solidification with basic metallurgical solid waste. *Journal of Materials Research and Technology*, *27*(August), 3644–3654. [Crossref], [Publisher]

Zacoeb, A., Dewi, S. M., & Jamaran, I. (2013). Pemanfaatan Limbah Bottom Ash Sebagai Pengganti Semen Pada Genteng Beton Ditinjau Dari Segi Kuat Lentur Dan Pembesar Air. *Jurnal Rekayasa Sipil*, *7*(1), 81–87. [Publisher]

Zulaehah, I., Sukarjo, S., & S Harsanti, E. (2020). Pengujian Baku Mutu Logam Nikel Pada Tekstur Tanah Yang Berbeda Dengan Indikator Tanaman Padi. *Jurnal Tanah Dan Sumberdaya Lahan*, 7(2), 263–271. [Crossref], [Publisher]