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Review on the Progress of Treatment Methods of Heavy Metals in Municipal Solid Waste Incineration Fly Ash

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Abstract: Municipal solid waste incineration is an important method of solid waste management, though this method reduces a great portion of the waste volume, it also produces fly ash which is rich in dioxins, heavy metals, soluble salts and other harmful substances that can be detrimental to the environment if not well treated. The disposal of incineration residues especially fly ash has been of great concern, due to the wide range of heavy metals and soluble salt which are harmful to the environment and groundwater This paper aims to evaluate the advantages and disadvantages of the different treatment techniques (land fill, chemical stabilization, acid extraction, cement solidification etc.,) of heavy metals in Municipal Solid Waste Incineration Fly Ash (MSWIFA) which have been used. Over the years scientist have experimented better ways to either eliminate, utilize or consolidate heavy metals in fly ash. Therefore, a systematic and structural review of both ancient and recent treatment methods of heavy metals in MSWIFA for different geographical locations is done following three principal criteria's; (i) treatment efficiency, (ii) cost, and (iii) operability. The study depicts that the cement solidification method was mostly used because it is cheap and easy to operate, whereas vitrification method is expensive due to high energy consumption. On the other hand, methods such as; chemical stabilization, melting process, geopolymer and acid extraction are very costly. This review provides some guidance; on the selection of the best treatment methods of heavy metals in MSWIFA, useful for the application of a zero-waste concept which goes beyond traditional composting and recycling.

Keywords: Municipal Solid Waste Incineration Fly Ash, Treatment Methods, Heavy Metals

1. Introduction

In recent years, environmental preservation and conservation have been of great importance in our society. The increase in population worldwide has affected the amount of solid waste production which is estimated to increase from 2,200,000,000 tons to 4,200,000,000 tons between 2025 and 2050 [1]. Municipal solid waste (MSW) is generated from; domestic activities, restaurants, residential, commercial, institutional, construction demolition and treatment plant sites. Poor management of these solid wastes will create breathing grounds for mosquitoes and other pests which can cause diseases to humans. Moreover, piles of waste can cause gas generation, and blockage of drainage systems which can lead to floods [2]. To manage these wastes, a sanitary landfill was used as a disposal method for human health and safety. Due to the increase in waste production by humans, it has been so difficult during the past years to secure landfill locations for the direct dumping of solid waste, especially in urban areas. Municipal solid waste incineration (MSWI) has become one of the means of discarding waste generated by municipalities. Incineration comprises a high temperature dry oxidation process that curtails flammable and organic waste to nonflammable and inorganic waste. Over the past years, treatment of solid waste by incineration has been widely used owing to its satisfactory volume (85-90%) and mass (80%) recovery capacity [1]. A complete process of a municipal solid waste incineration system is illustrated in Figure 1. Despite these advantages, incineration of waste can generate different sorts of residues that is; bottom fly ash, air pollution control (APC), and fly ash residue which is still dangerous if not well treated. More than 3500 tons of MSWIFA are produced every day in China

[3]. During incineration, most MSW materials are transformed to burnable residues such as fly ash and bottom ash. Fly ash is classified as "general waste requiring special control". Fly ash is a fine- dust particle with white or dark grey coloring rich in dioxins and toxic heavy metals. Under the microscope fly ash has different particle sizes (needle, strip, and spherical), high porosity, low water content, and a large specific surface area [4]. Countless studies have presented that the different physical and chemical characteristics of the fly ash depend on the incineration plant, operating conditions and the properties of the MSW [5]. The main components of fly ash are heavy metal, nonmetal oxide and soluble salts. In 2018, fly ash was classified as hazardous waste HW18 by the National Hazardous waste list and waste code 802-002-18 [3]. Fly ash is characterized by high chloride content and a significant amount of heavy metals and toxic organic compounds especially polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans (PCDDs and PCDFs) [6]. Generally, the major components of fly ash are soluble salts including: CaO, SiO_2, Al_2O_3, Fe_2O_3, MgO, Na_2O, K_2O, P_2O_5, TiO_2, MnO, CuO, ZnO, PbO, Cr_2O_3, and SO_3 [7]. Whereas, the minor components are: Zn, Pb, Cr, Cd, Cu, Sn, Ba, Sb, Zr, As, Co, Mo, Rb, Bi, V, Ce, Ga, La, Nd, Nb, and Hg [8]. Finally, the heavy metals present in fly ash can easily be leached out if not well treated affecting human health and environmental pollution. Therefore, selecting a safe and efficient method is essential for the treatment of MSWIFA. Historically, several treatment methods have been employed among which are; (1) Sanitary landfill, (2) Immobilization through Cement solidification, (3) Melting process, (4) Extraction by Acid or Alkaline and (5) Chemical stabilization.

The fundamental objective of this research is to estimate and categorize the evolution of municipal solid waste incineration fly ash treatment process globally used, and a focus on their application based on the; (i) geographic location, (ii) type of heavy metals treated, (iii) advantages and disadvantages of each treatment methods.

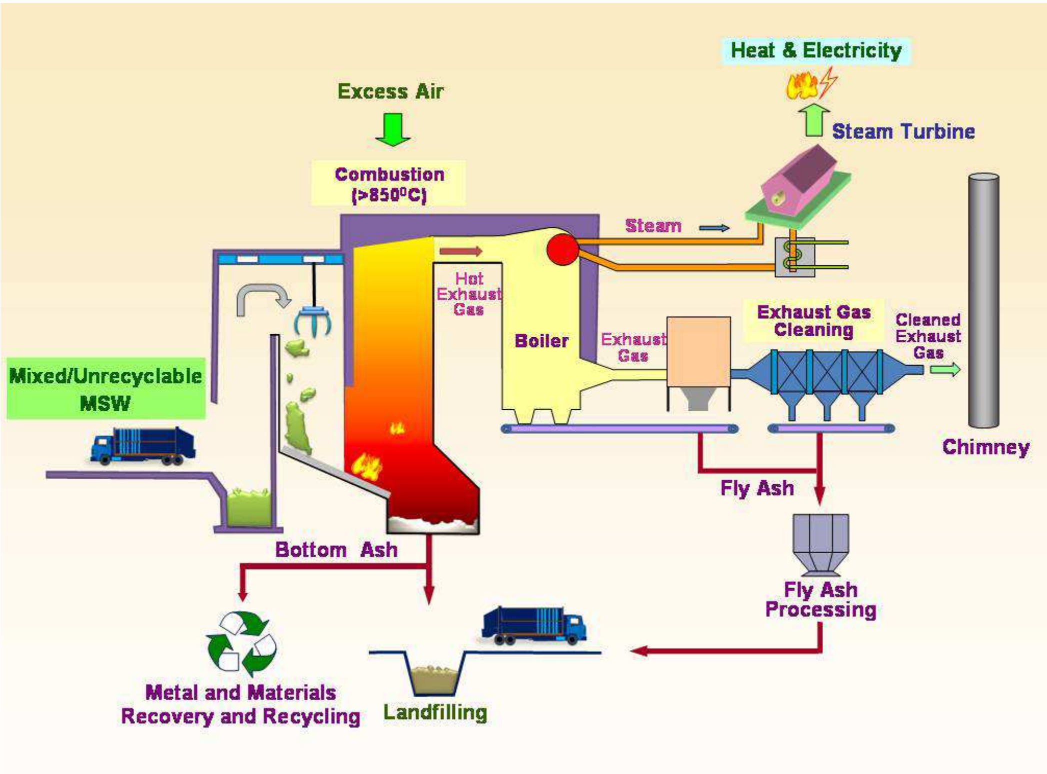

Figure 1. *Incineration of Municipal Solid Waste. source Jiang et al., (2020).*

2. Literature Review

2.1. Early Studies on the Treatment Methods of Municipal Solid Waste Incineration Fly Ash (MSWIFA)

Under this section, we reviewed MSWIFA treatment methods that were used by early researchers in different countries from the year 1992–2010. Careless disposal of incinerated residues is environmentally unfriendly which made it imperative for technological ideas on safe disposal or treatment methods. Due to the absence of robust and highly efficient treatment methods, most countries applied physical and chemical techniques to treat MSWIFA. Some of the commonly used early treatment methods describe under this section are; landfilling, chemical stabilization, cement solidification, melting process and acid extraction.

2.2. Landfilling

Landfilling has been an early disposal method of MSWIFA. Dumping of waste on land has been an ancient, simple and most popular method because of the availability of land that existed before the industrial revolution. Here layers of compressed garbage are cover with layers of earth until the facility attain their life span. Although it helps in MSW disposal it has some serious disadvantages of leachate contamination with soil, groundwater and the environment [2], not forgetting high operating and construction costs for sanitary landfill. This landfilling method cannot encourage the further resource utilization of fly ash, hence alteration of MSWIFA into secondary resource and the development of recent technologies for the fly ash treatment has gained interest over the past years [3]. Fly ash is estimated to be 2-5% of the MSW mass. Zhang et al., [9] estimated that the production of fly ash in China will reach (2.9–7.3) $x10^6$ tons in 2020. Many projects have been encouraging the reuse of ashes over landfilling. Several researchers from various countries such as the USA, China, Japan, Belgium, Sweden and the rest, have introduced different treatment techniques for the elimination of toxic substances in MSWIFA. Also, a European working group called "Phoenix" worked on finding practical solutions related to the management of MSWI residues [10]. The most commonly used early treatment methods of heavy metals in MSWI fly ash by the 1992 legislation were; acid extraction process, cement solidification process, melting process and chemical stabilization process. With cement base material, extraction by dissolution into acidic or alkaline medium and sintering or vitrification [11]. In Table 1 below, we outline examples of common case studies where these early treatment methods are applied.

2.3. Cement Solidification

Cement solidification involves the mixing of MSWIFA with cementitious material to reduce the harmful waste from leaching into the environment. Solidification is not just a process to bind waste into solid products using cement materials, other materials like kiln dust, lime and phosphate can also be used [12]. The main purpose of solidification is to reduce the long-term effect of heavy metals in disposal sites from leaching in to the surroundings. Most plants mix cement and fly ash for solidification before disposal because immobilization of heavy metals using cement and other solidification agents often yields relatively low stabilization to leaching after a long period [13]. Over the years Portland cement has been used with fly ash for concrete production. According to Jakob [14], three different cement solidification technology exist that is; solidification of unwashed fly ash, solidification after neutral/basic washing and solidification after acid washing. Shi and Spence [15] design a cement base formula for the solidification/stabilization of waste, while discussing the compatibility between cement and waste materials. Jianguo et al., [16] investigated the stabilization of heavy metals in MSWI fly ash using a heavy metal chelating agent. Results showed that heavy metal chelating agent was a better stabilization for heavy metals than a chemical agent such as sodium sulfide and lime. Malviya and Chaudhary [17] did a review on hazardous waste bearing heavy metals such as sludge, filter cakes, slag and fly ash that affect the properties of cement and other binders. Youcai et al., [13] worked on the chemical stabilization of MSWIFA, among the chemicals used it was discovered that sodium hydroxide, was not suitable for the extraction of heavy metals in the fly ash, rather sodium sulfide and thiourea are effective treatments for MSWIFA. A more stable and simpler treatment method of fly ash was developed, the Acid extraction-sulfide stabilization process (AES process), where the fly ash is acid extracted and stabilized with NaHS [7]. Bosshard et al., [18] experimented while adding four additives; NaOH, Na_2S, Na_3PO_4 and a combination of NaOH and Na_2S in a ratio of 1:1 to the curing of asphalt and MSWIFA. Results showed that every additive could reduce the leaching rate of heavy metals in the fly ash, but Na_2S had the best stabilization effect of heavy metals in the asphalt solidified body. When asphalt is mixed with fly ash at a certain temperature and ratio, a saponification reaction occurs causing the harmful substances in the fly ash to stick to the asphalt to form a solidified body.

2.4. Melting Process

The melting process immobilizes heavy metals, reduces the volume of the fly ash, and has stable slag properties. When properly managed thermal treatment can produce suitable materials for further utilization that is; the melting slag can be used as a resource again [19]. The melting process works by keeping the temperature at 1400°C in a furnace by electricity or fuel combusting. The melted-solidified slag can be used as construction material for road and land reclamation. Guerrero et al., [20] investigated the effect of hydrothermal treatment on MSWI fly ash. Results show that 100% of the chloride and metallic aluminum from the fly ash can be dissolved. Sun et al., [21] used the sintering of MSWIFA by microwave energy, the authors concluded that the sintering of MSWIFA decreases the Toxicity Characteristics Leaching Procedure (TCLP) of heavy metals. Lee et al., [22] stabilized the fly ash by sintering at a temperature of 1200°C, the dense and glassy structure formed encloses the heavy metals present making it very difficult for leaching. According to Li et al., [4] the decomposition efficiency of dioxins reduces with an increase in melting temperature. The migrations of heavy metals elements during the melting of MSWI fly ash are quite different that is Cr, Zn and Ni are usually nonvolatile metals while Cd and Pb are volatile [23]. The most common thermal treatment method is by mass-burn technology. Shi and Kan [24] proposed an experiment on the leaching behavior of heavy metals in MSWIFA used in concrete. The experiment results show that the effect of cement on the immobilization of fly ash in MSWI is good.

2.5. Acid Extraction

Acid extraction involves the addition of organic or inorganic acid to recover heavy metals in the fly ash. Some researchers use inorganic acid (hydrochloric, sulphuric, or nitric acid) to recover heavy metals from the ash [25]. Wan et al., [26] did an experiment of chemical extraction on fly ash samples from a large-scale municipal solid waste incineration plant located in East China. He studied the leaching characteristics of heavy metals such as Zn, Pb, Cd and Cu in MSWIFA. Xue et al., [27] used hydrochloric acid as an extractant to leach out heavy metals (Zn, Cd, Pb, Mn, Ni, Cr and Cu) from fly ash under microwave acid extraction conditions. Hydrometallurgical processes occur when the heavy metals can be removed from fly ash by washing in an acidic medium. The heavy metals are dissolved in an acidic solution. Wan et al., [26]. The transformation of the mineralogical species of the fly ash during the sequential extraction was studied using X-ray fluorescent (XRF) and X-ray powder diffraction (XRD). Zhu et al., [28] suggested an acid washing with sulphuric acid, phosphoric acid, and some chemical additives. These acids showed good results for the removal of Zn, Pb, and Cu.

2.6. Chemical Stabilization

The chemical stabilization method uses different chemical agents to react with the harmful substances present in the fly ash. Chemical agents can be divided into organic and inorganic agents. The most commonly used stabilizing agents are; phosphate, bleach, gypsum, sulfides and polymer organic stabilizers. So many methods have been suggested to stabilize fly ash in other to reduce leaching. Nakayama et al., [29] proved that organic agent chelating treatment of heavy metals in fly ash is better than inorganic agents. Lee et al., [22] stabilized fly ash by sintering it at about 1200°C, the glassy structure formed encloses the heavy metals making it difficult for leaching. Notwithstanding, Chou et al., [30] used an inexpensive chemical reagent polysulfide for the stabilization and solidification of lead in MSWIFA. Polysulfide agent generates a small quantity of hydrogen sulfide gas and obtains a long-term stabilization of lead.

Table 1. *Metal recovery from MSWI fly ash using the various treatment methods.*

Treatment method	Additives	Metal Recovery	Country	Authors
Solidification/ chemical Stabilization	Chelating argent	Pb, Cd, Zn and Cr reduce to over 90% with 0.6% chemical dosage	China	Jianguo et al., 2004
	Phosphate	Zn, Pb and Cu	France	Piantone et al., (2003)
	Sodium sulfide	Pb and Cd have satisfying leachability toxicity standard of 0.5g of Na_2S with 5% fly ash	China	Youcai et al., 2002
Geopolymerization	Red mud	Fe (86%), Ni (83%), Cr (58%), Zn (86%), Cd (99), Pb (98)	China	Geng et al., 2020
	Red mud	Fe	China	Chen et al., (2017)
Acid Extraction	HCl	Pb, Mn and Zn were recovered at 100%	Japan	Kurashima et al., 2019

3. Recent Studies on the Treatment of Municipal Solid Waste Incineration Fly Ash (MSWIFA)

Recent methods are trying to explore sustainable ways of treating MSWIFA and also add more flesh to some of the early treatment methods. Solidification or stabilization is one of the most widely used methods across the world, most especially in China. This technology has been reliable and efficient over the past years [31]. The use of solidification or stabilization method has reduced the use of Portland cement. According to Youcai et al., [32] Portland cement, phosphoric acid, and chelating agents are the binders or additives commonly used in the past. Recently the disposal of MSWIFA with Portland land cement has had opposition from the public due to high cost [33]. Due to these, other methods that can solidify or stabilize MSWIFA with other waste are sorted after for the treatment with MSWIFA. Mu et al., [34] use ignited fishbone richer in hydroxyapatite (HAP) for heavy metals stabilization in MSWIFA. With the advantage being that the HAP had no potential risk to the environment. Li et al., [35] studied the feasibility and effectiveness of silica fumes on the stabilization of heavy metals in MSWIFA ash. In their study, 8 different pastes were prepared and tested. Results showed that the addition of silica fumes could reduce the leaching of toxic heavy metals. Tang and Steenari [36] recovered copper and zinc from MSWIFA by a hydrometallurgical process based on combining leaching and sequential solvent extraction. LIX860N-I and Cyanex 923 were used to separate Zn and Copper from their acidic ash leachate giving an efficiency of 99% and 90% respectively. Phua et al., [37] effectively remove 90-95% of chloride from fly ash by the washing method. This method brought back clashes from Yang et al., [38] who raised some pertinent issues on the shortcomings of the washing method. This method releases heavy metals such as Cu, Pb, and Zn in the leachate which causes adverse environmental problems. Weibel et al., [39] extracted heavy metals from MSWIFA using hydrochloric acid and sodium chloride solution. The treatments of MSWIFA by modifying microwave-assisted hydrothermal process. Zeolite was used to absorb the heavy metal ions present in the fly ash [40]. Čarnogurská et al., [41] showed that heavy metals sealed in vitreous slag are low volatile heavy metals (Cr and Ni), contrary to Cd and Pb which exhibit a strong volatile property. A comparative study was done with original fly ash and vitreous slag, melting/vitrification slag is significantly lower than that of original fly ash because vitreous slag can seal heavy metals from fly ash [42]. Geopolymer is an inorganic polymer conglomerate developed by Joseph Davidovits in the 1970s. Geopolymer is produced from materials containing aluminosilicate for example; red mud, kaolinite, metakaolin, MSWIFA, coal fly ash and blast furnace slag [43]. Geopolymer is an innovative binder for solidification/stabilization technology. It utilizes MSWIFA and red mud as raw materials to form a cementineous material. The storage of fly ash has seriously damaged the environment, so new technologies are sorted after for the treatment of this hazardous waste. Geopolymer is better than Portland cement because it has better durability and lowers CO_2 emissions. These aluminosilicate compounds have found several applications in environmental and civil engineering such as in soil stabilization [44], heavy metals immobilization [45] and cement utilization. Some researchers such as Zheng et al., [46] investigated the synthesis of MSWIFA-base geopolymer with water, after washing with water for pretreatment to immobilize heavy metals. Ye et al., [47] co-treated MSWIFA with red mud to immobilize the heavy metals. The high alkalinity present in red mud was exploited for the dissolution of silica in the fly ash and red mud. It was concluded that the strength of the end product was directly proportional to the Si/Al ratio [48]. Liu et al., [49] co-treated MSWIFA with granulated lead smelting slag using a geopolymer system. Results from this study showed that the comprehensive strength of the geopolymer matrix reaches 15.32MPa after curing for 28 days. This is because granulated lead smelting slag contains more SiO_2 and Al_2O_3. Geopolymer from fly ash and red mud using sodium trisilicate and sodium hydroxide at ambient conditions are reported that the strength of the end products increased with prolonged curing up to 6 months, while preliminary curing at 100% relative humidity showed negligible strength improvement. It was reported that 5–20% red mud improved the compressive strength of fly ash based geopolymer activated with 6M NaOH [50]. MSWIFA was added to clay bricks and fired at a temperature of 1000°C, the physical and mechanical characteristics of the brick's changes, that is the fly ash influences the mineral composition of the clay brick [51]. At high temperatures, Pb and Zn are encapsulated inside the clay brick reducing their leaching values [52]. Jordán et al., [53] added 1-10% fly ash with 15-35% marble waste to a ceramic brick molding compound and fired at a temperature of 975°C – 1050°C. Results showed that the higher the fly ash content, the flexural strength decreases and the water absorption increase. Li et al., [54] use red mud and MSWIFA to prepare RGM by mechanical activation. The amount of MSWIFA used as a binder with red mud was 30%. The utilization of several additives has been carried out to improve strength and durability. The role of particle size fraction of red mud and fly ash on the geopolymer properties were investigated by many researchers [47]. The immobilization of MSWIFA using Bayer red mud through the geopolymer technology, where the heavy metal in the fly ash was transformed from leachable fraction into inactive fraction difficult to leach out. The result shows that the solidification/stabilization effects for heavy metals of red mud-based geopolymer exhibit the following order. Zhang et al., [55] reported that increasing the red mud content in the experiment decreases the strength of the fly ash geopolymer. Hu et al., [56] carried out an experiment using 20%, 50%, and 80% of red mud content with fly ash. results show that a blend of 50% fly ash and 50% red mud produce a geopolymer paste with 9.2-43.1MPa of 28days compressive strength. On the other hand, He et al., [57] applied the same experiment and obtained compressive strength of 13MPa. Other researchers like Galiano et al., [58] activated the mixture of coal fly ash, MSWIFA, and alkali solution to prepare geopolymer for the immobilization of heavy metals in MSWIFA. Liu and Chu [59] use MSWIFA, red mud, and sodium silicate to prepare red mud geopolymer material (RGM) by mechanical activation. The result showed that RGM has good stability and long-term durability and can solve environmental pollution problems. Zhang et al., [60] use 30% bauxite calcination-method red mud, 10% fly ash, 30% clinker, 8% gypsum, 21% blast furnace slag, and 1% compound agent.

Geng et al., [61] studied the utilization of MSWIFA (10-50wt %) and red mud (40g) through coal-based reduction and magnetic separation to recover crude alloy and clean slag. The result showed the recovery of metals that are an iron alloy, secondary fly ash, and vitrified slag from MSWIFA and red mud through the co-reduction process. The recovered element percentages were 98.9% Cd, 98.2% Pb, 86.7% Zn, 83.4% Ni, 76,6% Fe, 74.5% Cu, and 58.4% Cr. These results showed high and efficient recovery of Fe (96.47 wt. %) from the Fe-Cu-Ni-Cr alloy. Chen et al., [62] recovered Fe from MSWIFA and red mud. The crude alloy obtained from this process was used for weathering steel production. Moreover, the iron oxide in red mud and the siderophile metal compound in MSWIFA may be reduced to their metal phase to form the alloy. Zhou et al., [63] use Bayer red mud and coal gangue to prepare geopolymer precursor through mechanochemistry-alkaline activation which was used for the solidification and stabilization of municipal solid waste incineration fly ash. The TCLP test and the comprehensive test show that more than 99.6% of heavy metals in geopolymer could be immobilized when the geopolymer precursor exceeds 60%. Bajpai et al., [64] did a comparative study by investigating the activation of fly ash-base geopolymer paste modified by red mud and silica fumes. The results revealed that the water absorption of fly ash geopolymer increase with red mud. Compressive strength increases with the addition of modifiers and geopolymer containing silica fumes possess the highest compressive strength among the three. Singh et al., [65] studied the utilization of red mud (40g) and fly ash (60g) coupled with combustible additives such as sawdust to prepare lightweight foam brick which is susceptible to earthquake forces. Water washing helps remove chloride and salts from the ash. This method aims to reduce the leachability, solubility and toxic substances present in the fly ash using either an additive or a binder to immobilize the toxins in the MSWIFA. According to (Yu et al 2016) chlorination agents ($MgCl_2 \cdot 6H_2O$) improve the volatility of some metals; Cu-38%, Zn-95%, Pb and Cd-95%.

4. Comparative Analysis of the Advantages and Disadvantages of MSWIFA Treatment Methods

The different treatment methods of MSWIFA are aimed at carefully treating the harmful substances in the fly ash. From past research studies, it is observed that; chemical agents, chemical stabilization and cement solidification greatly influence the stabilization of heavy metals in MSWIFA. As compared to the melting/vitrification method which greatly influences the removal of dioxins. Early treatment methods like landfilling are cheap due to low operating costs, they generate a great source of energy and are eco-friendly if the technology is well designed with good soil lining and a leachate management system. On the other hand, landfilling sites are vulnerable to collapse, and can easily pollute air and groundwater.

The vitrification process consumes high energy and its equipment are very expensive with an inferior ability to immobilized heavy metal. However, this method reduces the volume of the treated waste to 60%. Moreover, it is resistant to leaching and is recognized as one of the most stable and safe methods because it stabilizes both heavy metals and decomposed dioxins in the melting process at a temperature of 1100°C with an efficiency of 99% (Yan et al., 2004). In addition, large numbers of heavy metals will be released with the soluble salts through water washing. Vitrification helps remove salts and chloride from the ash.

The acid extraction process is simple and easy to operate. The dehydrated soluble salts in the treated product are few and easy to transport (Sun et al., 2016). The soluble salt in the ash is dissolved in the water, which improves the treatment effect and increases stability. In other to ensure maximum recovery of the heavy metal, the concentration of acid must be high, the leaching of the heavy metals depends on the type of extraction solvent, PH, as well as the liquid to solid ratio. In chemical stabilization, the setting time and curing time can be controlled. This process improves soil strength and soil permeability. However, the cost of chemicals used in stabilization is expensive and the effect on dioxins is weak. Geopolymerization has lower CO_2 emission and better durability compared to Portland cement but the treatment methods are very costly. MSWIFA base geopolymer exhibit a lower comprehensive strength when the SiO_2 and Al_2O_3 content or molar ratio is low. Cement solidification is a well-known technology, coupled with wide usage, availability of chemical ingredients, low equipment and operation requirements. This method is known for its good impact and compressive strength, preventing the leaching of heavy metals. A huge amount of cement is required to give durability to the cemented solid and Compounds may degrade after a lifelong stockpile in the landfill (Shukla et al., 1992). As shown in Table 2 below, the different treatment methods for MSWI fly ash were systematically compared using three key criteria (treatment efficiency, cost and operability), to depict their respective advantages and disadvantages. Base on the results it was observe that land filling, cement solidification and water washing were cheap in terms of cost than the other methods.

Table 2. *Comparison of advantages and disadvantages of the various treatment method of MSWIFA.*

Comparison Criteria	Land filing	Cement Solidification	Chemical stabilization	Acid extraction	Vitrification/Melting process	Geopolymer	Water washing
Treatment Efficiency	Fair	Good, prevent leaching of heavy metals	Increases soil strength	Good removal for Zn, Pb, and Cu	Stabilizes both heavy metals and decomposed dioxins	Good at recovering heavy metals	Remove chloride and salt
Cost	Cheap	Cheap	Chemicals are expensive	Expensive	Expensive, high-energy consumption	Very costly	Cheap
Operability	Simple and easy to operate.	Low equipment and operation requirement	Complicated	Easy	Complicated	Complicated	Easy

5. Conclusion and Future Perspectives

Though various treatments methods have been used to solve fly ash, there are still some pending problems to be solved; for example, some of the heavy metals cannot be stabilized during the thermal process, while the solidification or stabilization method is poor under acidic conditions after a long aging period. Most of the recent studies are adequately disposed of by traditional methods on a laboratory scale. More research is needed for the application of these technologies on a large scale. So, promoting large and economic scale treatment of fly ash is still the focus of future research. Research utilization of the treated product is still the main issue to be looked out in the future. In addition, new technologies are working on the Zero waste principles where efforts are put to reduce the solid waste generation to nothing or encourage the recovery of solid waste through Composting, or Reuse. This policy discourages the dumping of waste in landfills, oceans, or incinerators. Other theories on the zero-waste concept go beyond recycling and composting at the tail end of the product's life cycle but envision the use of materials from the beginning of the product design that preserves value, conserve natural resources and are environmentally friendly. So, implementing the zero-waste policy will take away all waste discharge on land, air, water bodies that are a threat to human lives, animals, plants and the entire planet. The principal goal of this policy is aimed at eliminating waste rather than manage waste.

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