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Combination of energy production and plastic waste management

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Abstract: One of the biggest tasks of the environmental science is creating more economic and environmentally friendly energy sources. The enormously increasing amounts of waste materials are also a huge challenge for the environmental protection. Significant parts of the waste materials are plastics or man-made polymers. The treat of the plastic wastes can be in three ways: reuse, energy recovery and landfill. The recycling and reuse of the plastics are unsolved problem recently. The present states and difficulties of these techniques are shown in this paper. The incinerations of the polymers seem a good solution, because they have very high energy content per volume. The uneven energy consumption requires peaks in the production of energy seasonally. The energy consumption is higher in winter than in summer in northern part of Europe. Such a seasonal deviation of energy consumption can be compensated with the waste burning in winter during the cold weather. The significant portions of municipal wastes are burnable and hardly biological degradable (e.g., polyurethane, PET, PVC, PE, etc.). Moreover, several types of them cannot be recirculated. The plastic materials can be used for high efficiency energy production in a big extent. This paper is mainly a review type, but we also proposal for the future: the plastic waste materials must be collected and stored during the less energy consuming period and burn them when the energy requirements are high. The selected burnable waste can be collected during the whole year period and stored in compressed forms. The abandoned open cast mines are appropriate for such depots. In this way the consumption of fossil fuel will significantly be reduced, and the waste stream will be decreased. Several alternative ways are also shown for the use of plastic waste in this paper.

Keywords: Energy management, harmonization, plastic materials, waste management, incineration

I. INTRODUCTION

The recent time is being called polymer age since the middle of 20th century [1]. Practically the modern life cannot be imagined without plastic materials. Nowadays the production of plastics is more than double by volume than the production of crude steel production worldwide (Fig. 1) [2].

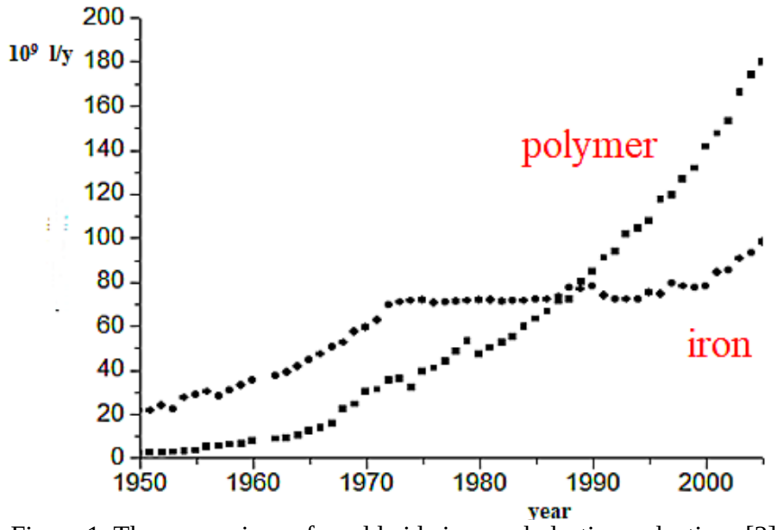

Figure 1. The comparison of worldwide iron and plastic productions [2]

The global plastics waste production reached 360 million tons in 2018, and Europe took 61.8 million tons share of it [3,4]. The 40% of world productions of plastics were used as packing materials. The success of polymer originates from various sources. They are rather cheap and versatile materials. They can be produced and formed among mild conditions. They contain only traces of poisonous chemicals (plasticizers, starting materials etc.).

On the other hand, such an enormous volume of the plastic products results in very big amounts of wastes. Overwhelming part of the products becomes waste [4]. Majority of plastics are persistence materials. They are non-biodegradable materials or hardly decomposing compounds. Moreover, the bio originated wastes can be composted, which processes are disturbed by the presence of significant portion plastic wastes [5]. The selective waste collection, however, can overcome for this drawback of plastics. The pollution effects of plastic partly caused the low-density feature of the plastics. The majority of the plastics float on the water surfaces disturbing the life conditions of vegetation under such cover. The plastic layers on the surface trammel the diffusion of the oxygen from the air to subsurface region of water creating oxygen poor conditions, can promote mass fish mortality. In addition to, the plastic layers adsorb the sun radiation, decreasing the photosynthetic abilities of subsurface vegetation [6]. Moreover, the fragmented polymers, the nano and micro plastics are toxics coming from their sizes [7].

Recently one of the most important goals of the environmental protection is to reduce the enormous amount of plastic waste pollution. The decrease of production of plastic also reduces the amount of plastic wastes. Non synthetized polymer products cannot pollute the environment because they can decompose easily in the nature. The less prodigal packaging material usages are one of the main goals of environmental protection. The other important goal is increasing the recycling and reusing rates of the used plastics. The energy recovery is a meaningful part of the reuse techniques [5, 8]. It is obviously that, the energy consumption of the modern world cannot be based on fossil fuels in the future. The plastic wastes can be considered as supplementary energy sources, but there are several other ways of utilization of the used plastic materials.

It is important to draw the attention, the plastic themselves do not pollute the environment. The plastic pollutions caused by human population with their inappropriate waste managements and their prodigal attitudes.

Subject of this paper is to show the seriousness of the plastic pollutions. We are presenting various possible solutions methods for the reduction of the plastic pollutions, including their energy use. The theme of this paper is important not only from the point of environmental science, but it is also useful in education aspects too [9].

II. GENERAL CHARACTERISATION AND DESCRIPTION OF POLYMER MATERIALS

A polymer is a substance or material consisting of very large molecules, or macromolecules, composed of many repeating subunits. Plastics are a wide range of synthetic or semi-synthetic organic polymer compounds. They build up chemically connected monomers reaching several thousand molecular weights. Generally, the plastic molecules themselves are indigestible and non-poisonous persistence materials. Their toxic effects come from their additives (e.g.,ftalates) or the remaining traces of their monomers and oligomers (e.g., styrene, bisphenol-A, vinyl chloride). Namely these monomers are rather reactive having toxic features. The micro and nano plastics can cause trouble with their chemical features. Their toxic effects cause their particle sizes. For example, the small particles can inflict, silicosis type diseases independently from their chemical composition [7]. The indigestible plastics particles may deposit and pile up in the digestion systems of various animals which were demonstrated with belly content of birds of Midway Islands [6]. The swallowed nanoparticles clog the ingestion tracts of fish larva's [10]. Some types of the plastics are biodegradable, but the majority of them non or hardly biodegradable materials. Originally this non degradable feature was expected as advantageous features in their use. On the other hand, the environmental difficulties come from these non-degradable features. Very huge amount 359 million tons of the plastics waste were produced worldwide, with 61.8 million tons European share in 2018 [3, 4].

III. PLASTIC WASTE MANAGEMENT

Approximately the same amounts become wastes as the plastic production yearly. Not only the significant parts of recent yearly produced plastics are discarded, but previously produced materials also have transformed wastes in the same year.

The volume of the plastic waste can be reduced, decreasing the production volume of produced plastic. Stopping the prodigal plastic use is an effective way to decreasing the waste flood. The packing materials have almost 40% share in the European plastic production [4]. The more economic and environmentally friendly packing must overwrite the recent spectacular and marketing-oriented packing habits. These tendencies can be confirmed by authorities with increased product charges of the plastic packing use.

Only parts of the plastic wastes are collected selectively. 29.1 million tons of plastic were collected selectively from the 61.8 million tons plastic productions in Europe [4]. It seems more than the half of the used plastic volumes were not collected selectively or were not collected at all.

The situation of the plastic pollution is rather bad, because the significant part of the plastic waste is not collected at all. Unfortunately, the voluminous part of discarded plastic can reach the oceans [11, 12]. Yearly 8 million tons plastics reach the ocean without any treatments or selections [12]. The parts of the thrown away

plastics gather in ocean surface [6]. The Great Pacific Garbage Patch is the largest accumulation of plastic waste in the world (Fig. 2). This huge garbage accumulation has bigger territory than France close to Midway-Islands. It is consisted of 2.41 million tons plastic garbage in 1.6 million square kilometers [6]. The more meters thick plastic blanket adsorbs the sun radiation, preventing the photosynthesis of vegetations under this cover. On the other hand, this big amounts of plastics of Pacific garbage patch are not only garbage, but they can be used as raw materials of energy production.

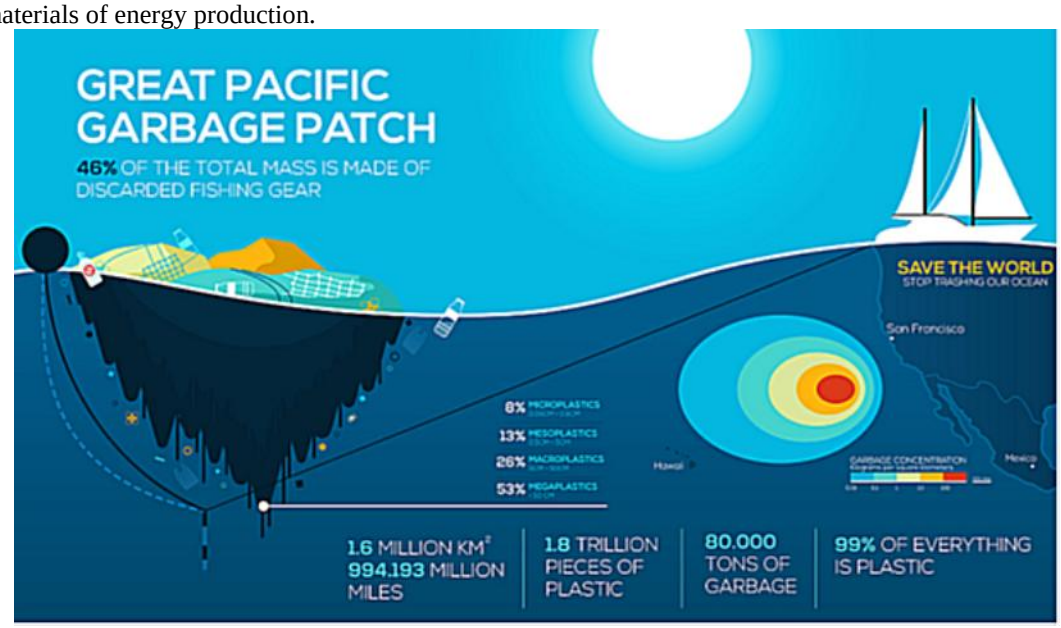

Figure 2 The big garbage patch at Midway-Islands [6]

The treatment of plastic waste is unsolved recently but is necessary to overcome this trouble urgently. First of all, the selective collection of the plastic wastes has to be solved with high efficiency. Unfortunately, less than the half of the plastic waste is collected separately todays. For example, 275 million metric tons of plastic wastes were produced by coastal countries, and 4.8 -12.7 million metric tons were discarded into the oceans in 2010 [12]. The European plastics manufacturers are committed to reach 60% rates of reusing and recycling for plastic packaging by 2030, 100% rate by 2040 [11]. According to other authors the recycling efficiency cannot exceed 70%.

IV. THE FATE OF THE SELECTIVELY COLLECTED PLASTIC MATERIALS

There are three ways of the fates of plastic materials: recycling, energy recovery and landfill [4].

The most effective selective waste collection is the selective collection in site. The households can be directed toward to selective waste management with the appropriate taxation policy of authorities. The selectively collected waste must be transported and deposited also dividedly. The separations of different wastes are rather expensive in the waste yards. The effective separations of plastic waste can be done by manually in a big scale [11]. Generally, the workers stand along a conveyor belt picking up the visually recognized plastic objects with their hands [13]. Such selections are nor profitable among the European salary conditions, without changing the recent taxation and subsidization conditions. The situation has become more serious since China banned the plastic waste import. [14]. Namely, China imported approximately 45% of collected plastic waste in 1992-2018 period.

Of course, there are several experimental methods under developments for the automation of waste selection methods, but they are not widespread routinely in big scales. The selection can base on the infrared absorption spectra of different wastes [15]. Another way, the selections is executed according to the density differences of the wastes [16]. In this method, one type of the solid wastes float in the surface of liquid, but other types accumulate on the bottom of the selection liquid. The separations can be adjusted by the density change of the liquid.

V. SELECTIVE PLASTIC WASTE TREATMENT

The collected plastic waste can be treated in different ways: recycling, energy recovery and landfill. The selective waste collections push the plastic waste treatments toward to advantageous direction with increased

rate of recycling and energy recovery. The fates of the plastic wastes show in a significant improvement recently in Europe according as the Fig. 3 shows [4].

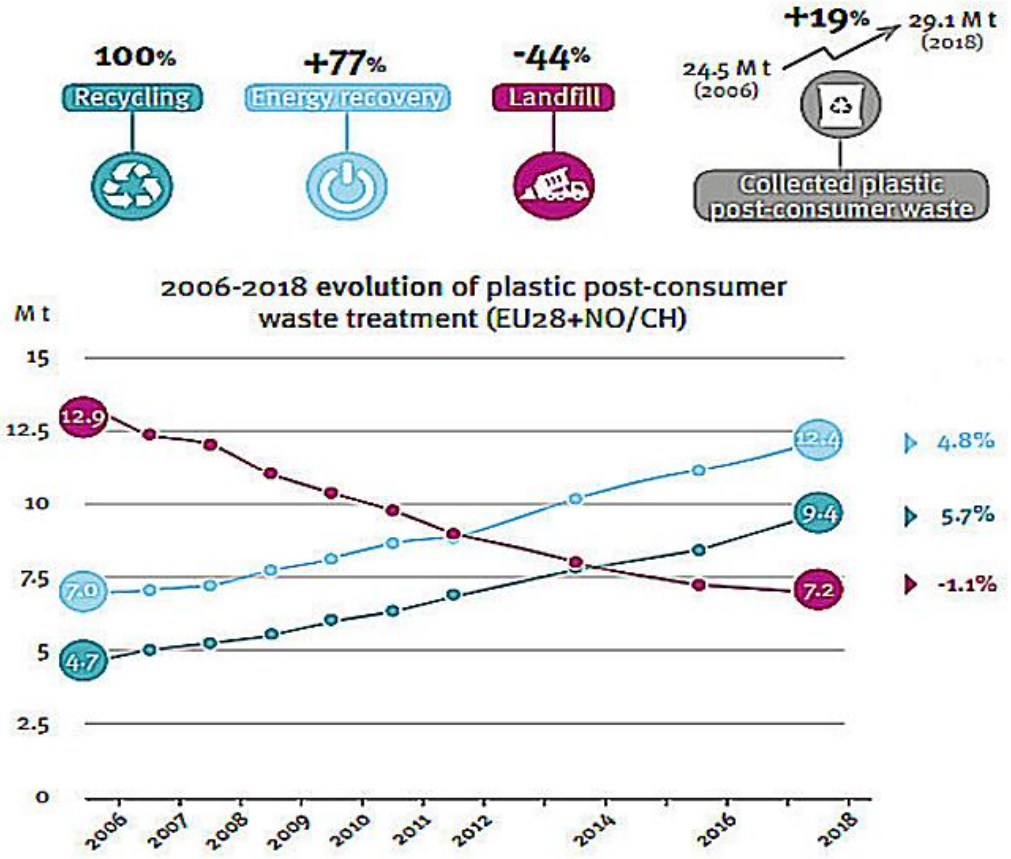

Figure 3 The trends in the fates of plastic waste in Europe between 2006-2018 [4].

The amounts of collected waste have increased with 19% from 24.5 million tons to 29.1 million tons, more steeply than production amount of plastic materials. The ratio of energy recovery and recycling increased steeply, and the ratio of landfill decreased greatly. The expression landfill covers also the non-selectively collected plastic wastes. Even the absolute amount of landfills also has decreased. These tendencies are promising, but the landfills still share 18% of the plastic wastes.

The recycling materials can be used in original forms of objects as the bottle redemption and refilling methods do. The refilling of the plastic bottles requires extra cleaning and well-organized logistic network. These direct recycling process, however, do not pay off among the recent taxation and product charge conditions. Another way of recycling to create new products from the plastic, making textile from the grinded PET bottles or use them as raw materials of art objects.

An efficient way is to decrease the flood of PET bottle to produce soda at home. There are commercialized instruments with more than 100 times refillable bottles with carbon dioxide cylinders. The contents of these cylinders are sufficient for production 80-liter soda [17]. Such an instrument is appropriate to produce more concentrated soda, than the sodas are sold in PET bottles. Shrinking of the volume of discarded PET bottles is also an efficient way to reduce the plastic waste flood. The instruments are recommended which grind or crush the bottle at home. The instruments are not recommended, which shrink the bottles with heat. These methods mold the traces of original contents and labels of the bottles inside of the shrunk plastics. This molding shrinking process results in hard compacted plastic structures, which is unpractical from point of view grinding process in the reusing cycle.

A rather popular way for recycling is the gridding, molding, threading, weaving and sewing, with everyday objects end products. It is trendy to wear suits, shoes, or bags from recycled plastics.

VI. ENERGY RECOVERY

It is well known method, the energy recovery from waste called Refuse Derived Fuel (RDF) [18]. The economical RDF, however, needs financial support or technical improvement among the present conditions in

Europe. The energy recovery seems more easily manageable than recycling. The energy recovery needs less organization and investment than the recycling.

Several research try to solve the energy production of the future using solar energy.

Generally, the energy production of the sun and wind are not harmonized with the peaks of energy consumptions. Increasing role of the solar and wind energy productions, makes necessary to develop good energy storing method. Possible ways of the energy storing are the transformations of electric and heat energies into chemical energy form.

Hydrogen can produce with the electrolysis of water, gaining very high energy content raw material from electric energy. The produced hydrogen can be stored in subsurface natural caverns, for example in a depleted natural gas subsurface mine. The Fischer-Tropsch reactions result in hydrocarbon from the reaction of hydrogen and carbon dioxide [19], producing more safety and easily stored raw materials.

The hydrogen has approximately 3 times higher energy contents (140MJ/kg) by weight than plastics (40-60 MJ/kg), but the energy content by volume of plastics are much higher than hydrogen according to Fig. 4 [20]. The plastic wastes can store more effectively and safety the energy than the pressurized hydrogen or gaseous hydrocarbons. The storage of the plastic wastes is advantageous in compressed bales. The compressed plastic waste bales can be stored in abandoned open cast mines until their use without significant investments.

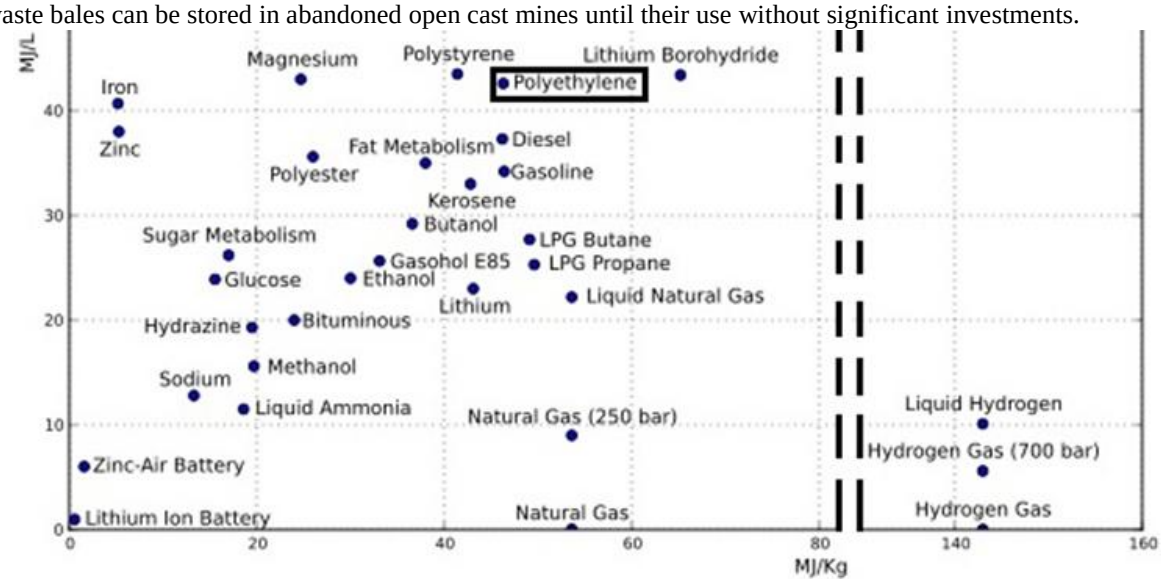

Figure 4: The energy densities of different materials (exception of oxidizing chemical agents) [20]

Moreover, the collected plastic materials can be used as fuel materials in the peak seasons of energy consumptions. Seasonal deviation of energy consumption can be easily compensated by plastic wastes. The summer collected plastic waste can be burnt in winter. The materials of Great Pacific Garbage Patch can be expected potential raw materials of electricity productions. Such of plastic wastes burnings require precautions. The burning PVC can produce hydrogen chloride and extremely toxic dioxins even in ppt level [21]. On the other hand, there are effective techniques for the elimination of toxic materials from the exhaust gases. These techniques are typically used in the up-to-date waste incinerator. A well-designed garbage incineration is good not only for environment, but it can be an artistic object too as the Hundertwasser has designed waste incinerator demonstrated it. The waste incinerator of Copenhagen does not pollute the environment, and also good for skiing and snowboarding from the roof to basement [22].

VII. THE FUTURE OUTLOOK OF WASTE MANAGEMENT

The most important goal is to increase the interest rate in the waste collections and management. The efficiency of the waste management can improve a lot in the following ways.

1. Scaling up the product redemption system is crucial. The worn out and broken products must be taken back into the same places, where they were bought. In this way the waste items are transported back to the producer through the commercial chain. The producer has the greatest ability to resolve the recycling of a used devices. The non-reusable materials are concentrated during the recycling processes, and they can be treated effectively by the specialized firms. The expenses of recycling and demolishing must be included the price of the products. The values of recycled materials can be decreased the price of the products. The expenses of the logistic are also

reduced because the vehicles are packed in both directions. Occasionally, such practices still occur today. The prices of the new cars and some household appliances are reduced with the values of replaced items.

2. The system of packaging materials needs to be significantly improved. The redemption of used plastic and glass bottles and cans should be returned in whole scale, at the same places where the original products were purchased. The return can realize with vending machines of the shops. In this way, the redemption wastes are selected and cleaned to be appropriate forms for recycling. The redemption fee should be set to be incentive, regardless of the real value of the returned packaging material. Level of incitement should be profitable enough for some people (e.g., homeless) to collect the thrown away materials.

3. It is also important to collect other packing materials (e.g., paper, plastic foils composite materials). The most important aspect is the recycling must be profitable for the specialized companies. The recycling companies know the best forms of implementations and the incentive systems for these materials. The cost of the recycling must also be covered by the product fee.

4. The remaining waste would be collected in three fractions, similar to the current system.

4/a.Combustible wastes, which include wastepaper, wood and plastic that cannot be recovered according to the previous points.

4/b. The selectively collected food residues and garden wastes are appropriate for composting. They can be returned to the agricultural cycle after their composting. This fraction could be rewarded by the collector if the waste has adequate quality.

4/c. Other unsorted wastes are not recyclable. The cost of collection and disposal would be borne by the waste producer, similar to the current waste collection system. Secondary fuel (RDF) could be gained from this fraction during waste treatment.

5. The collection of hazardous waste and inert construction waste must be ensured through regular actions. Free of charge collections must organize for these materials from the public. The free of charge mode is important. Namely the cost of remediation and collection of illegal dumping have higher price, than the expenses of the free of charge collections such a type of wastes. The unresolved state of the collection of inert construction waste is indicated by the high percentage of cinder after incineration of municipal waste. The cinder level is 20% of the input waste instead of the theoretically justified few percent.

Administrative regulations and paper works should be avoided and minimized as much as possible. There is no way to ban the production and distribution of certain devices and packaging materials because their collection, recycling or disposal have not been solved.

Of course, the financial and regulatory instruments are not enough for significant improvement of waste management. Further technical developments and innovations are required in the waste management. The environmentally conscious behavior of people is also very important. The education has a crucial role gaining environmentally conscious behavior.

VIII. CONCLUSION

The plastic materials are indispensables in our recent life. The plastics themselves do not destroy the environment. The environmental troubles are caused by the humans with their unsparing and careless attitudes. The attitudes of people must be changed toward to plastic waste.

The waste stream of plastic can be reduced in several ways. The use of decreased amount of packing plastic materials can significantly reduce the plastic waste flood. The non-produced plastics do not become plastic wastes. The selective waste collections and separations of the plastics from other waste materials are another significant ability to make a better waste management. The plastic waste can be used very effectively as secondary energy source. The seasonal deviation of fossil fuel consumption can be balanced with the use of plastic waste as fuel in the peak seasons. The storage of collected wastes are safety and no need big investments. To overcome the plastic waste trouble, need significant improvement in attitudes from education to legislation in the waste management.

IX. ACKNOWLEDGEMENTS

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