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Plasma Technology: An Ultimate Solution for Solid Waste Management

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Abstract

The growth of the population is related to urbanization, development, and industrialization. There found a strong correlation between population, industrialization, and waste production. The famous thermodynamics laws offer insights into the technological/marketing impact on waste production and energy conversion processes. The conventional methods such as land filling, combustion, gasification, incineration, etc. not enough to manage such a huge volume of waste. The non-segregation tendency, consumerism nature makes this waste management work problematic. The paper studies the natural efficiency in the waste management system and also the inability of traditional technology's to handle rapidly increasing waste volume. The plasma-based waste technology is similar to the natural waste management cycle, but with high volume capacity in a short duration. This also has a scope of waste to energy (WtE) conversion. Though plasma has high installation and maintenance costs, revenue generation from byproducts like syngas and slag will create it financially viable.

Keywords: Waste Management; Waste to Energy; Plasma Technology; Gasification; Incineration

Introduction

Technical or economic development is that the basic characteristic of human beings. The demands for product are increasing due to increasing populations and technology advancement. Various energy resources are required to complete our technology product demands. The inefficiency of technological process results in waste production. It can either be in the form of physical waste or heat energy. This waste presumed to be a non-essential qualitative component of industrial production. Technological ability, to absorb and release energy, controls development as well as the surrounding environment. The waste disposal and management is a key factor and mismanagement not only damages the atmosphere, but has a adverse effect on human health [1,2]. The urban areas are witnessing an increasing production of waste to the ever-increasing desire for energy. Such energy thrust also over-exploitation natural resources, and so increases waste quantity. Such huge waste generally goes to landfill space or buried beneath the ground. Such easy waste disposal method neither manages by nature nor by human process, and produce adverse effect. The issue of waste is actually due to a failure of the market (and policy) in some extend. In certain cases, waste and its disposal also constitute an external marketing influence.

Nature also addresses such environmental concerns associated with energy and waste, in terms of the various mechanism involved. Various cycles like water, carbon, nitrogen, etc are vital components in natural waste management. These also involve synthesis, respiration, various living, and nonliving factors, etc. These dynamic

and static processes can be explained with help of laws of thermodynamics. These laws can forecast and also imposed limits on such processes. So these help in reducing and assessing waste effects on environmental. This reveals a different relevant aspect of waste production and management. Social, Income, culture, economic, geography conditions play important role in waste characterizations and analysis. The waste volume is challenging and various kind of treatment are used for waste analysis and some are specific [2,3]. Such waste disposal neither manage by nature nor by human process. Various studies focus on recycle, refuse, and reduce as viable option for waste management. The population, industrialization and adopted technology are key factor for waste management. Recently developed plasma based gasification is latest one in this series.

This work discusses how the concept of matter energy can be helpful in waste management .The waste volume, and its relationship with population, industrialization is discussed in section 2. Nature plays an important role in waste management. The idea of Waste to Wealth Conversion arises as a vital element for waste management, which is discussed in section 3.

The nature play an important role in waste management and how idea of Waste to Wealth Conversion arise is discussed in section 3. The limitation of various waste treatments and how nature inspires plasma based technology will be a better alternative for waste management in last sections. This work show that plasma based technology help in recycling of waste and energy. It also emphasizes waste to energy conversion as well as speedy natural waste conversion.

About Waste Management Scenario

World most countries are well populated and have fastest-growing economies. They are experiencing unprecedented growth in its industrial sector and a rapid urbanization. Since human evolution history, a tremendous changes in population has occurs. The 20th century alone witnesses the world population from 1.65 billion to 6 billion, Figure 1 reflects such change pattern (data source: https://www.worldometers.info). The use of new product has been increase in accordance of population. So waste production is also increasing and world generates around 2.01 billion tonnes of municipal solid waste annually. Recent decade waste generation has increased massively around the world and there are no signs of it slowing down [Global waste generation]. On average per person per day generated wastes worldwide range from 0.11 to 4.54 kilogram. The average world consumption is 0.74 kilogram. The study show that waste generation is growing at fast rate due to large number of producers. Global waste will reach 3.40 billion tones by 2050 [https://www.worldometers.info]. Much variability of per capita waste generation is found in accordance with the size and class of the cities. The waste generations have a positive correlation with income level and also depend on regions. The waste collection play a crucial role in waste management, it rate varies with income levels. The counties with upper-middle- and high-income have nearly universal waste collection. The industrialization led to a drastic change in the type of waste produced. Earlier, there were large quantity (70-80%) of biodegradable waste but now there is only 45-50% of biodegradable waste. The variation in other waste produce including plastic, paper, hazardous, biomedical etc is also found [4]. The low-income region generally dumped openly for it's more than half of the waste being produced. These have vast implications on environment, human health and need urgent action (Figure 2).

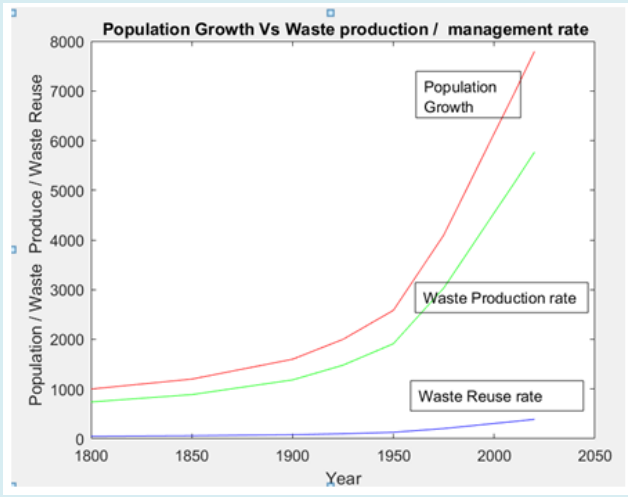

Figure 1: Population growth Vs reuse.

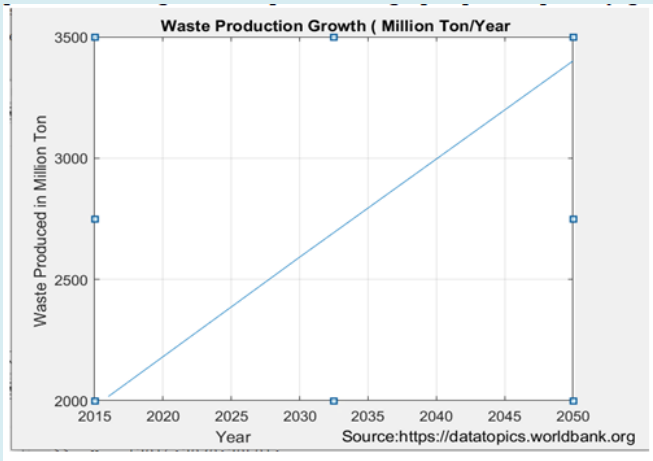

Figure 2: Population Growth Vs Produced.

Waste to Wealth Conversion

Like technology, nature has its own technological systems which can be understood through law of thermodynamics. The natural system working is based on the exchange of matter and energy and rate of transmission is govern by the factors such as Temperature, pressure and heat carriers (such as humidity) etc. The nature utilized all of its output with no waste. Almost every natural process outcome is being utilized as an energy input for next structural / energy processes. The various natural cycle - carbon, nitrogen, water plays a great role in this regards. The food cycle is one of the best examples in this regards. Every process tends towards totality a harmonized complexity which again breaks apart into various channels of special efforts and a tendency to balance matter and energy. The large number of natural organism and process are involved for well balances natural systems [5]. This is one of way of energy and matter exchange management and also a solution to complexity.

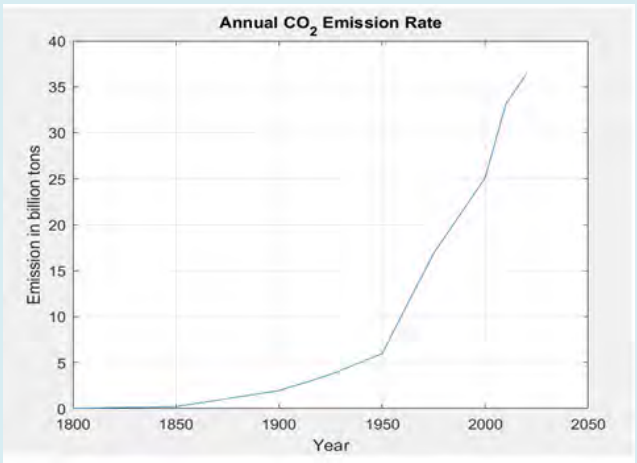

Figure 3: Annual Vs Tons.

The rapid urbanization and industrialization has disturb such cycle, and also disturb the chemical content of the atmospheres at various level. This results in disturbance in heat trapping and effect nature waste management. Figure 3 show impact of carbon concentration component (CO_2 only). The combine effect of all other components have introduced some significant changes in natural waste management system. The nature has sustainable waste management system as far as minimum deviation is concern. The various element and energy cyclic utilized previous process waste, such process are time consuming. The scale of time is main factors for such inefficient waste management system. The exponential growth of population, urbanization and industrialization are increasing gravity of problems [6-8].

Nature waste management provides the concept of waste to wealth among the multiple components of the system. The concepts of minimal entropy change, free energy, Gibbs function are some indication for natural waste minimization. In order to minimize such waste one need either to minimize waste volume under natural limit or to have some technology to work with nature. This can be done either by reducing waste at source and through adaptation of key elements of waste management hierarchy as refuse, reduce, reuse, recycle and recover [9].

Technologies for Waste Management

From last century the land filling is cheapest and easiest way for waste disposal. This open natural treatment is associated with health issues and environmental damage. The associated risk is also get increase due to longer span for natural decay. The modern process like gasification, pyrolysis, incineration etc are waste conversion processes. They are characterized by Temperature, pressure, physiochemical process. The main advantage of such process is waste volume reduction. The temperature and pressure are used to break chemical bonds of waste and generated heat or gas is used for energy generation. Despite all these conservation are also associated with environmental pollutants. The Table 1 provide the comparisons of such technologies on basis of the factors like mass reduction ratio, cost analysis, LCA and Environmental impact. These technologies efficiency depends on waste segregation and treatment efficiency varies with type of waste used in process. In addition-Government is also start focusing on public awareness for higher efficiency [3,10].

From the previous section, nature give the idea of waste management, waste to energy conversion and it also show how important is conversion of matter and energy in waste management. The current waste treatment process are associated with the problems like not having good mass reduction ration and various pollutant are associated with them. The rapid population growth and their demand are basic reasons for increase in waste volume. In view of such scenario it is better to have a process having very high mass conversion ratio preferably hundred percent, no waste sorting requirement and also have a capability of waste to energy conversion can solve our waste related problems.

	Parameters	Incineration	Gasification	Pyrolysis	Plasma gasification
Operating Parameters	Process	To maximize waste conversion to high temperature flue gases mainly CO_2 and H_2O	To maximize waste conversion to high heating value flue gases mainly CO, H_2 and CH_4	To maximize thermal decomposition of solid waste to gases and condensed phases	To maximize waste conversion to high temperature flue gases
	Operating Condition	Oxidizing(oxidant amount larger that required by stoichiometric combustion) in presence of Air Between 850°c and 1200°C under atmospheric pressure	Reducing(oxidant amount lower that required by stoichiometric combustion) Air, pure oxygen, oxygen enriched air, steam Between 550°C and air gasification) and 1000-1600 °C under atmospheric pressure	Total absence of any oxidant Between 500°C and 800°C slightly over pressure	Oxidizing Very high temperature(150 to 5500°C) under atmospheric pressure
Environmental Impact	Mass reduction (wt%)	75	82	84	90
	Residue(ton/ton MSW)	0.22(ash)	o. 2(ash)	0.21(ash)	0.18(ash)
	Ash disposal & production of vitrified slag	No	No	No	Yes
	Pollutant	SO_2 NO_2, HCI, PCDD/F, particulate	H_2S, HCI, COS,NH_3, HCN, tar, alkali, particulate	H_2S, HCI, NH_3, HCN, tar, particulate	-
	Gas cleaning	Treated in air pollution control units to meet the emission limits and then sent to the stack	It is possible to clean the syn gas to meet the standards of chemicals production processes or those of high efficiency energy conversion devices	It is possible to clean the syn gas to meet the standards of chemicals production processes or those of high efficiency energy conversion devices	It is possible to clean the syn gas to meet the standards of chemicals production processes or those of high efficiency energy conversion devices
Cost	Installation	Very high	Moderate	Moderate	High
	Operational & maintenance cost	High	Moderate	Moderate	Very high
	Plant service life(year)	30	30	20	20

Processing Capability	Wet waste handling	Limited	Limited	No	No
	Automation level	Moderate	Moderate	Moderate	High
	Waste sorting required	Yes	Yes	Yes	Yes
	Power generation capacity(MW/ton of MSW)	5	5.5	5.5	5
Energy	Net energy production potential(kWh/ton of MSW)	50	20	40	-

Table 1: Comparison of different waste technology.

Plasma Based technology for SWM

Plasma is the fourth state of matter with equal number of positive and negative particles in equilibrium position. These particles are generated through the electromagnetic force which pulls electron from nuclei. Generally a high voltage current between two electrode is used to create a very high intense beam to remove the electrons from waste in the plasma waste management technology. It will generate a temperature from 1000 degree Celsius to 10000 degree Celsius. Three type of plasma - thermal plasma, cold plasma and warm plasma based on temperature range.

The high temperature and pressure is created by high intense electrical beams to excite and ionize gas molecules. Generated electrons further collide with consequent atoms in-elastically and chain reaction like situation creates more and more ions and electrons. The self-sustaining nature of process provided a steady source of energy with thermodynamical equilibrium. The plasma arc furnace uses a plasma torch which converts the waste into molecules with a useful synthetic gas and power to run generator. The concept of gasification and pyrolysis are used with plasma to have - Plasma Gasification / Pyrolysis technologies. are generally the plasma pyrolysis or the gasification with the concept of Plasma [3,10].

Plasma gasification uses various thermo-chemical process and furnace is part of part of the technology, where such reaction take place. This reaction involves heat energy generation or requires some energy. Few of such endothermic / exothermic reactions are:

$C(s) + H_2O = CO + H_2$ [Endothermic] (1)
$C(s) + CO_2 = 2CO$ [Endothermic] (2)
$C(s) + 2H_2 = CH_4$ [Exothermic] (3)
$CH_4 + H_2O = CO + 3H_2$ [Endothermic] (4)
$CO + H_2O = CO_2 + H_2$ [Exothermic] (5)

The extremely high heat (order of few thousand degree) is generated which are capable of breaking all organic chemical bond and reducing all waste materials including organic material, paper, glass, wood, plastic, paper, glass, etc. to basic elements. This generated heat can also melts metals, which are recoverable. Plasma technology includes high thermal efficiency, waste volume reduction, high energy density, pretreatment is not required, and absence of fossil fuels [8].

Plasma based Technology convert the matter into energy perfectly like nature does for waste management. It will read not only reduce the waste volume but also require very less time for the waste treatment. It is also associated with the very high value output product in the form of synthetic gas and slag. The comparison of plasma with other popular Technology such as incineration, gasification and paralysis with the same operating parameter is already shown in Table 1. The plasma technology have very high volume reduction ratio, less residue, and pollutant gas cleaning with high energy. The plasma based Technology will also eliminate the need of landfill and remove the long haul trucking on road. The various author has claim the very high input cost installation and maintenance and the staff for Plasma base waste Technology such high input is Counter by high value is generated revenue such as electric power value product like Hydrogen Fuel and other chemical in long run the plasma based Technologies we back also create a circular economy as that done by the nature. There are few reason for not having the popularity of Plasma base which technology one of the reason for it that this technology is relatively new and have limited process understanding for awareness. Because is deal with the high energy so associated with lots of safety concern in required various government regulation as well as end user motivation the currently most of the plasma base plant are big in size and have limited commercialization success story [11,12].

Conclusion

Since the origin of life energy play a vital role for the development of humankind. The energy use is associated with technology and energy transformation limitation. The population growth, industrialization, technological limitation has created a huge amount of waste. The natural waste management capabilities has been disturbed by excess waste pressure, also disturb the natural components. Our market policy along with population disturbances has disturbed waste to wealth cycle. The waste management technique like incineration, gasification, plasma etc. are used to reduces the waste volume. The comparison of all these show that Plasma based technology have higher waste volume reduction through matter- energy conversion in short span. Plasma technology mimic nature mass-energy conversion with no residual which will shorten conversion time and no of involved components. The volume reduction ratio, waste to energy conversion, matter-energy conversion nature, will make plasma technology is valuable option for the waste to energy conversion. This will not only stop landfill disposal option, but also have remarkable effect on reduction of filled landfill sites. Recycling and re-using waste with plasma based technology will be attractive options for further increase in waste volume. High initial capital, operational costs of plasma based technology can be taken along with generated high revenue from generated synthesis gas, energy produced from the process. Generated high valuable byproduct can be utilized as resources and create economy circulation. The parameters such as the higher mass-energy conversion, low process time, monetary revenue, environmentally favorable technique make this better waste management technology.

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