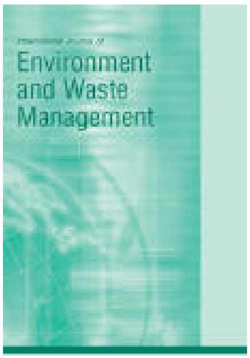

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Mini plasma waste plant: a solution to COVID-19 biomedical waste

Mukesh Kumar, S.K. Singh

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Mini plasma waste plant: a solution to COVID-19 biomedical waste

Mukesh Kumar*

Department of Physics, SSNC,
University of Delhi,
Delhi, India
Email: physics.ssn@gmail.com
Email: sksinghdce@gmail.com
*Corresponding author

S.K. Singh

Department of Environmental Engineering,
Delhi Technological University,
Delhi, India
Email: sksinghdce@gmail.com

Abstract: World environmental health is threatened by biomedical waste. The plastic footprint is increasing by the day due to the ongoing COVID-19 pandemic. Biomedical waste (BMW) due to COVID-19 is creating a problem for the survival of human beings. The high survival rate of the COVID-19 virus in the human body, air, and on any material is a matter of concern. The problem of management of BMW disposal gets aggravated due to increasing waste volume and shortage of waste treatment plants. The waste management technologies such as incineration, autoclaving, chemical treatment, dry heat technologies, and plasma-based technology can also deal with such infectious waste. In this paper artificial intelligence equipped with a mini plasma waste plant model for waste volume reduction and as well as a waste-to-value solution with zero infection risk has been discussed. The proposed waste power plant model with a tunnel and vent webs shall be a better alternative approach for COVID-19 BMW management.

Keywords: bio-medical waste; COVID-19; Covid-19 waste; plasma waste technology; artificial intelligence; risk minimisation.

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Biographical notes: Mukesh Kumar has more than 15 years of teaching, research, and administrative experience at Swami Shraddhanand College (University of Delhi). He is actively involved in the fields of energy and waste. He has published 25 papers, research projects, and organised various conferences.

S.K. Singh is engaged in teaching, research, administration, and consultancy for the last 30 years. Presently is a Head and Professor of Civil and Environmental Engineering at Delhi Technological University, Delhi (formerly

Delhi College of Engineering). He has received numerous felicitations and awards from professional bodies. He has various published papers in waste management's, environmental engineering, water pollution control, water resource management, and environmental biotechnology.

1 Introduction

Waste generated in human and animal treatment, diagnosis or immunisation, or biological research is called biomedical waste (Chartier et al., 2014). In addition to the laboratories, health facilities generate a wide variety of unsafe and hazardous waste. Worldwide around 16.84% of hospitals did not comply with the standard for managing biomedical waste. The healthcare sector produces enormous amounts of BMW with high infection communicable potential/damage capability compared to other waste types. Around 10.25% of health waste is estimated to be infectious (Hirani et al., 2014). This chemical or microbiological risk is mainly associated with waste handling, treatment, and disposal workforce, but healthcare workers and the general public is not far from such risks. This century has faced pandemics at a large scale caused by viruses, namely, Herpes, severe acute respiratory syndrome (SARS) and various respiratory related syndrome, etc. In November–December 2019, a new outbreak in this family was added as the new coronavirus disease.2019. This belongs to a group of very diverse RNA virus that is non-segmented enveloped with positive sense and single-stranded, so-called SARS-CoV.2 or COVID-19. The contagious nature of COVID-19 has caused havoc and has become a matter of serious global concern. Social distancing, lockdown, rapid tests, isolation, etc. measures are used to break the chain reaction (Singh et al., 2020; Singh and Aenab, 2012; Wang et al., 2020).

The health worker's PEE kits (personal protective equipment), surgical facial masks, facial protection, aprons, and gloves have been used to protect people from contaminants and pathogens. The health care facilities and high demand for PPE kits from all walks of life from anxiety about infection in health workers (CPCB, 2019; Govt of India, 1998; Hirani et al., 2014; Pasupathi et al., 2011). This has led to the overuse of personal protection, worsening the problem by generating vast quantities of BMWin this situation. Based on some earlier experiences, research, and limited virus data, the various recognised organisation like World Health Organization (WHO) and the Health Ministry issued guidelines concerning the rational use of infrastructure, medical equipment, and personal protective kits for COVID-19 treatment. The use of personal protection in domestic isolation and individual protection is also accumulating potential infectious waste streams. Even the community worsened the scenario with its indiscriminate use and disposal of masks. The limited infrastructure, trained manpower, storage, treatment plants, and transportation facility for the high risky COVID-19 waste community worsened the scenario with its indiscriminate use and disposal of masks. The non-availability of separate containers in-home and residential areas increases the risk of mixing BMW with the common kitchen/general waste. Such improper disposal of the BMW in general waste puts the health and safety of the community at risk (Mahalaxmi and Arumugam 2017; Ministry of Health and Family Welfare, 2020; Mountouris et al., 2008; Singh et al., 2020). All such concerns are serious ones for BMW in high population areas, low-education level, and developing countries.

The impact of COVID-19 waste on BMW volume can be easily understood from Indian experiences. India has more than six lakhs hospital beds and 23,000 primary care facilities in India, as well as more than 15,000 private and personal hospitals (CPCB, 2019, 2021). The government of India has issued BMW (management and handling) Rules in 1998 and it is mandatory for hospitals, clinics, and different medical and veterinary institutes to eliminate BMW strictly under such guidelines. The amount of BMW has also increased rapidly with the improvement of medical facilities. The safety of public health requires the safe treatment of an enormous amount of infectious waste (Singh et al., 2020). Few studies claim BMW about 50 to 60% of the total solid waste generated and a high infectious waste-related death percentage due to BMW in India (Hirani et al., 2014). The Central Pollution Control Board (CPCB) has reported about 18,000 tonnes of COVID-19 bio-medical waste between June 2020 and 10 May 2021 (CPCB, 2019, 2021), details are mentions in Table 1.

Table 1 COVID-19 BMW (tons)

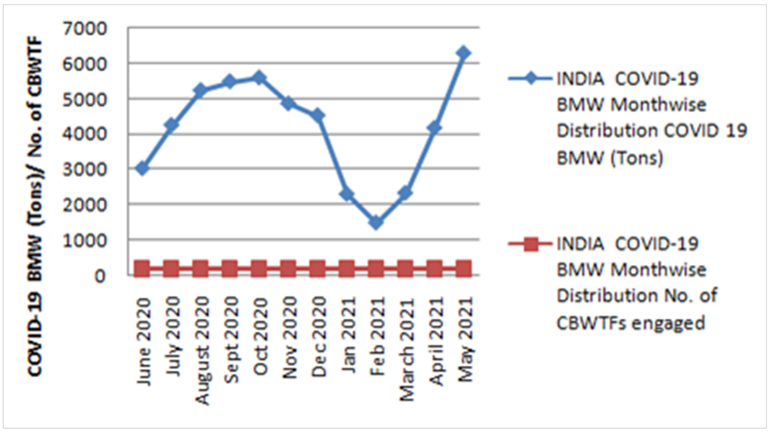
Month	*COVID 19 BMW (tons)*
June 2020	3,025.41
July 2020	4,253.46
August 2020	5,238.45
September 2020	5,490
October 2020	5,597
November 2020	4,864.53
December 2020	4,527.55
January 2021	2,294
February 2021	1,484
March 2021	2,325
April 2021	4,170
May 2021	6,293

Source: CPCB (2021)

This includes from syringes, face masks, helmet suit, plastic covers, gloves and personal protective equipment (PPE) to health care equipment used by both health workers and patients. This amount of COVID-19 related bio-medical waste is increasing day by day. India generated 3,025.41 tones of COVID-19 related bio-medical waste in June 2020 and in next month its show rising trends with a peak of 5,597 in October 2020. Further, it shows a decreasing trend with a minimum of 1,484 tones in Feb 2021. Thereafter, it shows an increasing trend with a value of 6293 only in the 10 days of May 2021. The waste generated by COVID-19 is additional to the regular BMW generation of about 3267.59 tonnes (as of June 2020) (CPCB, 2021).

The present work target and proposed a safe and efficient way of COVID-19 waste generation. One of the possible solutions to get out of this situation is to break the chain through less physical contact. For this we need to shift our BMW management strategies, involving minimisation of human interference, less transportation, and some favourable technological modification. This work analyses the plasma waste technology for COVID-19 waste management in comparison with traditional COVID-19 waste techniques such as incineration, autoclaving, chemical treatment, dry heat technologies, etc. To minimise human interference and to reduces the transportation leakage risk, an underground in-house mini plasma power plant is proposed. The use of vents web with automated control using artificial intelligence help a lot to achieve retro risk target. This will not only serve the purpose of hazards BMW recycling, zero infection risk but also for energy harvesting. Plasma waste management seems to a better alternative approach for COVID-19 management (Munasinghe, 2020; Pasupathi et al., 2011).

Figure 1 India COVID-19 BMW monthwise distribution (see online version for colours)



Source: CPCB (2021)

2 Strategies for COVID-19 waste management

The traditional principle of biological waste management - reduce, recycle, recover, treat, and lastly dispose of CPCB (2019), does not apply to COVID-19 waste, because of its communicable nature. Therefore best practice for such BMW management methods is to avoid the generation of waste at the source or recovering as much waste as possible. The disposing/dumping requires a lot of time and energy and with the risk of infection. This is seemed to a very tedious task, in the situation of less infrastructure, manpower as well as an increasing number of infections. The very first step in COVID-19 waste management is its classification based on infection risk probability. This classification of waste not only helps time-efficient waste management but also helps in reducing waste volume, Usually different colour bags with have clear marking are used to avoids the chances of infection spread among waste handlers. Based on waste categorisation, the bags waste are treated and disposed of, short details of such are available in Table 2 (Chartier et al., 2014; Hirani et al., 2014; Mahalaxmi and Arumugam, 2017; Kumar and Singh, 2021). These risky wastes need to be disinfected first as per the laid down procedure and then packed properly in a double-layered plastic bag before transportation from the generated place/ward. The bag's colour is usually yellow.

Table 2 General Biomedical waste classification and treatment/disposal

Category	*Type of waste*	*Bag colour*	*Treatment and disposal options*
Yellow	• Human tissues, organs, blood components, soiled waste, chemical waste • Infected fluids and discarded disinfectants • Body fluids, clothes contaminated with blood • Microbiology / clinical laboratory waste	Yellow-colored non-chlorinated plastic bags or Separate safe plastic bags or containers	• Plasma pyrolysis • Incineration or deep burial • Autoclaving or hydroclaving • Microwave • Shredding, mutilation, or a combination of both • Pre-treat with nonchlorinated chemicals on-site according to WHO guidelines
Red	Contaminated waste	Non-chlorinated plastic red colored bags or containers	• Shredding/mutilation • Autoclaving / hydroclaving • Microwave or combination of above • Recycle for energy recovery
White (Translucent)	Waste sharps including metals	Separate safe plastic bag or containers	• Dry heat sterilisation • Autoclaving • Shredding or encapsulation in a metal container or cement concrete
Blue	Glassware and metallic body implants.	Cardboard boxes with blue-colored	• Combination of shredding cum autoclaving • Iron foundries disposal

Source: *CPCC (2019, 2021) and Mahalaxmi and Arumugam (2017)*

Table 3 Waste management technologies comparisons

	Incineration	*Pyrolysis*	*Microwave*	*Chemical*	*Dry heat technique*
Process	Controlled combustion in presence of oxygen under high Temperature	Combustion in presence of limited oxygen supply	Disinfection by moist heat and steam generated by microwave energy	crushed hospital wastes are mixed with chemical disinfectants (such as sodium hypochlorite calcium hypochlorite, chlorine dioxide, etc.) and stayed for a sufficient time	Hot air targets waste in a way that causes the waste particles to rotate turbulently around a vertical axis.
Temperature	800°C–1,200°C	540oC -830°C	177 °C -540 °C	-	>100 °C
Mass reduction (w/w%)	90%	90%	10–15%	0	20-25%
Strengths	Incineration is simple operation, of BMW / COVID-19 waste and complete waste destruction	Pyrolysis is complete destruction process for toxins like furan and dioxins	Release less pollutant without gaseous emission and low temperature saves energy	These produce rapid and and stable performance, it has wise spectrum of sterilisation.	This have good compatibility with polymeric material and have reprocessing possibility
Weakness	Energy-intensive, high Capex, toxins release, solid residual waste	The investment cost is high and the need for waste heat value	Disinfection narrow-spectrum sometimes needs to be applied with autoclaving	Does not reduce the volume and mass of BMW	Layers decontamination of trapped virus in particles is questionable
Environmental impacts	Produce bottom ash and dioxin, furans affect environments	Not known and consider a safe technology	Complex impact factors of disinfection	Formed aerosols inhalation can penetrate alveoli, skin atomised disinfectants absorbance can cause cancer	Layers decontamination of trapped virus in particles is questionable

Source: *Kumar and Singh (2021) and Singh et al. (2020)*

The various previous studies Kumar and Singh (2021), Ministry of Health and Family Welfare (2020) and Munasinghe (2020) show that most of the BMW waste generated from hospitals is not infectious/hazardous, no need for special treatment or disinfection. However, the mixing of such waste with other hazardous or infectious pollutants creates problems. This not only increases the volume for special treatments but also not a good economic option. The categorisation or separate storage treatment for hospital waste is therefore a necessary precondition for effective disinfection. So various disinfection and disposal methods should be adopted based on the characteristics of different hospital wastes. It is the government that is responsible for the standards of citizen health and safety. It occasionally issues various guidelines and is based on previous knowledge and practices. If new challenges like COVID-19 or if the need arises, guidelines get updated. Central Pollution Control Board issues the details of such guidelines for hospitalised or Quarantine camps and homecare of COVID-19 patients in India, and many authors have discussed such guidelines (CPCB, 2019).

The various technologies including incineration, pyrolysis, microwave, chemical treatment, and dry heat technique are used for BMW treatment (Li and Jenq, 1993). The technology or combination of technology must be selected attentively based on different factors, such as disinfection efficiency, reducing volume and mass, waste quantity/type, infrastructure, space, and regulatory requirements, etc. The type, thermo-chemical nature of waste, and nature of risk involved are the prime factors for such selection. All these help in waste volume reduction to a greater level, which ultimately minimised waste impact on the human being as well as the environment. Table 3 compares few such technologies based on parameters like temperature, mass reduction, strength, weakness with environmental impact. Ministry of Health and Family Welfare (2020) and Munasinghe (2020).

Various studies have been done on COVID-19 BMW waste management and suggested incineration, autoclaving, microwave, and chemical treatment. Some suggested that COVID-19 highly infectious hospital waste directly to the incinerators, high-temperature burn. Because only about 10–15% of waste is highly infectious, the rest can be with other technologies. The clothes can be chemically treat using NaCl solution or other chemicals. Similarly, the glasswares can be sterilised by autoclaving or microwave techniques. During home quarantine, it is observed that the waste generated is dealt with indiscriminately. The waste is dumped with the municipal waste generated which may cause a spread of coronavirus as it can survive for 36–72 hours depending on the environment. So the generated waste should be collected in a separate colour-coded bin and should be wrapped, marked, and sanitised and the bin should be sent to a designated treatment facility for corona waste or to the nearby medical facility (Mahalaxmi and Arumugam, 2017; Li and Jenq, 1993; Kumar, 2020; Kumar et al., 2021).

The common BMW treatment and disposal facility (CBWTB) is specially designated for the processing of COVID-19 Waste. The detail of such unit engaged during the period June 2020– May 2021 is shown in Table 4. The number of CBWTFs engaged is almost 198 throughout the COVID-19 period. All this leads to COVID-19 BMW volume and needs some technological change because of waste volume and safety (Kumar and Singh, 2021; Kumar and Rana, 2020).

Table 4 Monthwise number of CBWTFs engaged in India

Month	*CBWTF no*
June 2020	193
July 2020	198
August 2020	198
Sept 2020	198
Oct 2020	198
Nov 2020	198
Dec 2020	198
Jan 2021	198
Feb 2021	198
March 2021	198
April 2021	198

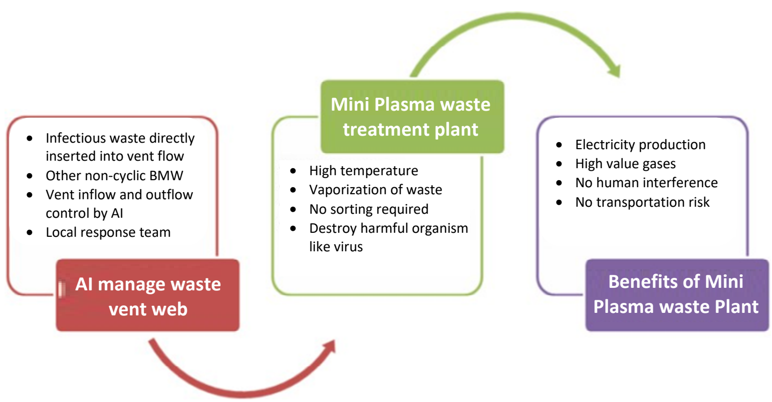
Source: CPCB (2021)

3 Plasma waste technology

Recently scientists use plasma science in waste management. The plasma-based waste technology (plasma pyrolysis /gasification) used thermochemical properties of matter to transform waste into molecular form. This is achieved by heating any type of waste to super-high temperatures, so that waste so melts and then vaporises. Conventional incineration or gasification makes use of the chemical reaction for waste treatment, whereas plasma technology uses high temperatures (anywhere from 1,000–15,000°C) for ionisation. This super-high temperature can most easily be achieved by using the electrical device called a plasma arc. By striking arc discharges between a suitable anode and the cathode is called plasma torch. The arc discharges uses gases such as oxygen, nitrogen or argon to quickly achieve temperature of thousands of degrees. This is designed in such a way to generate the re-entry conditions for high enthalpy gases at high stagnation pressures. External magnetic fields, walls helps in controlling thermal and electromagnetic instabilities. The current plasma torches are derived from plasma jet sources developed for this use. This technology is existing in the following two forms: Plasma pyrolysis and plasma gasification. These technologies can be a better way for ultimate disposal because they kill all viruses and disease-causing pathogens. Plasma technology is applied to destroy highly toxic compounds. It also modifies refractory compounds in a more environment-friendly way as compared to convention gasification/incineration. The high energy value of associated vapor can utilise for power generation. Such high waste vapor cools down into relatively clean gases in the case of organic/carbon-based material but cools to vitrified solid in the case of metals and an inorganic compound. These clean gases are a mixture of useful high-value gases like carbon monoxide, hydrogen, ammonia, methanol, etc. (Kumar and Singh, 2021). The "vitrified" solid can also be re-used. This not only helps in treating toxic waste but also recovers energy from waste.

As far as BMW including the current COVID-19 scenario, it is recommended to use plasma technology. It is quickly decomposing biological COVID-19 BMW waste with no requirement of waste sorting. This technique has shown low emission, inert residuals, reductions in volumes up to 95%, and mass cut up to 90%. This will also help in eliminating landfills requirement, remove waste transportation pressure from our roads. It is also financially viable, as high-value products synthetic gas and electric power generation. The disadvantages like high electricity consumption, operating costs are overcome by the added value of potentially reusable by-products (Singh et al., 2020).

Figure 2 AI-equipped plant waste flow (see online version for colours)



4 AI equip mini plasma plant model for COVID-19 waste

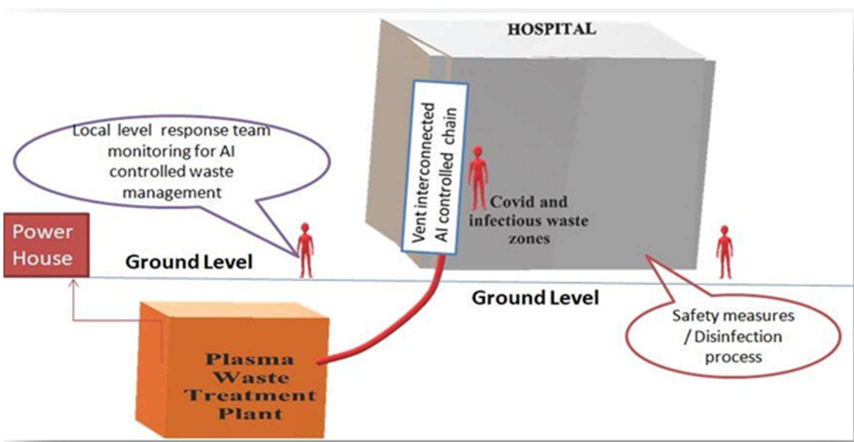
The various study shows important aspect for biological waste treatment is waste volume, timely transportation, and social security despite the availability of technology.

The existence of a waste plant far from the hospital or isolation centre increases the risk of infection. In COVID-19, various local-level response teams focus on the on-site treatment of COVID-19 BMW. This involves waste feeding and the segregation process. Presently uses sterilisation with microwave, ultraviolet light, ozone water treatment, dechlorination, and disinfection, etc. to residual discharge (Kumar and Singh, 2021; Singh et al., 2020), Most of the processes increase human involvement and have a large processing time. All these factors increase the risk of infection.

The various studies claim Plasma-based waste treatment one of the best ways for volume reduction as well as for social and environmental security (Kumar, 2020). This will not only save waste sorting time but also eliminate long processing selection or processing. Instead of installing a big-size biological waste plasma plant, megaton capacity to mini size plasma plant that can handle few kg risky waste locally. The scale-down of a plant not only decreases installation cost, running cost, etc. but also helps in dealing with hazardous waste at the source itself. To deal with high contagious COVID-19 BMW, a mini plasma waste treatment plant with a tunneling system can be a better alternative in this regard. The tunnel is proposed with an arrangement of vents (Vent –Web) in such a way as to collect waste from the different sensitive parts of the building structure. The design of Vent-Web is such a way that sloping of vent or some motor is capable to transport infected waste completely. The vent of different diameters and its heat-bearing materials will have additional operational benefits in this regard. The flow of heat through vents also makes it 100% safe, leaves no scope of microorganisms transmission. To increase power plant safety issues, installation shall be done underground. This will create a safety layer for any type of leakage and also gravity help in waste transmission.

Artificial intelligence can help to avoid any human interference in waste collection. AI operated small window at designated place improves the care that requires service for waste segregation and processing. These can collect and process harmful environmental toxins like furans, dioxins, etc. which otherwise to handle carefully. The vent size, mouth opening and closing time, etc. are various decisions that can be maintained easily with the help of artificial intelligence. This will help in risk data analysis, well time decisions, decision–making, and also the administrative task like vent network structure layout and its extensions, if require. This also helps in using the vent network in efficient ways. The waste amount and infectious quality will affect the part of complete network uses. Such AI-controlled mini waste is suggested and the basic layout is shown in Figure 3. The connected tunnel and vent structure play an important role here.

Figure 3 Mini plasma waste model (see online version for colours)



The proposed design of a mini Plasma Waste Treatment Plant eliminates all scope of COVID-19 BMW infection risk. AI-operated vents channels process BMWcompletely without any human interference. AI also optimised the vents channel and the tunnel systems. The successful operation of installed plasma plants all over the world clearly shows the worth of such mini plasma technology for biological COVID-19 BMW treatment.

The disadvantages like high installation cost, costly operation due to high electric consumption are nothing against human life. On the other hand, added value by-products like power generation and synthetic gases reduce the financial burden. All make mini plasma waste plants self-sufficient and cost-effective.

5 Conclusions

The best practice in any type of waste management process is always to reduce, reuse and recycle, but not applicable to biomedical hospital waste. Hazardous biological waste like COVID-19 waste has a very high risk for human beings and such waste need special treatment. It cannot be stored in an open environment as the COVID-19 virus can survive inside/outside the host for several hours. Such waste is generally treated with processes like chlorination, combustion, incineration, etc. But all such process releases harmful toxins in the environment and also have a risk to waste handlers. Plasma-based, incineration/pyrolysis technology can be used to process BMW completely. This will not only reconvert hazardous inorganic/organic waste to nature in its atomic form but also have value-added synthetic gases and electric power generation. The high installation cost, high electricity consumption, and other costs of operation can not be compared with human life. The reduction in end by-products reduces the financial burden of such plants. The utilisation of plasma waste plants will reduce the financial burden and also associated system safety risk. The AI-equipped vent web and tunnel reduces human interference with infected waste. Local installation of mini plasma waste plant at the hospital or community removes waste transmission infection risk and a huge reduction of risky biological waste volume at the source itself. Mass awareness can also help in reducing plasma waste management-related safety norms.

We recommended for such mini plasma waste plant not only for COVID-19 waste but also for other types of solid wastes. Mini Plasma waste plants are going to be the most important tools for solid waste management.

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