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A review on modern and smart technologies for efficient waste disposal and management

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ABSTRACT

In the current scenario, the word waste management holds much importance in every individual's life. Pollution and the generation of vast waste quantities with no proper waste management process have become one of humanity's biggest threats. This review article provides a complete review of the innovative technologies currently employed to handle and dispose of the waste successfully. This work aims to include the different solid, liquid, gaseous, and radioactive waste management processes. The novel and improved plasma gasification concepts, transmutation, incineration, bio-refineries, microbial fuel cells (MFC) have been thoroughly explained. In addition, some new techniques like Mr. Trash Wheel and the Smart bin approach provide much hope of adequately managing waste. The work's novelty lies in adopting several successful methods of various countries for waste disposal and management. To incorporate or improve India'sIndia's same techniques and processes, we have to tackle the ever-increasing waste disposal problems and find economic and eco-friendly ways of waste management.

1. Introduction

Human beings are very greedy creatures, and to satisfy their insatiable greed, they have destroyed nature. They have given rise to concrete jungles and the modern-day giant problem known as pollution. It has resulted in the production of vast quantities of waste which has worsened the situation (Watkins et al., 2013). Pollution is spreading like wildfire, and waste management is the biggest concern in the modern-day scenario (Chai et al., 2020).

Pollution of air, water, and the soil is already very evident, but now the roots of pollution have spread much further with radioactive and hazardous waste (Fernando, 2019). As a result of all these, many solid, liquid, and even gaseous waste are generated. The most significant danger arises when these are directly released into the environment without proper treatment methods and disposal procedures (Fang et al., 2019). This paper focuses on producing a short review of various innovative ways for appropriate waste disposal and efficient waste management (Cremonez et al., 2021; Schnell et al., 2020).

Every country has taken some or other measures to manage the vast amount of waste generated. For example, bio-refineries have proved advantageous for handling much biomass and converting it into liquid fuels and producing electricity (Palgan and McCormick, 2016). On the other hand, incineration has proved handy in managing vast solid waste volumes by combustion techniques and producing ample energy (Solo-Gabriele et al., 2020). The development of various inorganic ion exchange materials and vitrification techniques is highly beneficial for managing radioactive waste (Han et al., 2018).

The MFCs mesmerizingly utilize different microorganisms, which act

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as biocatalysts and aids in the oxidation of organic matter and bioelectricity production (Li et al., 2018).

The Mr Trash Wheel concept is another highly used approach for cleaning harbours and water bodies, which helps to preserve our aquatic fauna and flora (Lindquist, 2016). In addition, utilizing various ceramic materials is beneficial in managing nuclear waste (Su et al., 2016; Xiao et al., 2020).

The earlier concept of waste management was limited. Small teams of people collected the trash from the streets and threw them in a wagon or dump it at a specific site (Brancoli et al., 2020). After the wagon was filled, it was emptied in a particular place. The earliest techniques involved simple landfill techniques, which suffered from many disadvantages. Slowly the improved methods came into existence. These techniques replaced the penalties with several innovative ways (Cremonez et al., 2021). Lately, several improved technologies have enlightened all waste management processes (Brancoli et al., 2020).

Innovative technologies like Mr. Trash Wheel, newer landfilling techniques, MFC, smart waste bin concepts have revolutionized the waste management process (Xiao et al., 2020). The idea of deriving energy from discarded rubbish has solved energy deficiency's problem to some extent—the concept of biorefineries and biological reprocessing have revolutionized the waste management process. Sweden has demonstrated itself as a country that has done all in the magic in managing waste, and it is now a role model for all the other nations suffering from waste management problems (Xiao et al., 2020; Uddin et al., 2021). This paper aims to cover these innovative approaches and shed light on the various initiatives the most prosperous countries manage waste and disposal. Plasma gasification and the Swedish initiative to manage waste provide high hopes and promises towards a better future and greener earth (Aid et al., 2017; Sanlisoy and Carpinlioglu, 2017).

The concept of biodegradable plastics can lead us to a new world free from the havoc caused by plastics. Many starch-based plastics have been developed and given much importance as starch-based biodegradable plastics are eco-friendly. Most importantly, these plastics do not contain any stabilization chemicals, which generally, on other occasions, hamper the decomposition process. These plastics automatically degrade and slowly disintegrate totally (Fairbridge, 1998). The cullet or broken glass pieces remanufacturing by melting them can help us recycle and reuse the glass (Christensen, 2011).

The objectives of this study include:

(i) To understand the different strategies employed in the solid, liquid, gaseous, and radioactive waste management process.
(ii) To clearly understand the novel and improved concepts behind plasma gasification, transmutation, incineration, bio-refineries, and microbial fuel cells (MFC) and understand how these concepts can be applied to the Indian scenario.
(iii) Understanding the mechanisms of new techniques like Mr. Trash Wheel and the Smart bin approach to manage waste adequately.
(iv) Adopting several successful techniques of various countries for waste disposal and management and incorporate or improve the same techniques and processes in India to tackle the ever-increasing problems of waste disposal and find economic and eco-friendly ways of waste management

2. Innovative ways of waste treatment

2.1. Solid waste management (SWM)

It is found that municipal solid waste can be a suitable energy source. A study reveals that municipal solid waste (MSW) contains around 20.72 % organic waste content, 37.86 % combustible items, 20.95 % saleable items, and 20.46 % miscellaneous waste and have a high calorific value, which indicates that MSW can be a suitable replacement for coal and can be effectively utilized in the cement industry (Rehman et al., 2020; Verma et al., 2020). Several innovative technologies have been integrated to enhance solid management process efficiency. These processes may include the web-based geographic information system technology (Idowu et al., 2012; Rada et al., 2013), global system of mobile for managing waste (Arebey et al., 2010), automatic bottle selection process, automated sorting and deinking technique (Wangyao et al., 2009; Verma et al., 2020). The integration of geographic information system technology with the waste collection has helped the municipalities manage waste management's Collection and disposal process in Italy (Bindhya et al., 2010; Sudha et al., 2009, 2010, Sudha et al., 2011 2010; Balachandar et al., 2008).

2.1.1. Collection and transport with different types

Waste produced by houses is sent to communal bins fabricated from metal made from concrete (Yadav and Karmakar, 2020). Several commercial complexes or industrial units often engage municipal authorities to transfer the massive amount of waste by paying some amount (Kumar et al., 2009; Yadav and Karmakar, 2020). In India, the most common ways of the transportation of waste include bullock carts, hand rickshaws, compactors, trucks, tractors, trailers, and dumpers (Kumar et al., 2009; Verma et al., 2020).

2.1.2. Sorting and segregation

An unorganized sector generally accomplishes the segregation of waste. This process occurs in unsafe and unhygienic conditions (Kaushal et al., 2012; Verma et al., 2020). One of the biggest challenges is to acquire a zero-waste policy. Several innovative technologies have been integrated to enhance the SWM process's efficiency (Yadav and Karmakar, 2020). These processes may include the web-based geographic information system technology (Idowu et al., 2012; Rada et al., 2013), global system of mobile for managing waste (Arebey et al., 2010; Verma et al., 2020), automatic bottle selection process, automated sorting and deinking technique (Wangyao et al., 2009).

The integration of geographic information system technology with waste collection has helped the municipalities manage waste management's Collection and disposal process in Italy (Idowu et al., 2012). Rag pickers play an essential role by sorting out different recyclable materials like plastics and glass (See Table 1). Different Smart Trash Segregator (STS) types at offices, airports, railway stations, bus stops, and malls can be highly fruitful (Mahakala and Radha, 2021; Verma et al., 2020).

2.1.3. Recycling

The concept of biodegradable plastics can lead us to a new world free from the havoc caused by plastics. Many starch-based plastics have been developed and given much importance as starch-based plastics are eco-friendly and biodegradable. Most importantly, these plastics do not contain any stabilization chemicals, which generally, on other occasions, hamper the decomposition process (Umar et al., 2021). These plastics automatically degrade and slowly disintegrate totally (Fairbridge, 1998). The cullet or broken glass pieces remanufacturing by melting them can help us recycle and reuse the glass (Christensen, 2011; Umar et al., 2021).

Thermoplastic starch (TPS) can be produced from glycerol, acetic acid, and potato starch. This TPS can be shaped in a variety of thicknesses. The waste iron filings can be introduced to prepare the thermoplastic starch. Hence, the blacksmith operations' scrap iron can be successfully utilized (Battistelli et al., 2020; Tulebayeva et al., 2020).

2.1.4. Waste processing

2.1.4.1. Anaerobic-aerobic and treatment. Solid waste management has always remained a significant challenge. Controlling vast amounts of municipal solid wastes has always been an important concern (Mahalaxmi et al., 2021). Anaerobic-aerobic and treatment mechanisms are considered adequate for managing solid waste (Kumar et al., 2009). This

Table 1
Scenario of solid waste management in India demonstrating the government's different available techniques and methods for waste management and disposal.

Process	Current status	Reference
Segregation	Unorganized sectors handle the process, and the process's efficiency is low.	(Kaushal et al., 2012; Verma et al., 2020)
Collection	The waste that is generated by the household is sent to the communal bins.	(Kumar et al., 2009, Verma et al., 2020)
Reuse/Recycle	Rag pickers play an essential role by sorting out different recyclable materials like plastics, glass, etc.	(Pattnaik and Reddy, 2010; Umar et al., 2021)
Transportation	Mainly bullock carts, hand rickshaws, trailers, dampers, temps are used to transport the waste.	(Joseph, 2002; Yadav and Karmakar, 2020)
Disposal		
Open dumping	One of the biggest problems is significant surface water contamination and groundwater contamination due to leachate percolation.	(Mor et al., 2006; Tulebayeva et al., 2020)
Landfilling	One of India's most accepted practices, mainly in metropolitan cities, and the landfill sites are already overloaded.	(Sharholy and Ahmad, 2008; Tulebayeva et al., 2020)
Treatment of organic waste		
Aerobic composting	Mechanical Composting units have been installed in several metro cities of India.	(Sharholy et al., 2007; Uddin et al., 2021)
Vermicomposting	Earthworms are introduced on semi-decomposed organic waste. As a result, earthworms have a surprising capacity to consume five times of organic matter per day compared to body weight.	(Joshi and Ahmed, 2016; Zziwa et al., 2021)
Thermal treatment	Incineration cannot be appropriately carried out from the Indian perspective as the solid waste is high in the organic constitution, moisture content. However, a very small incinerator can be used for the burning of hospital wastes.	(Sharholy et al., 2005; Schnell et al., 2020)
Anaerobic digestion	Initiatives are being taken for bio-methanation; however, this initiative is at its young or very early phase. Special efforts are being taken to properly utilize the enormous amount of waste produced from the vegetable market and yards.	(Ambedkar and Shekar, 2004; Cremonez et al., 2021)
Gasification	An innovative procedure for reducing or managing the large amount of solid waste generated by employing this thermal treatment technique. This process can efficiently decrease pollution and help to harness more energy.	(Sharholy et al., 2007; Chai et al., 2020)
Refuse derived fuel	This technique helps in the efficient production of power or thermal energy from solid wastes. Thus, it helps in reducing the overdependence on the landfill.	(Joshi and Ahmed, 2016; Yang et al., 2021)

process is mainly carried out in three phases or zones (Cremonez et al., 2021). These are the pretreatment and feeding, followed by the anaerobic digestion process. Mesophilic conditions are maintained during the anaerobic digestion process (Rajaeifar et al., 2017).

Heated air and the refining process are employed so that compost can be obtained to stabilize the solid residue from the anaerobic stage (Gomez et al., 2008). Many biogases are produced, transferred to the Jenbacher engines to produce thermal energy and electricity. The energy obtained can be around 204 kWh/ton of bio-waste (Rios and Kaltschmitt, 2016).

2.1.4.2. Mechanical-biological treatment. Mechanical-biological treatment employs various steps like bag opening, storage, sieving, shredding, bailing, and bio-drying multiple types of acceptable waste collected (Deng et al., 2014). The waste is then made to move inside a rotating drum to separate the bio-waste and various inert materials. The application of biological stabilization then addresses these, and the remaining residue is finally sent to the landfill (Budzianowski, 2016).

2.1.5. Recovery of energy

2.1.5.1. Aerobic composting. Mechanical Composting units have been installed in India's several metro cities. This process helps convert organic waste into compost in the presence of oxygen or air (Sharholy et al., 2007; Uddin et al., 2021). Aerobic microorganisms help break down the organic matter and result in carbon dioxide, ammonia, water, heat, and humus (Sharholy et al., 2007).

2.1.5.2. Vermicomposting. Earthworms are introduced on semi-decomposed organic waste (Zziwa et al., 2021). Earthworms have a surprising capacity to consume five times of organic matter per day compared to body weight (Joshi, 2016).

2.1.5.3. Thermal treatment. Incineration cannot be appropriately carried out from the Indian perspective as the solid waste is high in the organic constitution, moisture content. However, a very small incinerator can be used (Sharholy et al., 2005; Schnell et al., 2020).

2.1.5.4. Anaerobic digestion. Initiatives are being taken for bio-methanation; however, this initiative is at its young or very early phase. Special efforts are being taken to properly utilize the tremendous amount of waste produced from the vegetable market and yards (Ambedkar and Shekar, 2004; Cremonez et al., 2021).

2.1.5.5. Gasification. An innovative procedure for reducing or managing the large amount of solid waste generated employs this thermal treatment technique. This process can efficiently decrease pollution and harness more energy (Sharholy et al., 2007; Chai et al., 2020). Anaerobic digestion coupled with stage separation has been known to produce high yields when substrates like vinasse and manipueira are taken into count. Methane and molecular hydrogen are created when a high concentration of various fermentable sugars is utilized (Cremonez et al., 2021).

2.1.5.6. Refuse derived fuel. This technique helps in the efficient production of power or thermal energy from solid wastes. It reduces the overdependence on the landfill (Joshi, 2016; Yang et al., 2021).

2.1.6. Different types of disposal

2.1.6.1. Open dumping. One of the biggest existing problems is significant surface water contamination and groundwater contamination due to leachate percolation (Mor et al., 2006).

2.1.6.2. Landfilling. One of India's most accepted practices, mainly in metropolitan cities, and the landfill sites are already overloaded (Mor et al., 2006; Sharholy and Ahmad, 2008; Tulebayeva et al., 2020).

2.2. Liquid waste management

Wastewater treatment and management have been of great concern, mainly in Asian countries (Liao et al., 2021), and novel wastewater surveillance strategies are needed for wastewater management (AnilaV et al., 2020). It is a complicated and tedious procedure to manage the liquid wastes mainly because they cannot be easily removed like solid wastes (Verhuelsdonk et al., 2021). These wastes spread quickly and thus pollute the environment faster than solid waste and even pose an extra threat of reaching the groundwater sources and polluting them. Therefore, liquid waste management should be done very carefully (Hu et al., 2020). Industrial and domestic wastewater in municipal wastewater treatment plants can be suitably combined, and this process can be profitable. It has been found that various heavy metals like copper and cadmium exhibit a negative effect on heterotrophic bacteria (Buaisha et al., 2020).

A large amount of waste is generated in the leather industry, which needs to be adequately handled. Membrane bioreactors produce much sludge while being incorporated in wastewater treatment and require expensive management techniques (Fida et al., 2021). The vital points like waste management, reduction of greenhouse gases, and energy efficiency should be carefully considered to properly manage the waste (Omoloso et al., 2020). Nanobots can efficiently absorb harmfully, and toxic chemicals have been an innovative and new approach for managing and treating wastewater (Shivalkar et al., 2021). Verhuelsdonk et al. demonstrated an innovative model for recycling the wastewater generated from a brewery based on reverse osmosis. This model has successfully removed the chemical oxygen demand by as high as 93.6 % and obtained an exciting yield of 63 % on the pilot scale (Verhuelsdonk et al., 2021).

2.2.1. Faecal sludge management

When human excreta collect in a pit latrine, the solids settle at the bottom and form slurry, faecal sludge matter (Murray et al., 2011). It ensures that people and the environment are protected from these hazards (Diener et al., 2014; Devaraj et al., 2021). To achieve safe sanitation-faecal sludge treatment has been a very effective method, mainly in small towns and cities. However, several challenges are needed to be considered to enhance the management of faecal sludge management (Devaraj et al., 2021).

2.2.2. Pit emptying

The process of pit emptying is sometimes called desludging. It is divided into manual desludging and mechanical desludging (Burt et al., 2019). Vacuum trucks, vacutug, hand-operated pumps, disposal of the sludge are included in the method of pit emptying. Vacuum trucks are quick, powerful, and efficient. They are equipped with a storage tank and pump with a hose (Chipeta et al., 2017). Vacuum is a smaller version of the vacuum truck. It is cheap, easily serviceable, and operated in a narrow passageway (Jakariya et al., 2018). Hand-operated pumps are a simple design that consists of a PVC pipe containing two valves. The sludge disposal can be used directly onto land and used as a soil conditioner (Thye et al., 2011).

2.2.3. Septic tanks

Septic tank comprises concrete, fibreglass, or PVC in which sewage is collected and partially treated. Wastewater treatment options include waste stabilization ponds, reed beds, mechanical-biological wastewater treatment, and can reduce the amount of biodegradable material and solids, remove toxic materials, and eliminate pathogenic microorganisms (Shaw and Dorea, 2021).

2.2.4. Recycling of plastics

Plastics are non-biodegradable, so recycling plastics can be crucial in preventing the pollution caused due to the dumping of plastics in the water body. A simple way of preventing water pollution is recycling plastic or preventing plastic waste from getting dumped into the water. It can help preserve the aquatic flora and fauna (Alaerts et al., 2018). Recycling plastic bottles is critical to control the havoc caused by plastics. Plastics are generally discarded after use, and they choke the drainage system and posses a constant threat to the ecosystem. It has been found that plastics can be successfully used as a construction material. The plastic bottles can be filled with sand, soil, several solid waste materials as a mortar that can be bound with a mortar and can be used as a substitute for masonry unit production (Dadzie et al., 2020).

2.3. Gaseous waste management

With the population explosion, the number of vehicles, factories, and industries has increased. The release of toxic gases has always posed a threat to human beings' very survival (Tsui and Wong, 2019). These poisonous gases have resulted in several diseases, from mild to highly severe cancer. It has become imperative to preserve the air quality, and therefore the management of various pollutants that may result in air pollution should be countered (Lui et al., 2017). It mainly includes ashes to very minute-sized particulate matter and gaseous pollutants. Settling chambers and filters have been widely used to collect dust particles or any other particulate matter before releasing them into the environment (Papapostolou et al., 2017). The electrostatic method is employed to move the unwanted particles to the desired target locations. It is done by moving the toxic gases between the electrodes' high voltage influences so the unwanted particles can get trapped there (Yang et al., 2019).

3. Swedish model for pollution-free earth

Talking about waste management, Sweden has been the most successful country. Sweden is known to recycle around 99 % of the waste they produce locally. Sweden has adopted recyclingthe waste as its culture (Peters et al., 2019; Brancoli et al., 2020). Therefore it is crucial to understand the procedure they employ to complete this gigantic task (Aid et al., 2017; Brancoli et al., 2020). Citizens are highly encouraged to follow the practice of reuse. Residents themselves separate other wastes before their disposal. It reduces the tremendous effort required to unravel the same and saves much time (Stoeva and Alriksson, 2017). The households in Sweden take an active role in waste segregation segregating the waste in several fractions like food waste, plastic, glass, paper, electronics, batteries, etcetera. Sweden thus preserves a considerable amount of its resources by mastering the art of repurposing (Čičková et al., 2015; Brancoli et al., 2020). They have incorporated incinerators and several incineration plants known to supply heat to more than a million houses. The Swedish model uses water and dry filters to filter the smoke from burning the waste. Pipelines are fitted under the roads, helping vacuum the garbage from the houses' incineration plants (Bendz and Boholm, 2019). In turn, it helps to get rid of the foul smell of the rubbish, and there is no accumulation of waste at the street level. Less than one per cent of waste is sent to landfills (Bolton and Rousta, 2019; Brancoli et al., 2020).

4. MFC

MFC is a new technique considered a green and clean procedure for generating electricity from liquid wastes, particularly wastewater (Du et al., 2007). Bacteria and oxygen are believed to do this miracle. By employing the process of anaerobic digestion, the wastewater is treated. This process may reduce pathogenic microorganisms and even help convert biogas to electricity (Logan, 2009; Wang et al., 2015). Special spiral spacers enhance energy production by creating a helical flow. MFC is mainly a biochemical device known to extract the various respiring microorganisms' energy and convert organic matter present in the waste directly to electrical power (Hou et al., 2011). The basic principle is the series of oxidation-reduction reactions occurring at its core (Osman et al., 2010).

MFCs mainly depend on the biocatalysts' presence that aid electrons' movement. Cellular respiration is the critical mechanism that converts nutrients into energy and exothermic redox reaction (Kiely et al., 2011). Nearly all types of wastewater that contain organic matter can be easily treated by this process. It may include brewery wastes or even domestic wastewater. The cell is designed so that the wastewater properly flows over the anode surface through the cell. Many designs have been employed to improve this process's efficiency (Pandey et al., 2016). It involves a tubular microbial fuel cell design in which the cathode is fixed on the outer side, and the entire internal space is offered to the anode. Wastewater can flow through the anode from one side to another (Gajda et al., 2018; Li et al., 2018).

5. Smart waste bin approach

The smart waste bin concept is a new concept that incorporates the Internet of things (IoT) and wireless sensor network technologies. The application of IoT devices and Radio frequency identification (RFID) tags has revolutionized the waste management process (Zeb et al., 2019; Brancoli et al., 2020).

These bins are called smart because of IoT devices' integration and equipment and several other latest technological equipment like RFID reader, ultrasonic sensor, weight sensor, solar cell, and light-emitting diodes acting as the indicators for the setup. These indicators are coloured red and green to make their detection easier (Al-Jabi and Diab, 2017). Small batteries charge or power the various sensor nodes in wireless sensor networks. Special attention is given to conserving the battery and put this into action; a duty cycle is employed (Sah and Amgoth, 2020) (represented in Fig. 1). When the sensor mode is idle, it is automatically put to sleep mode when not sensing anything. End-to-end delay indicates the time taken by a single message or signal from the point of origin or the source to the destination (Lee and Lee, 2015). These sensors help detect the total volume of garbage and are engineered to be fixed to bins, and can successfully detect waste. For every sensor cluster, a gateway node is installed, and the outdoor range and density of the bins help determine the size of the cluster (Folio et al., 2015; Brancoli et al., 2020). The nodes help receive the sensor data, and then the data is forwarded to the backend server (Brancoli et al., 2020). Different internet sources like Ethernet, WiFi or the 4G connections make this process possible and attainable. The data collected by the bin's sub-system is analyzed by the analytics module, which then processes and sends the signal to the nearby base station (Catarinucci et al., 2015). This information is then communicated to the concerned authorities, who then direct the garbage collection truck to the correct waste bin. Then the garbage is sent to the reuse and recycling unit (Wijaya et al., 2017). Modern and intelligent technologies are being given much importance and hailed by municipal and private organizations. Vehicles are computerized to properly plan the route and adequately schedule the waste collection process. It, in turn, helps in monitoring the process of collecting waste and ensuring that the garbage is enough transferred and transported to the various recycling units (Gupta et al., 2019).

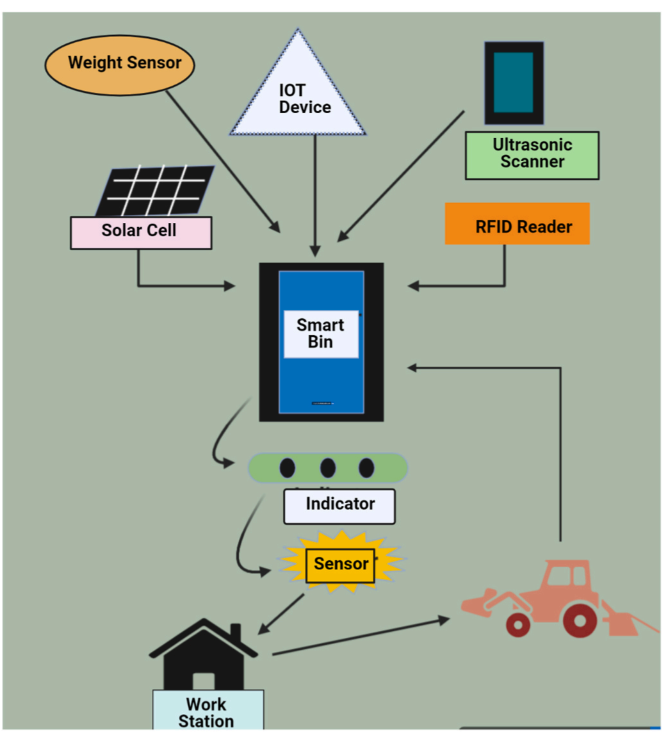

Fig. 1. SMART WASTE BINS: This flow chart demonstrates the innovative approach to waste management with the aid of intelligent waste bins. These bins are integrated and equipped with an IoT device and several other latest technological equipment like RFID reader, ultrasonic sensor, weight sensor, solar cell, and light-emitting diodes acting as the setup indicators. These sensors help detect the total volume of garbage and are engineered to be fixed to bins, and can successfully detect waste. The nodes help receive the sensor data, and then the data is forwarded to the backend server.

6. Concept of bio-refineries

Bio-refineries have been widely used to generate liquid fuels from various materials, including biomass materials, lignocellulosic, and different other crop materials discarded as waste (Gomez et al., 2008). It can efficiently lead to biofuel production, including biodiesel and bio-ethanol, which can be used as transport fuels. These liquid biofuels are much safer and cleaner alternatives to the existing fossil fuels (Taylor, 2008; Parotte and Fallon, 2020). Feedstocks are generally used to produce biodiesel, mainly from oil-based crops, whereas starch-based crops are mainly used to produce bioethanol (Parotte et al., 2020). The classification of bio-refineries can be done in three phases. This classification is mainly based on input, processing, and product generation (Palgan and McCormick, 2016).

7. Biological reprocessing

Biological reprocessing is a straightforward concept that is highly important to understand. Recycling and reusing the products is the sole principle of biological reprocessing. It aims to reduce waste as much as possible, limiting waste production (Gharfalkar et al., 2015). Different organic materials like paper products, food scraps, and various plant materials can be easily recycled by applying digestion processes and biological composting (Zaccariello et al., 2015; Brancoli et al., 2020). The methane gas produced resulting from this is then harvested and used to produce heat and electricity. There are several processes by which biological reprocessing is done, such as anaerobic digestion. The most common technology is found to be highly efficient and is found to be more efficient than incineration and landfills. It promotes waste reduction, an essential step in waste management (Álvarez-Gallego et al., 2015; Brancoli et al., 2020). Reuse of the products can save many resources and reduce waste produced. The simple idea of repairing items instead of buying new ones and encouraging the buyers to refrain from disposable products can also be a vital part of waste reduction (Cremiato et al., 2018).

8. Mr. Trash Wheel

Mr. Trash Wheel is an innovative approach for cleaning water bodies and mainly harbors. It is often referred to as the 'healthy harbor initiative.' This initiative was first taken jointly by many non-profit organizations and the government to clean the Baltimore harbor (Kumar et al., 2009). This initiative successfully installed the first-ever trash interceptor, utilizing solar and hydropower. The engine's main design includes a 14 feet wheel made of steel and is powered by the river's current. The water wheel does not power a mill but a rake and conveyor system, and this, in turn, creates the force or pressure enough to pull the litter floating on the water body and then successfully dumps it in a dumpster barge (Xiao et al., 2020).

Mr. Trash Wheel is also known to consist of solar panels for the sole purpose of powering the pumps, which pump the water onto the wheels and placing the trash on the conveyor belt to keep the entire setup functional (Xiao et al., 2020). It also ensures that the setup remains available even if the water current is light. These two mechanisms work hand in hand and successfully help collect anything that floats down the river. Surprisingly this setup even collected the cigarette butts. Its vitality increases as all the garbage from the streets come floating onto the water body (McIlwraith et al., 2019) (represented in Fig. 2). The Mr. Trash Wheel concept has successfully collected vast waste quantities and successfully removed them from the water body. It protects the aquatic flora and fauna of small rivers and water bodies. It may also help prevent eutrophication and reduce the water body's biological oxygen demand if it is successfully combined with several other modern technologies (Lindquist, 2016).

9. Plasma gasification

Plasma gasification is an innovative method to handle many biomass and various types of harmful wastes. It can be converted into a form that can produce an unbelievable amount of energy (Mazzoni and Janajreh, 2017; Brancoli et al., 2020). This technique successfully converts various industrial, medical, low-grade coals, various biomass types into syngas that mainly comprise carbon dioxide, hydrogen, and low carbon monoxide levels (Chai et al., 2020). The different types of biomass are burned or fired up in the combustion chamber, and the expected output is mainly heat, but this has a drawback as this process emits a tremendous amount of emission gases. This problem is solved by subjecting the fuel into a medium oxidant starved and at high temperatures to produce syngas (Sanlisoy and Carpinlioglu, 2017; Brancoli et al., 2020).

Thus, syngas can be successfully used to generate electricity, produce hydrogen, and are often used as a fuel in various combustion systems. Plasma consists of free electrons, ions, and even neutral particles and can be easily ionized (Breeze, 2017; Brancoli et al., 2020). Plasma gasification works by consuming an external power source to get heated up. It can break down different materials, which are the main reason for converting toxic compounds into less harmful products. This technique has successfully derived energy from plastic wastes, municipal solid wastes (Zhang et al., 2012; Chai et al., 2020).

Additionally, biomasses, used tires, wastes from oil and gas industries have also been taken into account for the successful generation of energy. It converts carbon-based hazardous materials into fruitful and beneficial fuels and can achieve zero waste accumulation milestones (Oboirien and North, 2017). Plasma gasifiers are classified into three main types. These are plasma fixed-bed gasifiers, plasma entrained-bed gasifiers, and plasma moving bed gasifiers. Most importantly, the enhanced temperature has, in turn, helped the gasification of municipal solid waste (Munir et al., 2019; Chai et al., 2020).

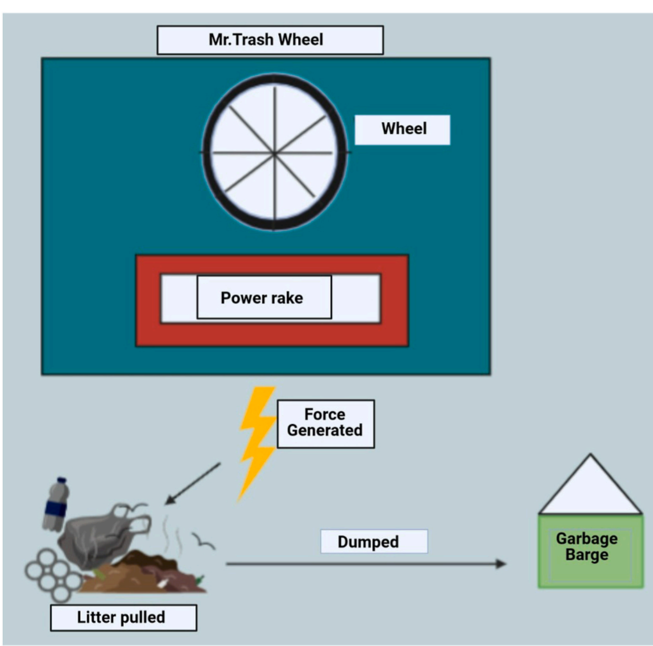

Fig. 2. Mr. TRASH WHEEL: Mr. Trash Wheel is an innovative approach for cleaning water bodies and harbors. The engine's main design includes a 14 feet wheel made of steel and is powered by the river's current. The water wheel does not power a mill but a rake and conveyor system, and this, in turn, creates the force or pressure enough to pull the litter floating on the water body and then successfully dumps it in a dumpster barge.

10. Incineration

Incineration is widely utilized for waste management and waste disposal. It mainly targets the various organic materials present in the waste (Cheng and Hu, 2010; Brancoli et al., 2020). It works at a very high temperature and is therefore referred to as the process of thermal treatment. With this process, ash, flue gas, and a large amount of heat is generated from the waste materials. Inorganic materials are mainly responsible for ash production and may get converted to solid lumps (Liuzzo et al., 2007; Brancoli et al., 2020). It is essential to clean the flue gas before getting exposed to the atmosphere. Incineration can successfully generate a large amount of heat which can then be converted into electrical power (Tsai and Chou, 2006). This process involves pyrolysis, gasification, and anaerobic digestion to convert waste to energy. The original mass of the waste is reduced by 80–85 %, and it successfully reduces the total volume by 95–96 %. Incineration is highly suitable for treating various clinical waste and hazardous waste (Samolada and Zabaniotou, 2014). The different types of dangerous microorganisms are killed at high temperatures (Brancoli et al., 2020). An incinerator can be considered a furnace for burning waste in simple words. The modern-day approach has improved the design of the incinerators, which now also treats the flue gas produced so that it does not cause any harm to the environment (Solo-Gabriele et al., 2020).

10.1. Rotary kiln incinerator and fluidized bed incinerator

The rotary kiln incinerator is the most commonly seen in the industries and is used by the municipalities. It consists of a couple of primary and secondary chambers (Huber et al., 2016; Brancoli et al., 2020). A fluidized bed incinerator is one of the most common incinerators used. It allows the passage of a powerful airflow through a sand bed (Li et al., 2015). This air is continuously passed till the sand particles are separated, and the air passes through it. As a result, the fluidized bed is created, and the waste matter is then introduced. The air is allowed to pass in a fluid-like state which helps in the entire circulation of the waste material and sand in the furnace (Lu et al., 2017; Brancoli et al., 2020).

11. Practical approach for radioactive waste management

The biggest challenge that the world is facing is regarding the radioactive waste management process, as it is tough to manage the radioactive waste and dispose of them properly. In simple words, radioactive waste refers to all the nuclear industries' waste (Han et al., 2018; Brancoli et al., 2020). According to Balachandar et al. (2014), cytogenetic endpoints helps in the detection of chromosomal alterations that occurs in individuals exposed to ionizing radiations in laboratory settings. It may range from nuclear medicine, nuclear research to nuclear power production and rare earth mining. Radioactive wastes can be classified broadly into Low-level waste, intermediate, and high-level waste. The management of all these wastes becomes critical and should be immediately considered (Chen and Liu, 2020).

11.1. Vitrification

Vitrification is a commonly known procedure for the treatment of radioactive wastes. Sugar is added to the high-level wastes, followed by calcination. Calcination involves passing the waste through a rotating heated tube (Harrison, 2014). This aids in evaporating the water from the waste and de-nitrating the products. The calcine thus produced is sent to a fragmented glass containing a heated furnace (Aloy, 2011). The waste products are made to bind to the glass matrix; the glass present inside the cylinder is a shiny black substance. The entire process is carried in scorching systems (Winter 2017). Sugar is added to control the ruthenium interaction and prevent the formation of the various ruthenium isotopes. The glass types commonly used are borosilicate glass or phosphate glass (Suneel et al., 2019). This product is then transferred to cylindrical containers made of stainless steel. On cooling, the fluid vitrifies or solidifies into a glass. Following this, the cylinder head is welded with a seal. The cylinder is then washed and stored preferably in an underground repository (Yan et al., 2020).

11.2. Phosphate ceramics

Phosphate ceramics is an effective and innovative method to stabilize waste by neutralizing the product and making hazardous waste much safer. The immobilization process in which a phosphate-based ceramic is mainly used for direct incorporation ispreference (Kowalski et al., 2017). These ceramics withstand severe thermal, chemical and radioactive degradation over time. Additionally, these ceramics can remain viable over a large temperature, pH, and different porosity ranges. Most commonly used ceramics include monazite type ceramics and are very efficiently used to immobilize radio-nucleotides (Su et al., 2016).

11.3. Ion-exchange

Many medium-active wastes are generated in the industries, commonly treated with ion-exchange techniques, and concentrate the radioactivity into the minimum volume. Ferric hydroxide can often remove highly radioactive metals from aqueous mixtures (Bhatnagar et al., 2009). As a result of this, ferric hydroxide absorbs the radioisotopes. The remaining or resulting sludge is often placed in a metallic drum before mixing it with cement to form a solid waste. Additionally, this technique has been quite fruitful in removing hexavalent chromium and various nitrate forms from the groundwater (Chen and Liu, 2020). Cesium radioisotopes can be easily removed from the contaminated water with inorganic ion exchange materials. Elemental sulfur can be encapsulated in various microspores of zeolites, enhancing the selectivity towards cesium in the presence of different other ions (Han et al., 2018). Genetic alterations have been observed in leather tanning industry workers in direct and indirect exposures of hexavalent chromium [Cr (VI)] (Balachandar et al., 2010) and other effects due to heavy metals (Kaviyarasi et al., 2020 &2021; Mukherjee et al., 2020 & 2021; Sudha et al., 2011).

11.4. Synroc

Synroc is a synthetic rock that is another very modern and innovative procedure for managing radioactive wastes. Pyrochlore, zirconolite, perovskite, and cryptomelane are present in synroc, which acts as hosts for the actinides (Gregg and Vance, 2017).

11.5. Above ground disposal

The spent fuel and inert gas are sealed in a steel cylinder and are later transferred into a cylinder made of concrete, which acts as the radiation shield. It is called dry cask storage. It is a cheap method and can be highly advantageous.

11.6. Geologic disposal and transmutation

The final disposal of radioactive waste has always been a great challenge. The idea of ocean floor disposal provides hope for this problem. It mainly involves dumping the waste under a highly stable abyssal plain, slowly carrying the waste downward towards the earth's mantle (Liu et al., 2013). A very profoundly dug borehole can be another solution. At least 5–6 km is considered a safe depth to place the radioactive waste materials and depends on the natural geological barrier to restrict the waste never to be a threat to the environment (Salvatores and Palmiotti, 2011).

On the other hand, transmutation mainly depends on converting hazardous, radioactive waste into less toxic waste. Transmutation aims to reduce radiotoxicity and effectively handle high-level waste (Ashraf and Tikhomirov, 2020). The different countries of the world take various innovative initiatives, and their basic principles to master the waste management process technique are represented in Table 2.

12. Practical applications and future research prospects

Waste management has become one of the biggest concerns in the

Table 2
This table demonstrates the various novel, innovative initiatives and their fundamental principles taken by the different countries of the world to master the waste management process.

Serial No.	Countries Name	Innovative Approach	Highlights	References
1.	Sweden	High-efficiency incinerators	Operates by combustion of various organic substances present in waste at very high temperatures.	(Aid et al., 2017; Brancoli et al., 2020)
2.	Australia	Microbial fuel cell	Wastewater treatment by anaerobic digestion with the help of microorganisms.	(Gajda et al., 2018; Li et al., 2018; Yazdani et al., 2021)
3.	Singapore	Smart waste bin	Incorporating the internet of things (IoT) and wireless sensor network technologies for waste management.	Zeb et al. (2019); Gupta et al. (2019); Ahamed et al. (2021)
4.	Belgium, Netherlands	Bio-refineries	Production of eco-friendly biofuel from biomass and other materials discarded as waste.	Taylor (2008); Pagan and McCormick (2016); Parotte and Fallon (2020)
5.	Sweden	Biological reprocessing	Reducing the quantity of waste generated by emphasizing the concept of reuse and recycle.	Cremiato et al. (2018); Brancoli et al. (2020)
6.	Massachusetts (USA)	Plasma gasification	Conversion of various industrial, medical, low-grade coals and various biomass types into syngas.	(Sanlisoy and Carpinlioglu, 2017; Munir et al., 2019; Paul and Bussemaker, 2020).
7.	Baltimore (USA)	Mr. Trash Wheel	Cleaning harbors and water bodies with a trash interceptor utilizing solar and hydropower.	(Lindquist, 2016; Xiao et al., 2020).

modern-day scenario. The countries which have mastered this art give us much-needed ideas and techniques that can be used to tackle the ever-rising burden of waste. The concept of generating energy from waste has always been the talk of the day. Many waste management models like the Swedish model of waste management provide us with ideas to obtain the highest energy from the waste generated. Adding to this, several new techniques like Mr. Trash Wheel and the Smart bin approach provide much hope of adequately managing waste. The idea of adopting several successful methods of various countries for waste disposal and management. To incorporate or improve India's same techniques and processes, we have to tackle the ever-increasing waste disposal problems. To find economic and eco-friendly ways of waste management has been the aim behind the paper. However, suitable investments and research are required to make this successful.

13. Conclusions

Finding alternative energy sources and new and innovative waste management techniques can be the only key to managing the vast amounts of waste generated. From an Indian perspective, these novel techniques can help us manage India's ever-increasing pollution and waste management problem. Techniques like smart waste bins can prevent huge waste dumped on the streets. Approaches like Mr. Trash wheel can be an eco-friendly way to clean small rivers and harbors as we know that the rivers are severely polluted, and we need an immediate measures to treat them. Surprisingly India can be an exporter of the waste generated as various countries import the waste for energy production. It may make India economically stronger. Following the Swedish model of waste management can lead India towards a brighter and greener India and solve growing energy demands.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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