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Waste Management, Environmental Pollution, Global Warming and Climate Change

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Important aspects of the four burning problems on our planet Earth, viz., (i) waste management (WM), (ii) environmental pollution (EP), (iii) global warming (GW) and (iv) climate change (CC), and the interrelationship of WM with EP, GW and CC as well as generation of value-added products during the processing of diverse types of waste are presented in this article.

Keywords: *Waste management, environmental pollution, global warming, climate change.*

I. Introduction

Waste is an unwanted natural byproduct that has been disposed of, after its primary use by the Society. It is diverse in nature - solid, liquid and gaseous -, and includes different types, such as garbage, sewage and household, agricultural, industrial, construction, chemical, plastic, electronic (e-), biomedical, pharmaceutical, toxic, hazardous, mining/mineral industry, nuclear waste, etc. Its safe disposal is one of the burning problems of our planet, the Earth, as its generation is of the order of millions of tons per year in different countries. According to the World Bank's 'What A Waste 2.0' report of 2018, India, with > 1.3 billion people, generates the highest amount of waste in the world - 277.1 Million tons (Mt) in 2016 and projected to 307.7 Mt and 543.3Mt, respectively, by 2030 and 2050 -, which is more than that of the most populous country with the largest economy (as per the IMF's World Economic Output 2020, based on the purchasing power parity, PPP), namely China (220.4, 295 and 335.8 Mt) and the USA (263.7, 311 and 359.9 Mt). However, the waste generation per person in both India and China is a small fraction of that by developed countries. In India, the top ten cities for waste generation (annually in lakh tons, in parenthesis) are Delhi (30.6), Greater Mumbai (24.9), Chennai (18.3), Greater Hyderabad (16.4), Bengaluru (12.8), Ahmedabad (12.1), Pune (6.2), Kanpur (5.5) and Jaipur (5.4) (Times of India, March 03, 2020)[1]. Apart from being the highest generator of waste in the world, India has a 'serious' severity of hunger, ranking 94 out of 107 countries in the '2020 Global Hunger Index' with a very low score of 27.2, as compared to all its neighbouring countries having better standards[2]; for this pathetic scene, one of the factors appear to be the large scale food-wastage. Besides, waste has been creating many problems for personal hygiene and societal sanitation, leading to the environmental pollution and ecological disturbances, all of which have implications for the global warming and climate change, indicating thereby their overall linkage. In order to reduce the (i) environmental pollution and (ii) global warming, and to mitigate the disastrous consequences of the climate change, such as frequent and untimely occurrence of drought, floods, cyclones, hurricanes, tsunamis and earthquakes, a proper disposal of waste by scientific and monitored *waste management* is an absolute necessity for the society. In this regards, the best waste management has been carried out in the city of Indore that generates > 1,115 metric tons of garbage a day. Under the '*Swachh Survekshan*' (clean survey) awards-2020, announced by the Government of India in August 2020, Indore was adjudged (continuously since 2017) as the 'Cleanest City', followed by Surat and Navi Mumbai, while the state of Chhattisgarh was given the award for the 'Cleanest State', followed by Maharashtra and Madhya Pradesh in India[3], indicating awareness among the citizens for cleanliness, personal hygiene and proper waste management in both the rural and urban areas.

In this article, important aspects of the (i) waste management (WM), (ii) environmental pollution (EP), (iii) global warming (GW) and (iv) climate change (CC), the linkage of these four and bearing of the WM on EP, GW and CC, together with the processing of waste for value-added products (VAP) during WM, with some examples that will create both wealth and employment required most for the developing countries like India, are presented.

II. Waste Management

Waste Management (WM) is all the activities and actions required to manage waste from its inception to its final, safe disposal. It is the process of treating solid wastes and offers a variety of solutions for recycling items that do not belong to trash. It is about how garbage can be used as a valuable resource. It disposes of the products and substances that were used in a safe and efficient manner[4].WM includes proper collection, sorting, transport, processing and disposal of waste. The methods that are usually adopted for WM are landfill, incineration, compaction, biogas generation, composting, vermicomposting, plasma gasification and recycling to recover/produce value-added products, if possible.

Methods of Waste Management: The most common method of disposal of garbage in India is 'open dumping'. Heaps of trash are generally left open to the environment and such heaps seldom have a sparse covering and can attract pests or vermin. Besides, these dumps are openly burnt, releasing fumes, including toxic fumes. Also, garbage is either frequently dumped into water-bodies, such as streams, canals, rivers and seas, or used to fill land-depressions thereby creating problems of degradation of the soil-quality and leaching of toxic chemicals into groundwater resulting in *environmental pollution*. To avoid these undesirable and environmentally polluting scenarios, proper waste disposal methods are to be adopted. Due to globalization and industrialization, there is a need for efficient waste disposal methods and the ones that are generally adopted are as follows: landfill, incineration, waste compaction, biogas generation, composting and vermicomposting. In the process of *landfill,* the waste that cannot be recycled or reused is separated and spread as a thin layer in low-lying areas across human habitations. A layer of soil is spread over each layer of garbage. When once such low-lying areas are completely filled, they are unfit for any construction for the next 2-3 decades, and instead can be used as a park or a playground. *Incineration* is the process of controlled combustion of garbage to reduce it to incombustible matter, such as ash and waste-gas that may be toxic and needs to be treated before releasing gas into the environment. This process reduces the volume of the waste by ~ 90% and, hence, is one of the most hygienic ways of waste disposal. The heat generated during incineration can be used to generate electricity. One drawback of this process is the release of greenhouse gases (GHG: CO_2, CH_4, CO, etc.,) and, hence, is not environmentally friendly. *Waste compaction* is a process in which waste material like cans and plastic items are compacted into blocks and sent for recycling. This process prevents the oxidation of metals and reduces the need of air-space, thereby making positioning and transportation easy. In the process of *biogas generation*, the biodegradable waste is converted into biogas by degradation, using bacteria, fungi and other microbes for which the organic matter in the biodegradable waste serves as food for these micro-organisms. The degradation can happen aerobically or anaerobically. The biogas generated is used as a fuel, while the residue is used as a manure for agriculture. *Composting* involves the burial of organic waste under soil and is left to decay under the action of microorganisms. This results in the formation of nutrient-rich manure that is much better than chemical fertilizers for agriculture. Besides, composting enriches the soil by replenishing it with nutrients as well as enhances its water-retention capacity. *Vermicomposting* is the process of degradation of organic matter into nutrient-rich manure by using worms that digest and consume the former. The byproducts of digestion, excreted out by worms, make the soil nutrient-rich, thereby enhances the growth of bacteria and fungi. This process is much more effective than traditional composting[5]. *Plasma gasification* is another form of waste management. Plasma is primarily an electrically charged or a highly ionized gas. Lighting is one type of plasma that produces temperatures in excess of 6982ºC (12,600ºF). In this method, a vessel uses characteristic plasma torch operation at + 5538ºC (10,000ºF), which creates a gasification zone till 1,649ºC (3,000ºF) for the conversion of solid or liquid wastes into a syngas. During the treatment of solid waste by plasma gasification, the molecular bonds of waste are broken down due to intense heat in the vessels and the elemental components. This process of waste disposal provides renewable energy and an assortment of other benefits. *Waste-to-Energy (WtE)*: This process involves the conversion of non-recyclable waste items into useable heat, electricity or fuel through a variety of processes. This is a *renewable source of energy* as non-recyclable waste can be used over and over again to create energy. It helps to reduce carbon emissions by offsetting the need for energy from fossil fuels. *Avoidance or Minimization of Waste*: The easiest method of waste management is to reduce creation of waste materials in the first place itself, thereby reducing the amount of waste going to landfills. Waste reduction can be done through recycling old materials such as jar, bags, repairing broken items instead of buying new ones, avoiding use of disposable products like plastic bags, reusing second hand items and buying items that use less designing[4]. There are certain types of waste that are considered hazardous and cannot be disposed of without special handling to prevent contamination; biomedical waste is one example.

The 5 R's of Waste Management: The 5 R's of sustainable WM are as follows: reduce, reuse, recycle, recover and residual management. *Reduce*: Reducing waste is the most important and easiest thing to do. By reducing waste, unnecessary use of resources, such as materials, energy and water can be avoided, which amounts to less waste to manage. Reducing waste is possible by the following ways: bulk purchase to reduce packaging; taking a reusable bag like a cloth bag for shopping to avoid plastic or paper bags; choosing products that need less packing; buying reusable rather than disposal items; sticking 'no junk mail' sign on letter-box; taking foodstuffs for lunch to office and school in a reusable container; and saying 'No' to a plastic shopping bag for only a few items. *Reuse*: Reusing waste material means less rubbish for landfill and no necessity to buy a new product, both of which save money, energy and resources that would have been used to make a new product. The following are some of the ways by which we can reuse waste: giving unwanted toys and books to schools or hospitals; using plastic containers for freezing or storing food items; saving wrapping paper and boxes for reuse; using old gars for storage; using online trading websites to buy items that are unwanted by others or shop at second hand stores; making memo pads out of waste paper, reusing envelops by pasting reuse labels, etc. *Recycle*: Recycling is the process of converting waste products into new products to prevent energy usage and consumption of fresh raw materials. It is the third component of 'Reduce-Reuse-Recycle' waste hierarchy[4]. This involves some form of reprocessing of waste material to generate another useful product. The main products that can be recycled are paper, cardboards, glass, aluminium, tin and plastic containers. Composting and worm farms are the methods of recycling organic waste. Also, one can buy products that are made from recycled materials, which is called 'Closing the Loop'. By recycling some major wastes, such as plastic and e-waste, many value-added products (VAPs) can be obtained; examples of these are given in the next section of 'VAPs during WM'. *Recover*: This is the recovery of waste without any pre-processing. For example, waste oils that cannot be refined for reuse in vehicles can be burnt for recovery of energy. Recovering the energy from waste oil reduces dependence on coal and imported oil to a little extent. *Residual Management*: This is the last option when waste cannot be used in any other way. Usually, this means sending rubbish to a landfill. Residual disposal of liquid waste is normally into a sewer or septic tank. It is important to manage residual solid and liquid waste properly, since waste not disposed of correctly can cause damage to health and the environment[6].

Generation of Value-added Products during Waste Management: A few examples of generation of value-added products during the processing of diverse types of waste are given below:

1. *Combustion/incineration of 80-90% waste* by volume to generate electricity in power plants, with Sweden being the leader in this field since over 20 y. The typical range of net electricity that can be produced is 500-600 kWh of electricity per ton of incinerated waste, the residue ash may be used as raw material for manufacturing cinder blocks or for road construction and the metals that may be burned are collected from bottom of the furnace and sold to foundries; some plants convert salt-water to potable water as a byproduct of cooling processes[7].

2. *Plastic waste into hydrogen and carbon nanotubes*: Over the past several decades, plastic waste has been found in the snow atop the highest mountains and in the deepest parts of the ocean. Micro-plastics are in our food and inside our bodies. A study in California found that 13.3 quadrillion microfibers (< 5 mm in length) are released into the state's environment every year. They get flushed out in the rinse cycle and then dumped into rivers and oceans, where they get ingested by plants and animals that up the food chain for humans. More than 70% of fish caught in the open oceans have micro-plastics in their stomachs. A group of researchers in the UK, China and Saudi Arabia have discovered a partial solution to this problem. An excerpt from the abstract to their study, published in October 12 issue of the journal, '*Nature Catalysis*' is given in the following. "Here we report a straightforward rapid method for the catalytic deconstruction of various plastic feed-stocks into hydrogen and high-value carbons. We use microwaves together with abundant and inexpensive iron-based catalysts as microwave susceptors to initiate the catalytic deconstruction process. The one-step process typically takes 30-90 seconds to transform a sample of mechanically pulverized commercial plastic into hydrogen and (predominantly) multi-walled carbon nanotubes. A high hydrogen yield of 55.6 mmol g^{-1} plastic is achieved with over 97% of the theoretical mass of hydrogen being extracted from the deconstructed plastic. The approach is demonstrated on widely used, real-world plastic waste. This proof-of-concept advance highlights the potential of plastic waste itself as a valuable energy feedstock for the production of hydrogen and high-value carbon materials"[8].

3. *Plastic to petrol, diesel and kerosene*: Three young technocrats (M/s. BV Satish Kumar, S. Mahesh and Mithun Prem Chand) have set up the world's first plastic-to-petrol producing plant at Guntur, Andhra Pradesh, India. The process (applied for a patent) involves conversion of 45-95% of any kind of plastic to gaseous state by electricity-based heating at ~ 700ºC under vacuum and at atmospheric pressure (with no air-pollution/chimney/ exhaust), followed by condensing and distilling the gas into diesel, kerosene, petrol and activated carbon, the last can be used as a manure. Around 2% methane that is produced during the process is used by a generator to produce the electricity. With 2-3 persons to handle, each batch takes 18 h for completion, and the value of output is at least five times more than the input cost[9].

4. *Value-added Products (VAPs) from Agriculture waste*: Over 400 million tons of agro-forest residues are generated annually in India. Huge quantities of agricultural and forest biomass can be used for large scale production of alcohol-based fuels. Rice straw may be used as the source of biomass and lignin (bot, an organic substance deposited in the cell walls of many plants, making them rigid and woody). Other non-woods available are straws of wheat, barley and grass seed, flax oil seed, corn and sorghum stalks, sugarcane bagasse, reeds, hemp fiber, sabai grass, cotton staples, stem fibers (jute, hemp and kenaf), etc. Technologies are available for the efficient conversion of low-quality or waste lingo-cellulose residues into fuel and industrially important chemicals. In the long term, agro-waste based processes will lead to development of novel, cost-effective processes and bio-products of industrial importance involving the rural people, academia and industries on a cost-sharing basis, leading to a sustainable development[10]. Other examples of converting agro-waste into VAPs are as follows: (i) *Stubble*, a major post-harvesting agriculture-waste, is generated in NW India – mainly in the states of Punjab, Haryana and western Uttar Pradesh. High-grade organic fertilizers can be prepared by mixing stubble with cow dung and a few natural enzymes so as to substitute costly and carcinogenic inorganic or chemical fertilizers. This method has been successfully operated in the state of Chhattisgarh by setting up 2,000 '*gauthans*', which are collecting centres in a dedicated 5-acre plot held in community by each village, where all the unused stubble is collected through *'Parali daan'* (People's donation). Furthermore, to solve the stubble-burning that is causing much pollution, microbial spray is an effective long term solution that is economically viable for the farmers. With stubble as a raw material, a USA-based company, 'New Generation Power International' has proposed to set up a 1000 MW biomass energy generating plants (200 plants each with 5 MW capacity) in Punjab to address the polluting stubble burning[11]. (ii) *Straw*, another agricultural waste, can be productively used for generation of electricity. (iii) *Cacao waste*: The cacao bean is a notorious agricultural waste-generator, with 12 pounds of biomass generated from one pound of cacao produced. The Colombian researchers were able to create new products using cacao waste, such as beer, desserts, juice and nutraceuticals, besides chocolate using the cacao beans and cacao bean-waste[12].

5. *VAPs by recycling of e-waste*: The e-waste is considered as the fastest growing waste stream in the world with 44.7 million tonnes (m te) generated in 2016. In 2016, Asia generated 18.2 m te of e-waste waste, followed by Europe (12.3 mte), USA (11.3 m te), Africa (2.2 m te) and Oceania (0.7 m te)[13]. E-waste includes discarded electrical and electronic devices and components, which can be used for refurbishment, reuse and resale, salvage recycling through material recovery or disposal. Recycling e-waste means separating materials, molecules or chemical elements so that they can be sold as raw materials for the manufacture of new materials. This involves dismantling the materials and components, their sorting and grinding, and finally separation of the materials, usually by incineration and then by solution-based chemical processes. As the e-waste is complex in nature, it is difficult to automate this step and, hence, disassembly is mainly carried out by costly manual methods. Sorting aims to minimize the chemical complexity of the mixture to be treated and its variability. The most common approach amongst recyclers, before chemical treatment, is grinding at the scale of the device or module, followed by the steps of separation by physical methods using the differences in density and magnetic properties. Magnets, eddy currents and trammel screens are employed to separate glass, plastic and ferrous and non-ferrous metals, which can be separated by a smelter[14]. Cu, Au, Pd, Ag and Sn are some of the metals sold to smelters for recycling that is the most effective solution to the growing e-waste problem, Furthermore, recycling reduces greenhouse gas emissions, caused by the production of new products[15]. *Extraction of gold from e-waste*: In New Zealand, microbes are extracting gold from e-waste by a process termed as 'bio-refining process'[16]. In this innovative system, the e-scrap material is first ground up into a sand-like consistency to make it sure that all the metal contained within to a subsequent chemical leaching process. Chemicals dissolve the powdered waste into a solution, with any material that has not dissolved filtered out. Then microbes are added to the mix. Gold atoms latch on to them in a process called 'selective biosorption'. Next, the microbes coated in gold are filtered, producing a paste that is ashed and then refined into solid, "recycled gold".

6. *VAPs from the Nuclear Waste*: Among the industrial waste, radio-active waste (RAW) or nuclear waste has two specific characters, viz., (a) the space requirement for storage is very little, and (b) the intensity of harmful effects gets reduced with the passage of time. For example, the operation of a large nuclear power station for one complete year results in only 4 m^3 of high-level RAW and about 100 m^3 of other long-lived waste materials, even after conditioning by incorporation into a solid host material1[17]. In the Indian context, the management of RAW includes all types of RAW generated from the entire nuclear fuel cycle, right from mining of uranium, fuel fabrication through reactor operations and subsequent reprocessing of the

spent fuel, and this fuel cycle is termed as 'closed'. RAW is also generated from the use of radionuclides in medicine, industry and research. Effective management of RAW involves segregation, characterization, handling, treatment, conditioning and monitoring, prior to the final storage/disposal in a highly integrated geological repository. RAW arises in different forms, viz., solid, liquid and gas with a variety of physical and chemical/radiochemical characteristics. Depending upon the level of radioactivity, RAW is classified as 'Exempt waste' with too low levels of radioactivity to warrant any concern from the regulators, 'Low-Intermediate level waste' [both short- (< 30 y half-life) and long-lived waste] and 'High Level Waste' (both short- and long-lived radio-nuclides), warranting high degree of isolation from the biosphere and usually requires final disposal into a deep geological repository. The overall philosophy for the safe management of RAW relies on the concept of__(i) delay and decay, (ii) dilute and disperse, and (iii) concentrate and contain. A wide range of treatment and conditional processes is presently available with mature industrial operations, involving several interrelated steps and diverse technologies[18]. Two examples of generation VAPs from nuclear waste are as follows:

(i) *Nano-diamond batteries from Nuclear Waste*[19]: As per NDB, a California-based company, its nano-diamond batteries will absolutely upend the energy equation, acting like tiny nuclear generators. They blow energy density comparison out of the water, lasting anywhere from a decade to 28,000 y without even needing a charge. They will offer high power density than lithium-ion batteries. They will be nigh-on indestructible and totally in an electric car crash. And in some applications, such as electric cars they stand to be considerably cheaper than current lithium-ion packs despite their huge advantages. The heat of *each cell* is a small piece of recycled nuclear waste. NDB uses graphite nuclear reactor parts that have absorbed radiation from nuclear fuel rods and become radioactive. Untreated, it's a high-grade nuclear waste: dangerous, difficult and expensive to store, with a very long half-life. The graphite is rich in the carbon-14 radioisotope that undergoes beta decay into nitrogen, releasing an anti-neutrino and a beta decay electron in the process. NDB takes this graphite, purifies and uses it to create tiny ^{14}C diamonds. The diamond structure acts as a semiconductor and heat sink, collecting the charge and transporting it out. Completely encasing the radioactive ^{14}C diamond is a layer of cheap, non-radioactive, lab-created ^{12}C diamond, which contains the energetic particles, prevents radiation leaks and acts as a super-hard protective and tamper-proof layer. To create a battery cell, several layers of this nano-diamond material are stacked up and stored with a tiny integrated circuit board and a small super-capacitor to collect, store and instantly distribute the charge. As per NDB, it will conform to any shape or standard, including AA, AAA, 18650, 2170 or all manner of custom sizes. So, ultimately it is a tiny miniature power generator in the shape of a battery that never needs charging – and as per NDB, it will be cost-competitive with, and sometimes significantly less expensive than – current lithium batteries. Radiation levels from this cell will be less than the radiation levels produced by a human body itself, making it totally safe for use in a variety of applications. At the small scale, these could include things, such as pacemaker batteries and other electronic implants, where the long lifespan will save the wearer for replacement surgeries. They could also be placed directly onto circuit boards, delivering power for the lifespan of a device[19].

(ii) *Medical isotopes from nuclear waste*: 'TerraPower', a nuclear innovation company in the USA has extracted actinium-225 (^{225}Ac) that results from radioactive decay of uranium and has shown promise in treating a range of cancers. The company hopes that mining the waste will yield between 200,000 and 600,000 doses currently available globally. If any of the ongoing clinical trials using ^{225}Ac to treat cancer pay off, repurposing such waste could be a key source of the element for those treatments. When ^{225}Ac undergoes radioactive decay, it ejects an alpha particle composed of two protons and two neutrons. A single alpha particle targeted at a cancer cell can stop the cell's growth in tracks. This whipping punch knocks cancer cells out so completely that so far little resistance to the treatment has evolved – a huge plus when treating tumors that can quickly morph into drug-resistant forms. As the alpha particles travel only a short distance through the body – about the same diameter of 2 or 3 human cells – there is minimal risk of damage to tissues beyond the target. In 1993, scientists discovered that ^{225}Ac could be attached to antibodies or other cancer-targeting biomolecules that they carry the isotope to the target cells, delivering radiation precisely where it is needed. And actinium is an ideal candidate to attach to drugs because it is a charged metal, which enables it tightly chelate an antibody. Furthermore, unlike other short-lived radioisotopes, such as bismuth-213 (half-life _ 45 minutes) and astatine-211 (half-life 7 h), ^{225}Ac has a relatively long half-life of 10 days. That gives scientists more time to extract it, process it into a drug and deliver that drug to a patient. Currently, such actinium drugs are being studied in pre-clinical models of breast cancer and glioblastoma, and clinical trials are ongoing in patients with acute myeloid leukemia and prostate cancer[20].

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7. *Cigarette-waste in construction*: In what amounts a catastrophe for our planet, Earth, six trillion cigarette butts are produced around the world every year, creating 1.2 m_ te of toxic waste, which is often thrown away on to streets. Cigarette filters can and are being recycled. A major study published by the Royal Melbourne Institute of Technology (RMIT) has demonstrated that manufacturers can use shredded or whole butts to produce next generation bricks. This initiative will result in a 10% reduction in production costs with incorporation of just 1% of recycled cigarette filter content. Incorporating recycled cigarette butts in just 2.5% of global annual brick production would effectively resolve the problem of a huge amount of waste that is thrown away on the streets or washed into world's oceans. Furthermore, environmental benefits can be reaped from the fact that the resulting bricks would be lighter and also more insulating[21].

The above examples of generation of value-added products from diverse types of waste, following the scientific methods of waste management (WM), from the collection to safe disposal of waste, presented in the earlier sections will create both wealth and employment on a large scale, which will be a big boon to a developing country like India.

III. Environmental Pollution

Environmental pollution (EP) is another burning problem on our planet. EP is defined as 'the contamination of the physical and biological components of the Earth/atmosphere system to such an extent that normal environmental processes are adversely affected'. Pollution was invented when the 'Quelccaya core' first records evidence of pollution from Inca metallurgy around the year, 1480 in the form of trace amounts of bismuth, likely released into the atmosphere during the creation of bismuth bronze, an alloy that has been recovered from the Inca citadel at Machu Picchu[22]. Activities by the human beings through urbanization, industrialization, transportation, exploration, mining, etc., are at the forefront of the global EP. It is triggered by the introduction of harmful materials, such as gaseous pollutants, toxic metals and particulate matter (PM) into the atmosphere. All the countries share this burden together, though awareness and stricter laws in developed countries have contributed to a larger extent in protecting their environment. Despite the global attention towards pollution, the impact is still being felt due to its severe long term consequences. Major forms of pollution include air/light/noise/plastic/thermal/visual and water, soil/radioactive contami-nation and litter. The environmental issues associated with the pollution are climate change, energy, water, chemicals, toxics and heavy metals, air pollution, waste management, ozone layer depletion, oceans and fisheries, and deforestation. The main sources of pollution are household activities, factories, agriculture and transport. The effects of pollution include muddying landscapes, poisoning soils and waterways, killing plants and animals. The major problems of EP are: ozone depletion, greenhouse effect, global warming, desertification, deforestation, loss of biodiversity and disposal of waste. Global warming is primarily caused by emissions of too much CO_2 and other heat-trapping gases into the atmosphere, when fossil fuels are burned to generate electricity, drive cars and power our lives. *Air pollution* is due to the release of chemicals and particulates into the atmosphere. Common gaseous pollutants include carbon monoxide, sulphur dioxide, chlorofluocarbons (CFSs) and nitrogen oxides, produced by industry and motor vehicles. Photochemical ozone and smog are created as nitrogen oxides and hydrocarbons react to sunlight. The particulate matter or fine dust is characterized by micrometer size PM_{10} to $PM_{2.5}$[23]. The ten causes of air pollution are: combustion from industry; emissions from vehicles of transportation, agriculture side-effects, home heating and cooking, forest fires, tobacco smoke and volcanic eruptions. Human beings are much harmed by pollution with long-term exposure to air pollution, for example, can lead to chronic respiratory diseases, lung cancer, heart attack, wheezing cough, breathing problems and irritation of the eyes, nose and throat. Air pollution also causes worsening of existing heart problems, asthma and other lung complications. The serious effects of air pollution on the environment are: global warming, climate change, acid rain, smog effect, deterioration of fields and extinction of animal species, respiratory health problems and deterioration in building materials. Some of the steps to reduce air pollution are: conservation of energy by turning off electric and electronic appliances when not in use; use of energy efficient light bulbs and appliances; and participating in local utility's energy conservation programmes. The groups most affected by air pollution are elderly residents, children with uncontrolled asthma and poor people. Vulnerable populations may experience more health effects, since they already have higher rates of heart and lung conditions. In India, the primary reasons for air pollution are the emissions from transporting media and industries, dust from construction and demolition sites, burning of biomass and agro-waste like stubble and poor waste management. During winter period, the pollution gets exacerbated when these factors combine with geographic and meteorological factors. To reduce the impact of air pollution, the Government of India has taken a number of measures both in Delhi-NCR and in over 100 cities across the country under the ongoing National Clean Air Programme (NCAP). An important measure among these is the introduction of BS VI compliant vehicle standards across the country since April, 2020 with an aim to reduce the NOx emissions by 70% in diesel and 25% in petrol vehicles, besides reduction of the Particulate Matter (PM) in vehicles by 80%. It is heartening to note that the global carbon emissions are down by 6.5% in 2020, as compared to 2019. The biggest contributor to this drop is the reduction in ground transport (possibly due to lockdown, imposed during the Covid-2019 pandemic period), which amounts for half of the change. Of the countries for which data are published, Spain has shown the highest decrease of 17.2% compared to 2019, as on August 31, 2020. In this year-on-year reduction in CO_2 emissions, India is second with 13.4%, followed by the US (12.9%), Germany (12.8%), UK (12%), Italy (11.8%), France (11.6%), Japan (7.1%) and PR China (2%) (Source: Carbon monitor)[24]. The effects of *water pollution* are the water-borne diseases, such as typhoid, cholera, paratyphoid fever, dysentery, jaundice, amoebiasis and malaria. Chemicals in the water also have negative effects on health. Pesticides can damage the nervous system and cause cancer because of their contained carbonates and organophosphates. *Land pollution* is the contamination of land and soil due to the deposition of waste materials, both the liquid and solid, on land that affects the soil and groundwater adversely. Land pollution is usually neglected, but it demands stronger reaction as air and water pollution. Disposing of waste has huge environmental impacts and can cause serious problems. Some waste will eventually rot, but not all, and in the process it may smell or generate methane gas that is explosive and contributes to the greenhouse gas effect. Leachate produced as waste decomposes may cause pollution.

Environmental pollution during the Covid-19 pandemic: Before the covid-19 pandemic, India was generating ~ 610 t of the biomedical waste per day, which after starting of the covid-10, has increased by another 101 t/day, *vide* the information submitted by the Central Pollution Control Board to the National Green Tribunal. In the four months from June to September, 2020, 18,000 t of covid-19 related biomedical waste was generated in the country thereby creating more environmental pollution. Of this, the highest contribution is from the state of Maharashtra (3,587 t), followed by Tamil Nadu and Gujarat. By October 21, 2020, the total tests in the country for covid-10 stood at > 97,200,000 with > 7,600,000 being positive. These tests, together with a vast amount of disposed material used for the testing and treatment of positive cases, have enormously increased the quantity of the bio-medical waste generated. As there are only 198 plants + 225 own facilities in some hospitals to process the biomedical waste in India with a population of 1.38 billion, much of the bio-medical waste has been disposed of in open places, thereby creating one of the worst disease-prone environmental pollution. For example, in the national capital, Delhi there are only 2 plants with a capacity to process daily 74 t of biomedical waste, whereas that generated in July, 2020 was of the order of ~ 350 t/day. Generally, the biomedical waste is burnt by incineration, which itself creates a lot of air pollution. To minimize this and other types of pollution due to the unscientific disposal of solid and liquid biomedical waste, steps are needed quickly to start many processing plants to treat the biomedical waste for bio-methane as well as reuse of some used items, after their thorough cleaning, sanitization and certification for safety. For example, the used PPE kits and other plastic items may be used as a bio-fuel and converted into pellets for use as some automobile spare parts, plastic covers and in road-construction[25]. Very recently, a study has concluded that long-term exposure to air pollution could be linked to 15% global deaths from the Covid-19. The researchers of this study combined health and disease figures with data about global exposure particulate matter in the air and concluded that "if both long-term exposure to air pollution and infection with the Covid-19 virus come together, then an adverse effect on health, particularly with respect to the heart and blood vessels" says vascular biologist Dr. Thomas Munzel (Al Jazeera)[26].

IV. Global Warming and Climate Change

Global Warming (GW) is characterized by a general increase in average global temperature. In the 20th century, surface temperature of the Earth has risen by 0.7-0.9ºC and, since the year 1975, this has doubled to 1.5-1.8ºC per century. The major causes for GW are: the emissions from power plants, transportation using fossil fuels of oil, gas and coal, extensive release of 'Greenhouse Gases' (GHG: CO_2, CH_4, N_2O, water vapor, ozone - O_3, halo-floro-carbon gases - HFC, PFC, SF_6 and NF_3) in the atmosphere, deforestation, use of fertilizers, drilling for oil and gas, permafrost, garbage, volcanic eruptions and wildfires in large areas, as exemplified in the recent years by those in the Amazon forest in Brazil, west coast states of the US, Australia and in some gulf countries. A large chunk of the world's emissions can be traced back to a few main sources; automobiles, electricity, coal and oil producers, CO_2, methane and the US citizens, who are responsible for the highest number of emissions with highest per capita carbon footprint, with 100 companies (mostly oil and coal producers) being responsible for 71% of the world's greenhouse gas emissions[27]. The impacts of global warming include: causing immediate and direct changes to the planet; hotter days (2015 was the hottest year on record); rising sea levels and increased ocean temperatures are melting glaciers and ice caps all over the world; more frequent and intense extreme weather events, such as bushfires, cyclones, droughts and floods, which are becoming more frequent and more intense; acidifying oceans as they have absorbed most of extra heat and CO_2

so far – more than the air – making seas both acidic and warmer, with the rising ocean acidity threatening shellfish, including tiny crustaceans without which marine food chains would collapse, and the countries that are at most risk in this regard are the Pacific and SE Asia nations, including Kiribiti, Tuvalu, Vietnam and the Philippines; stressing the ecosystems through temperature rise, water shortage, increased fire threats, drought, weed and pest invasions having two options – move or adapt; affecting both the food and farming due to changes in rainfall patterns, increasingly severe drought, more frequent heat waves, flooding and extreme weather making it more difficult for farmers to graze livestock and grow produce, reducing food availability and making it more expensive to buy; water shortages due to reduced rainfall and increasingly severe droughts; coastal erosion due to rising sea levels leading to weary away and inundating community and residential properties near the coastline; effects on health due to increasingly severe and frequent heat waves leading to death and illness, especially among the elderly, besides higher temperatures and humidity could also produce more mosquito-borne diseases; damage to homes due to increasingly severe extreme weather events, such bushfires, storms, floods, cyclones and coastal erosion will increase damage to houses, as well as more costly insurance premiums; and coral bleaching due to rising temperatures and acidity within the oceans, contributing to extreme coral bleaching events, like the 2016 event that destroyed more than one-third of the Great Barrier Reef[28].

Climate change (CC) is a waste management (WM) problem. From the WM perspective, CO_2 emissions represent metabolic byproduct of industrial activities on which billions of people depend to survive and this byproduct should be safely disposed of. The evidences for CC are: global rise in temperature, rise of sea-level, warming of the oceans, ocean acidification, shrinking ice sheets in the Arctic and Antarctic oceans as well as in the polar regions, retreat of glaciers, decrease in snow cover, increase in pollution levels, extreme events and frequent occurrence of natural disasters, such as drought, floods, cyclones, hurricanes, tsunamis, earthquakes, etc. To combat CC and to reduce/control GW, almost all the nations agreed for the Paris agreement on the climate change in 2015 (December 12, 2015) aimed at to strengthen the global response to the threat of CC by keeping a global temperature rise in this century well below 2ºC above pre-industrial levels and to pursue efforts to limit the GW even further to 1.5ºC. Additionally, the agreement aims to strengthen the ability of countries to deal with the impacts of new technology framework and an enhanced capacity building framework will be put in place, thus supporting action by developing countries and the most vulnerable countries, in line with their own national objectives. The Agreement also provides enhanced transparency of action and support through a more robust transparency framework. It requires all parties to put forward their best efforts through nationally determined contributors and to strengthen these efforts in the years ahead. This includes requirements that all parties report regularly on their emission and efforts of implementation[29]. Some of the *solutions* to fight CC and to control GW are as follows: 1. Tree plantation, 2. Creation of sustainable transportation habits, 3. Lower heating bill, 4. Divest from coal, 5. Encourage organic farming and vegetarian food, with less of non-vegetarian food, 6. Educate the girls, 7. Advocate for a healthy planet, 8. Behave sustainably and become a climate warrior, 8. Support green/renewable energy (wind, solar, hydro, hydrogen and nuclear), 9. Consuming less and avoid wastage to the maximum extent, 10. Add solar panels, 11. Change light-bulbs to LEDs, 12. Use programmable thermostat, 12. Wash clothes in cold water, 13. Buy new appliances with efficient energy star label, 14. Design work-space around natural light, 15. Unplug electronic devices, when not in use, 16. Manage water with rainwater harvesting, 17. Avoid unnecessary purchases, 18. Recycle products and Recover value-added products, 19. Reduce food-waste, 20. Walk small distances, 21. Work from Home, 22. Avoid plastic bags, 23. Avoid idling of car, 24. Go for e-vehicles, etc.[30]. India has kept the climate pledge by sticking to its commitment to CC, despite not being a pollutant. Some of the initiatives taken in this regard are as follows: (i) Clean energy will be used to incremental energy requirement that will be a substantial part of the global demand, but base demand will be met from crude oil and gas; (ii) focusing not just on petroleum but also other energy sectors, where they have been a series of reforms like methane from coal as a primary strategy; (iii) the country emerging as a cleaner, efficient and cost-effective base; and (iv) moving towards 100 Giga watt solar capacity[24].

V. Interrelationship of Waste Management (WM) with Environmental Pollution (EP), Global Warming (GW) and Climate Change

Interrelationship of WM and EP: With rapid population growth, the generation of waste is increasing at an alarming rate. In spite of the WM methods of incineration and other ways of waste treatment, landfill still dominates waste disposal due to insufficient funding for adequate WM, particularly in the low- and middle-income countries, in which the uptake of more advanced WM is also poor. Without proper WM, many landfills represent serious environmental hazards as typified by the landslide in Shenzhen, PR China on Dec. 20, 2015. In addition to formal waste recycling systems, ~ 15 million people around the world are involved in the informal waste recycling, mainly for plastics, metals, glass and paper. While informal recyclers contribute to waste recycling and reuse, the relatively primitive WM techniques they employ, combined with improper management of secondary pollutants, exacerbate environmental pollution of air, soil and water[31], pointing to the link between WM and EP.

Interrelationship of WM and GW: Current WM methods, specifically emissions from landfill, account for ~ 5% of total global greenhouse gas (GHG) emissions and 12% of methane emissions[31]. This problem can be addressed to by reducing landfill-waste (now ~ 70%) through composting, recycling (19%) and incineration (11%) to energy. WM, in the terms of reduction, separation and recycling, is the best option to reduce GW of the Earth, and the waste that remains would be burnt to create energy. Generation of bio-energy and conversion of plastics into liquid hydrocarbons and energy for diverse end-users of industries, agriculture, etc., can have positive effect in reducing GW and the ill-effects of CC as well, besides saving millions of dollars to import crude oil. Worldwide implementation of composting can reduce GHG emissions by 2.3 billion tons over the next 30 y. Reducing food-waste is one of the most important things to reverse GW and could have nearly the same impact on reducing emissions over the next 30 y as onshore wind turbines.

Interrelationship of WM and CC: According to the Clean Development Mechanism (CDM) and Joint Implementation (JI) of the Kyoto protocol, there is a great potential for addressing methane emissions by reducing the amount of waste that ends up in a landfill. Globally, nearly 70% of the solid waste is landfilled, a meager 19% is revered through composting or recycling, the remaining 11% is converted to energy through incineration or other waste-to-energy technologies. With aggressive measures for reducing landfilling put into place, > 1000 Mt of CO_2-eq could be converted by 2030, costing less than $100 per ton of CO_2-eq. per year. There are multiple technological options to reduce GHG emissions from post-consumer waste. Compaction can eliminate GHG emissions from landfill, and reduce overall the GHG emissions from solid waste. It is the organic material in the landfill that produces methane. Contrary to the decomposition that happens in a landfill which emits methane, composting is aerobic, which emits CO_2 that has comparatively lesser GHG potential per atom of carbon emitted. Offsetting this, the use of compose in agriculture increases C-sequestration, decreases the need for irrigation by as much 70%, and also reduces the need for chemical fertilizers. Waste-to-Energy via combustion is another option with potential for mitigation of CC. There are many of these plants worldwide, producing electricity and district heating for community by incinerating waste. For example, Switzerland, Japan, France, Germany, Sweden and Denmark are the countries in which 50% or more of the waste that is not recycled is sent to an incinerator reducing the amount of waste that is disposed of in landfills to as little as 4% of the overall waste generates. As per an ambitious package of policies, announced in December 2019, Europe aims to make it as the first climate-neutral continent by 2050; as per some scientists that to attain this, the European Union member states are outsourcing environmental damage to other countries, while taking credit for green policies at home[32], . Waste-to-Energy is often promoted as the primary option for reducing post-recycled waste landfilling. Post-recycled waste is the residue after all possible formal and informal recycling has been carried out[33]. Thus the WM methods, such as composting and waste-to-energy have the potentiality for mitigation of the adverse effects of CC, thereby demonstrating the link between WM and CC.

The above account, thus, points to interrelationship of WM with EP, GW and CC, all of which are the burning problems on our planet, mother Earth.

References

[1]. Times of India (ToI) (2020). In 30 y, India tipped to double the amount of waste it generates. March 03, 2020, Hyderabad ed., p. 2.

[2]. 2020 Global Hunger Index Results. www.globalhungerindex.org. > results.

[3]. Cleanest city in India: Indore bags the title of …(2020). <economictimes.indiatimes.com>… August 21, 2020.

[4]. What is waste management?-ERG Environmental Services. https://ergenenvironment.com/what-is-waste-management/

[5]. Waste disposable methods – Types of waste disposal/Solutions. https://byjus.com/biology/waste-disposal. August, 2020.

[6]. The 5 R's of Waste Management. LEARNZ navigation. https://www.learnz.org.nz/redvale181/bg-standard-f/the-5-r%27s-0f-2waste-management, August. 2020.

[7]. Waste-to-Energy plant. Wikipedia. https://en.m.wikipedia.org/wiki/Waste-to-energy_plant.

[8]. Hanley, Steve (2020). New process turns plastic waste into hydrogen and carbon nanotubes. (2020). https://cleantechnica.com/2020/10/16/new-process-turns-plastic-waste-into-hydrogen-and-carbon-nanotubes/amp.

[9]. Young technocrats set up world's first plastic-to-petrol plant in Guntur. The Times of India, Vijayawada ed., October 03, 2020. https://m.timesofindia.com/city/vijawayada/young-technocrats-set-up-worlds-first-plasstic-to-petrol-plant-in-guntur/amp_articleshow;78461260.

[10]. Barapatre, A., Aadil, K., Sahu, S. and Jha, H. (2013). Value added products from agrowaste. Conf. on 'Recent Research in Science & Technology', 5 (2), 7-12.

[11]. Stubble burning. https://www.drishtiias.com/daily-updates/daily-news-editorials/stubble-burning-2. Indian Express, 07/11/2019.

[12]. Agricultural waste turned into food/WhatsOrb. https://www.whatsorb.com/agri-gardening/turning-agricultural-waste-into-food-a-double-whamm-in-the-food-industry.

[13]. Balde , C.P. et al. (2017). The Global E-waste Monitor 2017, UNU, ITU, ISWA.

[14]. WEE recycling resources, Simsrecycling.co.uk (archived from the original on 6 January 2015; retrived on 6 June 2015).

[15]. Benefits of recycling, hardrawgathering.co.uk (archived from the original on 6 January 2015; retrived on 6 June 2015).

[16]. In New Zealand, microbes are extracting gold from electronic waste (2020). https://www.cnbc.com.2020/10/01/in-new-zealand-microbes-are-extracting-gold-from-electronic-waste.htmal.

[17]. Phadke, A.V., Dhana Raju, R. and Parthasarathy, T.N. (1986). Petromineralogical considerations in selection of rock candidates as high-level and long-lived radioactive waste repository in India. In: (Eds.) B.P. Radhakrishna and K. Ramachandran, 'Environmental Aspects of Geology', Geol. Soc. India, Mem. 5, 89-106.

[18]. Wattal, P.K. (2013). Indian programme on radioactive waste management. Sadhana, 38 (5), 849-857.

[19]. Blain, Loz (2020). Nano-diamond self-charging batteries could disrupt energy as know it. August 25, 2020, https://newatlas.com/energy/nano-diamond-self-charging-batteries-nsb/

[20]. Yan, Wudan (2020). Mining medical isotopes from nuclear waste. https://cen.acs.org/physical-chemistry/nuclear-chemistry/Mining-medical-isotoes-nuclear-waste/98129. July 27, 2020.

[21]. Best from Waste: Cigarette butts could soon be used in bricks to build houses (2020). https://www.news18.com/news/buzz/best-from-waste-cigarette-butts-could-soon-be-used-in-bricks-to-build-houses-2927869.html, Oct. 2, 2020, 3-21 p.m. IST.

[22]. When did humans start polluting the Earth? (2015). World Economic Form. www.weforum.org.> 2015/02 > whe…

[23]. Pollution. Wikipedia. En.m.wikipedia.org.

[24]. Times of India, Hyderabad ed., October 24, 2020, p. 17.

[25]. Arya (2020). Frightening Covid-waste (in Telugu). Eenadu, Hyderabad ed., Oct. 25, 2020, p.4.

[26]. Al Jazeera (2020). COVID deaths linked to air pollution. (cited in 'Nature Briefing', October 27, 2020.

[27]. Lemonade, T. (2019). How to stop global warming: The 8 best solutions. https://www.lemonadde.com/blog/climate-change-solutions. September 12, 2019

[28]. Impacts of Global Warming – WWF-Australia. www.wwf.org.au > … > Climate.

[29]. The Paris Agreement: essential elements. unfcc.int > process-and-meetings.

[30]. Sisson, P., Barber, M. and Walker, A. (2020). 101 ways to fight climate change – Curbed. https://www.curbed.com/2017/6/7/15749900/how-to-stop-climate-change-actions. Updated April 22, 2020.

[31]. Yang, H., Ma M., Thompson, J.R. and Flower, R.J. (2018). Waste management, informal recycling, environmental pollution and public health. Jour. Epidemiol Community Health, 72 (3), 237-243.

[32]. Europe's Green Deal: bad for the planet? Nature Briefing, October 27. 2020.

[33]. Solid waste management and climate change – be Waste Wise. https://wastewise.be/2013/08/solid-waste-management-and-climate-change/#.X4Rj7EThU0M