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Integrated Plastic Waste Management: Environmental and Improved Health Approaches

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Abstract

Plastics are integral part of society and have varied application. Plastics are composed of a network of molecular monomers bound together to form macromolecules. There are increasing concerns due to non degradability and generation of toxic gases on combustion during incineration. Due to fabrication of desired shape colour and specification convenient to customers there is increasing application in packaging, agriculture, automobiles and biomedical. They are indispensable to the modern generation due to development in information technology, intelligent and smart packaging system. Efforts are in progress for development of efficient and precise conversation of renewable raw materials into innovative polymeric product through recent technologies which are superior in terms of performance, environmental and cost perspectives. In rivers and at coastal regions the marine pollution is increasing at a faster rate due to indiscriminate disposal by the consumers. R&D studies are now centred for investigating whether consumption of plastic debris by marine organism translates into toxic exposures for people who consume seafood with particular relevance to plasticisers, stabilizers, heavy metals viz phthalates, BPA, lead cadmium, methyl mercury. Biological effects from pollution are linked with resulting economic effects and losses. A cornerstone of sustainable development is the establishment of affordable, effective and truly sustainable waste management practices in developing countries.

Plastic waste management is a critical issue. Over 300 million metric tons of plastics are produced in the world annually and about fifty percent of this volume is for disposal applications, product that are discarded within a year of their purchase. It is the boon and bane of our times. Although there are multiple uses, its waste and the resultant pollution clogs up our rivers, oceans, lands and adversely affects the biodiversity. We need to plan for disposal of new synthetic product, implants etc which have completed their shelf life. In future polymeric adhesives and implants are to be developed which address total joint replacement features for patients with varied complications and age. It should be robust, biocompatible with surface treatment options to allow for reduced friction and wear throughout the implant life. In a CPCB supported study we have found that the soil and ground water quality may be affected in dumpsite areas.

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The International Organisation for standardization [ISO] Organisation for Economic Cooperation [OECD] and development, British specification [BS] Indian Standards [IS] need to be implemented for appropriate application and safe disposal. Globally steps are being taken for development of environmental friendly, innovative plastic items using the concept of green chemistry and also with safe disposal methods. Integrated waste management practices are to be encouraged, strengthened and supported with state of art scientific applications.

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Introduction

Environmental concern caused by inadequate waste management as well as the steps to combat global warming promotes actions toward a sustainable management of organic fraction of the waste. Integrated waste management combines a variety of strategies for both waste management and waste reduction. It may involve burying waste in sanitary landfills and burning waste in mass burn incinerators. Solid waste management has become an issue of increasing global concern as urban populations continue to rise and consumption patterns change. Plastic is the general term for a wide range of synthetic or semi synthetic organic solid materials**.** Plastics are typically polymers of high molecular weight. They are usually synthetic, most commonly derived from petrochemicals, but many are partially natural. A polymer may contain other additives like plasticizers**,** stabilizers**,** lubricant**,** UV absorbing material**,** flame retardants to improve performance. Plastics have permeated every facet of human life such as packaging**,** agriculture**,** water transportation**,** building construction**,** telecommunication**,** education**,** medicine**,** transportation**,** defence**,** consumer durables to name a few**.** One of the reasons for great popularity of plastics is due to tremendous range of properties exhibited by them because of their ease of processing**.** Hence the demand for plastics has been increasing in modern living to improve the quality of life**.** The quantum of plastic waste in Municipal Solid Waste (MSW) is increasing due to increase in population, development activities and changes in the life style. The health and environmental implications associated with Solid waste management are increasing specially in the context of developing countries and regulatory requirements for environmental clearance. While systems analyses largely targeting well-defined, engineered systems have been used to help SWM agencies in industrialized countries since the 1960s, collection and removal dominate the SWM sector in developing countries. We should understand that the waste produced in the course of health care activities carries a potential risk of infection and injury than any other type of waste. The development of a national policy for proper waste treatment may be a significant step to abate Green House Gases (GHGs) emissions through controlled composting processes, mechanical biological waste treatment, waste air treatment etc with methodological prerequisites for proper measurement, data interpretation, planning, adequate financing, team work and administration.

Global Trends and Mitigation Strategies

Quantifying global trends requires annual national data on waste production and management practices. Estimates for many countries are uncertain because data are lacking, inconsistent or incomplete; therefore, the standardization of terminology for national waste statistics would greatly improve data quality for this sector. A wide range of mature technologies is available to mitigate green house gases emissions from waste. These technologies include land filling with landfill gas recovery, post-consumer recycling. composting of selected waste fractions and processes that reduce gases generation compared to landfilling Therefore, the mitigation from waste relies on multiple technologies whose application depends on local, regional and national drivers for both waste management and mitigation. Many developed and developing countries practise composting and anaerobic digestion of mixed waste or biodegradable waste fractions (kitchen or restaurant wastes, garden waste and sewage sludge).

Table 1: Population Growth and Impact on Overall Urban Waste Generation and Future Predictions

Year	Population (Millions)	Per Capita	Total Waste generation Thousand Tons/year
2001	197.3	0.439	31.63
2011	260.1	0.498	47.30
2021	342.8	0.569	71.15
2031	451.8	0.649	107.01
2036	518.6	0.693	131.24
2041	595.4	0.741	160.96

(Source: Sustainable Solid Waste Management in India by Ranjith Kharvel Annepu Advisor: Nickolas J. Themelis Stanley-Thompson Professor Emeritus, January 10, 2012)

Challenges in Strategic Management

Challenges in waste monitoring and strategic management range from environmentally friendly economic sectors exist, but face difficulties in terms of capital, unstable output of products, competitive advantages and low profits. The rapid loss of biodiversity, depletion of natural ecosystems, unsustainable use of natural resources, depletion of non-renewable resources and over-exploitation of fishing resources, especially in the inshore areas. Emerging pollution of inland river sediments with microplastics and consequently the implications on rivers as vectors of transport of microplastics into the ocean is worth consideration. The collection of municipal solid waste is a public service that has important impacts on public health and the appearance of towns and cities. Unfortunately many urban administrations seem to be losing the battle of coping with the ever-increasing quantities of waste. The challenge is made greater by the diversity of materials in the waste, which is no longer mainly food waste and ash, but includes more and more plastic packaging, paper and discarded electronic equipment.

Disposal of plastics waste has drawn attention of environmentalist due to their nonbiodegradability and anaesthetic views since these are not disposed scientifically and possibilities to contaminate soil and sub-soil water because of leachates. The technology employed is mechanical recycling is based on traditionally grinding extrusion to obtain granules. Mechanical recycling is the most preferred and widely used method of recycling and it recycles particular type of polymers used in water and soft drink bottles. As it requires selected plastic waste, the cost for sorting, cleaning and separating selected polymers increases the operating cost. The existing mechanical recycling process may emit harmful gases due to its old design components and not having provision for pollution control. The plastic waste including laminated plastics and carry bags are still remains the challenge for the process.

Energy Recovery from Plastics Waste

According to CPCB report the calorific value of plastic wastes can be utilized effectively by replacing coal. The use of plastic waste as alternative fuel will help to reduce the energy cost along with reduction in the CO_2 emissions. During co-incineration of plastic waste in blast furnace and cement kilns, it is completely burnt at high temperature and slag which remain as waste, can further utilized as cement and road construction. There is no risk of generation of toxic emission due to the burning of plastics waste in the process and the process is safe as per environmental norms. The establishment like Airport and Railways required developing environmental friendly waste management system for disposal of plastic waste generated from their premises. To reduce the burden of littered/discarded plastics, there is an urgent need for increase public awareness as people are responsible for the pollution caused by plastics. Keeping this in mind, few recommendations have been made, which may assist in formulating future policies for plastic waste management. Furthermore it is most important, to upgrade the technology for plastics waste disposal. The virgin plastic products shall be labelled with the plastic identification code to help in sorting and segregating as per IS 14535: 1998.

Municipal Solid Waste and Effects

The increased uses of plastics products as packaging application in the recent years have increased the quantity of plastics in the solid waste stream to a great extent. The quantum of solid waste is ever increasing due to increase in population, development activities, changes in life style, and socio-economic conditions. It is estimated that approximately 15722 tonnes per day (TPD) of plastic waste is generated on the basis of per capita consumption based on population of India. Plastic waste has a significant portion in total municipal solid waste (MSW). Hence, there is a formal system of waste collection in urban areas, however, informal sectors i.e. rag pickers, collect only value added plastics waste such as pet bottles etc. However, plastic carry bags and low quality plastic less than 20 micron do not figure in their priorities, because collecting them is not profitable. A study conducted by the National Environmental Engineering Research Institute (NEERI) for the Brihan Mumbai Muncipal Corporation, which handles more than 5,500 metric tones MSW per day shows that plastic waste is 0.75 %. In Europe and U.S.A, plastic waste makes up 8 % of total MSW. The rest is made up of organic materials (33%), paper and paperboards (30%), glass and metals (16%) and others (13%). The methods of recycling and the technology used for the same at present are quite outmoded and are in need of upgradation. It has also been observed that some of industries even recycle the plastic waste/scrap which is totally unhygienic and such is a health hazard for persons who use items made from such plastics and even used at times for packaging of foodstuff and medicines.

Microplastics as Plastic Debris

Microplastics are being detected in freshwaters of Europe, North America, and Asia, and the first organismal studies are finding that freshwater fauna across a range of feeding guilds ingest microplastics. According to the study in Korea floating debris around the mouth of the Nakdong River microplastics (<2mm) was present at all of the stations, whereas Styrofoam (2-5mm) peaked only at a few stations far from the Nakdong River mouth in July. They have used 330-μm mesh and hand-net (50μm). The dominant types were fibers (polyester), hard plastic (polyethylene), paint particles (alkyd), and Styrofoam (expanded polystyrene). Despite the large and growing literature on microplastics in the ocean, little information exists on microplastics in freshwater systems. They have attempted to evaluate the abundance, distribution, and composition of pelagic microplastics pollution in a large, remote, mountain lake and quantified pelagic microplastics and shoreline anthropogenic debris in Lake Hovsgol, Mongolia. Plastic debris is one of the most significant organic pollutants in the aquatic environment. Because of properties such as buoyancy and extreme durability, synthetic polymers are present in rivers, lakes, and oceans and accumulate in sediments all over the world. However, freshwater sediments have attracted less attention than the investigation of sediments in marine ecosystems. Depending on the catchment area and annual course of flood events, end points may either indicate an increase or a decrease of activity. In order to determine the ecological hazard potential of mobilized contaminants during flood events, the focus should be set on particle-bound pollutants. After landslides or floods runoff, remobilized sediments may cause an increase of ecotoxicologically relevant effects from contaminant reservoirs and contaminants may dislocate after flood in specific regions. In Asia, Japan and China are both encouraging ‘circular economy’ and ‘sound material-cycle society’ as a new development strategy, whose core concept is the circular flow of materials and the use of raw materials and energy through multiple phases. Regarding the future of up-front recycling and separation technologies, it is expected that wider implementation of incrementally-improving technologies will provide more rigorous process control for recycled waste streams transported to secondary markets or secondary processes, including paper and aluminium recycling, composting andincineration. The major impediment in developing countries is the lack of capital, which jeopardizes improvements in waste and wastewater management. Developing countries may also lack access to advanced technologies.

Table 2: Productions of Major Petrochemicals

(Figures in Thousand MT)

Group	Production/ Growth Rate	2006-07	2007-08	2008-09	2009-10	2010-11	2011-12	2012-13 (up to Sep., 12)
Synthetic Fibers	Production	2251	2524	2343	2600	2791	2697	1351
	Growth Rate (%)	18.1	12.1	-7.2	11	7.3	-3.4	
Polymers	Production	5183	5303	5061	4792	5292	6211	3198
	Growth Rate (%)	8.7	2.3	-4.6	-5.3	10.4	17.4	
Elastomers	Production	95	104	96	105	94	88	43
	Growth Rate (%)	4.4	9.5	-7.7	9.4	-10.5	-6.4	
Performance Plastic	Production	132	156	140	172	192	183	96
	Growth Rate (%)	3.9	18.2	-10.3	22.9	11.6	-4.7	
Major Petrochemicals	Production	8217	8672	8191	8287	9008	9802	4993
	Growth Rate (%)	10.3	5.5	-5.5	1.2	8.7	8.8	

Note: Production is aggregated based on monthly Production Returns from manufactures under large and medium scale.
[Source- Annual Report 2012-2013 (http://chemicals.nic.in/AR_2012-2013 (1-94).pdf)]

Environmental Contaminants-Phthalates, BPA, Heavy Metals etc.

Due to excess use of plastic materials its effect on environment and human health. Plastic is now regarded as a serious worldwide environmental and health concern essentially due to its non-biodegradable nature. Plastic containers and coatings help keep food fresh, but they can also leave behind neurotoxins such as BPA in the human body. PVC is used for everything from pipes and flooring to furniture and clothes, but it contains compounds called phthalates that have been implicated in male reproductive disorders. Studies have also shown that childhood exposure to environmental pollutants can have significant negative effects later in life. There is an ever increasing demand for new analytical methods suitable for monitoring of different phthalates in various environmental, biological and other matrices. Separation and spectrometric methods are most frequently used. However, modern electroanalytical methods can also play useful role in this field because of their high sensitivity, reasonable selectivity, easy automation and miniaturization, and especially low investment and running costs which makes them suitable for large scale monitoring.

Efficient Solid Waste Management Strategies

Typically, a solid waste management and treatment service helps municipalities businesses to manage solid waste by coordinating several activities. These activities include: source reduction, recycling and composting, and disposal in landfills or waste combustors. Source reduction alters the design, manufacture, or use of products to reduce the amount and toxicity of trash or garbage. Recycling diverts items such as paper and metals from the waste stream. Solid waste collection and scrap collection allows recycled materials to be processed into new products. Composting is a naturally-occurring process that decomposes organic waste to produce a humus-like substance. Appropriate solid waste disposal requires waste characterization, specification/description of chemical and physical properties. either directly or indirectly. Plastic pollution involves the accumulation of plastic products in the environment that adversely affects wildlife habitat, or humans.

The prominence of plastic pollution is correlated with plastics being inexpensive and durable, which lends to high levels of plastics used by humans. However, it is slow to degrade. Plastic pollution can unfavourably affect lands, waterways and oceans. Living organisms, particularly marine animals, can also be affected through entanglement, direct ingestion of plastic waste, or through exposure to chemicals within plastics that cause interruptions in biological functions. Humans are also affected by plastic pollution, such as through the disruption of the thyroid hormone axis or sex hormone levels. Increasing the level of understanding in these areas is essential if we are to develop appropriate policy and management tools to address this emerging issue. Plastic waste management is a critical issue. In India, for safer disposal of plastic waste, various technologies have been experimented such as Utilization of plastic waste in road construction, Co-processing of Plastic waste in Cement Kilns. In the last few years, state and central governments have started paying attention to the issues of plastic waste seriously. Consequently many legislations, acts and rules have been formulated to bring the situation under control.

Responsibility to protect the environment and enforcing the existing regulation lies within the Ministry of Environment and Forests (MOEF). Plastics play an increasingly important role in reaching the recovery and recycling rates defined in the waste electrical and electronic equipment (WEEE) category by Europeans. They pose an important environmental problem because these plastics commonly contain toxic halogenated flame retardants which may cause serious environmental pollution, especially the formation of carcinogenic substances Polybrominated dibenzo dioxins/furans (PBDD/Fs), during treat process of these plastics. Pyrolysis has been proposed as a viable processing route for recycling the organic compounds in WEEE plastics into fuels and chemical feedstock. However, dehalogenation procedures are also necessary during treat process, because the oils collected in single pyrolysis process may contain numerous halogenated organic compounds, which would detrimentally impact the reuse of these pyrolysis oils.

Waste, and especially plastic waste, is a major global challenge. Plastic is the fastest-growing component of the solid waste stream. And because plastic degradation takes up to one thousand years, it is becoming a long-lasting environmental problem for today's generation and those to come. Although plastics stand for approximately 10%-15% by weight of municipal solid waste generated (depending on country), it poses an enormous fraction by volume reaching up to 40%. This feature makes plastic wastes difficult to handle and collect. Disposal of plastic waste is a serious concern in India. In a study conducted during 2012-13 on Yamuna river water heavy metals such as cadmium, chromium, copper, nickel, zinc, and lead have been found in the river due to rampant discharge of industrial effluents into the river. The mean metal concentrations in the 15 sampling sites were in the range of (mg L(-1)) 0.02-0.64 (Cu), 0-0.42 (Cr), 0.13-2.22(Zn), 0.03-0.27 (Pb), 0-0.07 (Cd), and 0.01-0.13 (Ni). Multivariate statistics (PCA and HCA) were used to identify the possible sources of metal contamination and to examine the spatial changes in the Yamuna River as well as in the Najafgarh drain. Phthalic acid esters [PAEs] are a group of xenobiotics and hazardous compounds blended in plastics to enhance their plasticity and versatility. Enormous quantities of phthalates are produced globally for the production of plastic goods, whose disposal and leaching out into the surroundings cause serious concerns to the environment, biota and human health. Though in silico computational, in vitro mechanistic, pre-clinical animal and clinical human studies showed endocrine disruption, hepatotoxic, teratogenic and carcinogenic properties, usage of phthalates continues due to their cuteness, attractive chemical properties, low production cost and lack of suitable alternatives.

Rapid economic development and population growth, inadequate infrastructure and expertise, and land scarcity make the management of municipal solid waste become one of India's most critical environmental issues. The study is aimed at evaluating the generation, characteristics, and management of solid waste in India based on published information. A new institutional and legislation framework has been structured with the objectives to establish a holistic, integrated, and cost-effective solid waste management system, with an emphasis on environmental protection and public health.

Salient Regulatory Guidelines

An appraisal of implementation has revealed that desired results have not been achieved by the prescribed authorities due to various reasons and a need was felt to revisit these rules for the protection of public health and environment by DOEF in 2015. The new rules propose to increase the thickness of plastic bags to 50 microns so that their cost discourages people from using them. But penalties need to be made stricter for better implementation. Wet bio-degradable, dry recyclable and combustible waste and domestic hazardous waste shall be segregated at source in accordance with the Solid Waste Management (SWM) Rules, 2015. The processing, disposal of plastic (as well as the inert from recycling or processing facilities of plastic waste) shall be in compliance with the SWM Rules, 2015.

Table 3: Salient Guidelines on Plastics

Sl.	Title	Guidelines / Specifications
1.	Specifications for compostable plastics	ISO 17088:2012
2.	Guidelines for Recycling of Plastics	IS 14534:1998
3.	Guidelines for the recovery and recycling of plastics waste	ISO 15270:2013
4.	Sorting and Segregation of plastics	IS 14535:1998 and ICPE Newsletter Vol 6, Issue 2, 2005
5	Manual on Solid Waste Management (2001), CPHEEO, Ministry of Urban development, GoI, New Delhi.	MSWM, 2001
6.	Plastic Waste (Management & Handling) Rules, 2011	2015
7.	Methods for the preparation of test samples used in the determination of the ultimate aerobic and anaerobic biodegradability of plastic materials in an aqueous medium, soil, controlled compost or anaerobic digesting sludge.	ISO 10210:2012
8	Method for the determination of the ultimate aerobic biodegradability of plastics, based on organic compounds, under controlled composting conditions by measurement of the amount of carbon dioxide evolved and the degree of disintegration of the plastic at the end of the test.	ISO 14855:2012

Management of Plastic Waste

Plastic wastes are being generated at rapid rate of urbanization in India. Waste generation rates are often affected by socio-economic development, degree of industrialization, sector of operation and climatic conditions. Municipalities, local authorities and the communities-at-large encouraged by legislation have created regulations for waste management, aiming to reduce the amount of waste disposed on landfills through selective collection, reuse, recycling and recovery of various solid waste. In countries where waste management systems are considered to be advanced, plastic waste disposal is managed by one of the methods viz reuse, recycling, landfills or incineration. There should be inclusion of a heavy penalty for non-compliance with the rules for effective implementation. India generates almost 1.5 MT of plastic waste every year. Less than a quarter of the waste is being collected and treated.

Reuse, Recycling, Incineration and Landfill- How safe?

To reuse is to use an item again after it has been used. This includes conventional reuse where the item is used again for the same function, and new-life reuse where it is used for a different function. In contrast, recycling is the breaking down of the used item into raw materials which are used to make new items. By taking useful products and exchanging them, without reprocessing, reuse help save time, money, energy, and resources. Energy and raw materials savings as replacing many single use products with one reusable one reduces the number that need to be manufactured. Recycling is a process to change waste materials into new products to prevent waste of potentially useful materials. A landfill site also known as dumping ground is a site for the disposal of waste materials by burial and known to be oldest form of waste treatment. Historically, landfills have been the most common method of organized waste disposal and remain so in many places around the world. The recycling sector in India is dispersed between the formal and informal sector. Formal recycling units are registered, pay taxes and municipality has an account of them. Some landfills are also used for waste management purposes, such as the temporary storage, consolidation and transfer, or processing of waste material (sorting, treatment, or recycling). A landfill also may refer to ground that has been filled in with rocks instead of waste materials, so that it can be used for a specific purpose, such as for building houses. Unless they are stabilized, these areas may experience severe shaking or liquefaction of the ground during a large earthquake. Incineration is a waste treatment process that involves the combustion of organic substances contained in waste materials. Incineration and other high-temperature waste treatment systems are described as "thermal treatment". Incineration of waste materials converts the waste into ash, flue gas, and heat. The ash is mostly formed by the inorganic constituents of the waste, and may take the form of solid lumps or particulates carried by the flue gas.

Inference

The primary prevention of pollution and waste is feasible by directions to industries to eliminate or reduce the amount of harmful chemicals used in production, reduce packing materials for products and make products that last longer and are easier to recycle, reuse and repair. It aims to reduce the overall waste produced at the source. Moreover, we may educate and encouraging people to buy reusable products, repair broken items, recycle, reuse products and compost. In industrialized countries, public health, environment, resource scarcity, climate change, and public awareness and participation have acted as SWM drivers towards the current paradigm Infrastructure developments are needed for the sorting, collection and treatment of specific wastes. Formulation and application of incentive policies for recycling activities and establishing recycling funds are suggested. Plastic biomedical waste management practices are also one of the important aspects of infection control and need to be monitored. Leachates of landfills need to be monitored for phthalates and their metabolites, metals and other potential xenobiotics at periodic intervals to safeguard from adverse implications. GHG emissions from waste are directly affected by numerous policy and regulatory strategies that encourage energy recovery from waste, restrict choices for ultimate waste disposal, promote waste recycling and re-use, and encourage waste minimization.

The Extended Producers Responsibility [EPR] regulations extend producer responsibility to the postconsumer period, thus providing a strong incentive to redesign products using fewer materials as well as those with increased recycling potential (OECD, 2001). Contamination through plastics and polymeric products is an increasing environmental problem in marine systems where it has spread globally to even the most remote habitats. Plastic pieces in smaller size scales, microplastics (particles <5 mm), have reached high densities in waters and sediments, and are interacting with organisms and the environment in a variety of ways.. Efficient and precise conversions of renewable raw materials into innovative polymeric products that are superior in terms of performance, environmental, and cost perspectives. Disposal practices in tune to international guidelines and safety are needed. In future all-polymeric implants which are designed or developed should address environmental sustainability and be robust, biocompatible with surface treatment options to allow for reduced friction and wear throughout the implant life. Marine pollution levels are increasing due to indiscriminate disposal practices.

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