RESEARCH GUIDE ON WASTE MANAGEMENT

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Research Guide Snapshot

Waste management include the activities and actions required to manage waste from its inception to its final disposal. This includes the collection, segregation, transport, treatment and disposal of waste, together with monitoring and regulation of the waste management process. Waste management is a complex integration of resource management, economic development, public policy and acceptance, and government regulations while protecting the environment, promoting circular economy, and improving quality of life.

The *Research Guide on Waste Management* is developed by Knowledge Resource Centre, TERI to help locate information resources on waste management covering topics on policy and regulatory issues, technology, statistics, R&D, case studies, commercial perspectives, projects and current development. You are requested to share your views and resources to develop this subject guide into a more comprehensive and updated resource.

1. Sectoral Brief

The Basel Convention by United Nations Environment Programme (UNEP) define wastes "as substances or objects, which are disposed of or are intended to be disposed of or are required to be disposed of by the provisions of national law" (UNEP, 2011). Waste management include the activities and actions required to manage waste from its inception to its final disposal. This includes the collection, transport, treatment and disposal of waste, together with monitoring and regulation of the waste management process.

1.1 Classification of Waste

Waste can be classified based on source/origin, property, and effects on human health and the environment.

Classification by Source/Origin of Waste

- **Industrial Waste**: These are the wastes created in factories and industries generated by manufacturing or industrial processes. Many industries dump their wastes in rivers and seas which cause a lot of pollution. These wastes include dirt and gravel, masonry and concrete, scrap metals, trash, oil, solvents, chemicals, weed grass and trees, wood and scrap lumber, and similar wastes.
- **Commercial Waste**: Commercial wastes are produced in schools, colleges, shops, and offices. Examples include plastic, paper, etc.
- **Domestic Waste**: Various household wastes are collected during household activities like cooking, cleaning, etc. Examples include garden waste, vegetable peels, excreta, etc.
- **Agricultural Waste**: Various wastes produced in the agricultural field are known as agricultural wastes. These include cattle waste, weed, husk, etc.

Classification by Properties of Waste

- **Biodegradable Waste**: These are the wastes that come from kitchen and include food remains, garden waste, etc. Biodegradable wastes decompose themselves over a period of time depending on the material. Biodegradable waste can be composted to obtain manure.
- **Non-biodegradable Waste**: These are the wastes which include old newspapers, broken glass pieces, plastics, etc. Non-biodegradable wastes do not decompose by themselves and hence are major pollutants.

Classification of Waste by Effects on Human Health and the Environment

- **Hazardous Waste***: These wastes can potentially causing harm to the environment and human health* and therefore needs special, separate treatment and handling. Chemical and physical characteristics determine the exact collection and recycling process. Flammability, corrosiveness, toxicity, ecotoxicity and explosiveness are the main characteristics of hazardous waste. Liquid, gaseous and powder waste need special treatment by default to avoid the dispersal of the waste. Generally, separate collection and handling are established to avoid contact with non-

hazardous waste. Chemical treatment, incineration or high-temperature treatment, safe storage, recovery and recycling are possible modes of treatment for hazardous waste. Most hazardous waste originates from industrial production. Special kinds of hazardous waste include:

E-waste is waste from electric and electronic equipment such as end-of-life computers, phones and home appliances.

Medical waste originates from the human and animal healthcare systems and usually consists of medicines, chemicals, pharmaceuticals, bandages, used medical equipment, bodily fluids and body parts. Medical waste can be infectious, toxic or radioactive or contain bacteria and harmful microorganisms (including those that are drug-resistant).

Radioactive waste contains radioactive materials. The management of radioactive waste differs significantly from that of other waste.

- **Non-hazardous Waste***:* These wastes can be recycled and reused or treated and disposed, safeguarding the environment, in compliance with the statutory and regulatory requirements.

1.2 Challenges and Issues

According to the World Bank, global annual waste generation is expected to jump to 3.4 billion tonnes over the next 30 years, up from 2.01 billion tonnes in 2016 (World Bank, 2018). Efficient waste management is critical for sustainable, healthy, and inclusive regions and communities. The key to efficient waste management is to ensure segregation of waste at source and to ensure that the waste goes through different streams of recycling and resource recovery and finally scientific disposal in sanitary landfills. In each of these steps, trained and skilled manpower is required for better waste management process. Driven by rapid urbanization and growing populations, mankind is facing massive waste management challenge in issues like balancing objectives between promoting recycling and protecting consumers against harmful substances in recycled materials, insufficient data collection, quality aspects related to recycling, energy recovery of waste, and waste prevention. Mismanagement of waste can lead to the following environmental and health issues:

- **Air emissions**: Air emissions are mainly produced by fumes from incineration and landfill gases. Fumes from open waste burning practices release hazardous components into air. A significant proportion of greenhouse gas emissions related to waste is released into the air during the degradation of organic matter in landfills.
- **Soil contamination**: Hazardous substances may enter into soil as water trickles through contaminated sites leaching out chemicals, fertilisers or pesticides. Contaminated soil can damage flora and fauna directly and indirectly release toxic components into the food chain. Ingesting, inhaling or touching contaminated soil may have serious adverse impacts on humans and animals. Toxic components such as Persistent Organic Pollutants pose particularly great risks to human health and the environment as they bioaccumulate through the food chain.
- **Surface and groundwater pollution**: Surface water seeping through waste will absorb hazardous components from landfills, agricultural areas, etc, and carry them into surface and groundwater. This may lead to major effects on the ecosystem and the food chain. Contamination of surface and groundwater may cause damage to wetlands and their ability to support healthy ecosystems

and control flooding. Contaminated groundwater also poses a great health risk, as it is often used for drinking, bathing and recreation, as well as in agricultural and industrial activities.

- **Marine pollution**: Marine pollution constitutes a large threat to marine life, fisheries, mangroves, coral reefs and costal zones. The pollution comes from land-based sources, such as pesticides, POPs, heavy metals from mine tailings and electronic waste, radioactive substances, wastewater and marine litter. An estimated 8 million tons of plastics enters the ocean each year, as a result of the mismanagement of domestic waste in coastal areas (UNEP, 2019)

1.3 Integrated Waste Management

In 1996 the United Nations Environmental Programme (UNEP) defines Integrated Waste Management as "a framework of reference for designing and implementing new waste management systems and for analysing and optimising existing systems" (UNEP, 1996). Integrated waste management is an encompassing concept in which a framework is considered in an integrated manner which enables waste generators to utilise their waste streams more efficiently than just the disposal option. In recent years, the concept of integrated waste management is gaining prominence. This approach is based on a set of priorities known as the waste management hierarchy, as depicted shown in the Figure 1.

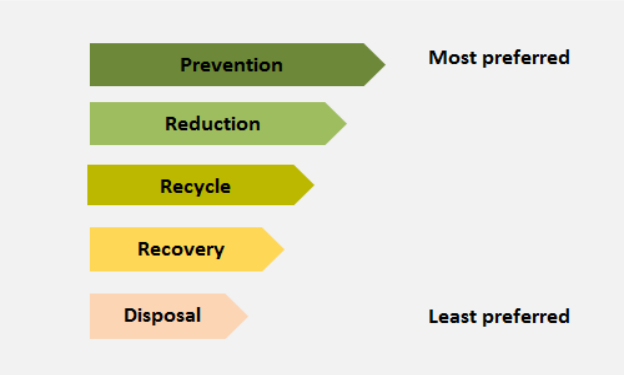

Figure 1. **Waste Management Hierarchy**

Source. UNEO Green Economy Report 2011

The hierarchy structure gives top priority to preventing waste in the first place. When waste is created, it gives priority to preparing it for re-use, then recycling, then recovery, and last of all disposal (e.g. landfill). In many countries, informal sector contribute significantly to waste management and resource efficiency by collecting, sorting, trading and sometimes even processing waste materials. The informal sector comprises waste pickers, scrap collectors, traders and recyclers.

1.4 Sustainable Transition to a Green Economy

The **circular economy** concept is fast becoming a new model for resilient growth. A circular economy is one in which products and materials are recycled, repaired and reused rather than thrown away, and in which waste from one industrial process becomes a valued input into another. Waste management is a critical part of the transition towards a circular economy. As circular economy is

increasingly being viewed internationally as a necessity and opportunity, integrated solutions to the issue of waste is a major challenge. The circular economy is based on three following principles:

- Design out waste and pollution
- Keep products and materials in use
- Regenerate natural systems

An emerging visionary concept, the **blue economy**, includes the circular economy and goes beyond it. Both are about radical resource productivity, zero waste and sustainability.

Sources.

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2. Government Policies, Acts and Regulations

Waste management in India falls under the purview of the Centre with the Ministry of Environment, Forests and Climate Change being the nodal ministry. The National Environment Policy, 2006 has laid emphasis on disposal, recycling and treating waste. It is the primary legislatures to protect the environment and regulation of waste. Major legislations include the following.

Plastic Waste Management Amendment Rules, 2021

Highlights include:

- Proposes a ban on the manufacture, import, stocking, distribution, sale and use of specific single-use plastic from July 1, 2022. These include plastic sticks for balloons, plastic flags, candy sticks, ice-cream sticks, and thermocol (extended polystyrene) for decoration.
- In order to stop littering due to light weight plastic carry bags, with effect from 30th September, 2021, the thickness of plastic carry bags has been increased from fifty microns to seventy five microns and to one hundred and twenty microns with effect from the 31st December, 2022. This will also allow reuse of plastic carry due to increase in thickness.

To access *Plastic Waste Amendment Management Rules, 2021*, click here

Hazardous and Other Wastes (Management and Transboundary Movement) Amendment Rules, 2019

Highlights include:

- Solid plastic waste has been prohibited from import into the country including in Special Economic Zones and by Export Oriented Units.
- Exporters of silk waste have now been given exemption from requiring permission from the Ministry of Environment, Forest and Climate Change.
- Electrical and electronic assemblies and components manufactured in and exported from India, if found defective can now be imported back into the country, within a year of export, without obtaining permission from the Ministry of Environment, Forest and Climate Change.

Read more

To access *Hazardous Waste Management Rules, 2016*, click here

E-waste (Management) Amendment Rules, 2018

Highlights include:

- Collection targets under the provision of Extended Producer Responsibility (EPR) in the Rules have been revised and targets have been introduced for new producers who have started their sales operations recently.
- The phase-wise collection targets for e-waste in weight shall be 10% of the quantity of waste generation as indicated in the EPR Plan during 2017-18, with a 10% increase every year until 2023. After 2023 onwards, the target has been made 70% of the quantity of waste generation as indicated in the EPR Plan.

- Producer Responsibility Organizations (PROs) shall apply to CPCB for registration to undertake activities prescribed in the Rules.
- Under the Reduction of Hazardous Substances (RoHS) provisions, cost for sampling and testing shall be borne by the government for conducting the RoHS test. If the product does not comply with RoHS provisions, then the cost of the test will be borne by the Producers.

Read more…..

To access the *E-Waste (Management) Rules, 2016*, click here.

To access the salient features of the *E-Waste (Management) Rules, 2016* in comparison to the *E-waste (Management & Handling) Rules, 2011* with the reasons /and likely implications, click here.

Bio-Medical Waste Management (Amendment) Rules, 2018

Highlights include:

- Bio-medical waste generators including hospitals, nursing homes, clinics, dispensaries, veterinary institutions, animal houses, pathological laboratories, blood banks, health care facilities, and clinical establishments will have to phase out chlorinated plastic bags (excluding blood bags) and gloves by March 27, 2019.
- All healthcare facilities shall make available the annual report on its website within a period of two years from the date of publication of the Bio-Medical Waste Management (Amendment) Rules, 2018.
- Operators of common bio-medical waste treatment and disposal facilities shall establish bar coding and global positioning system for handling of bio-medical waste in accordance with guidelines issued by the Central Pollution Control Board.

Read more…

To access the *Bio-medical Waste Management Rules 2016*, click here.

Solid Waste Management (SWM) Rules, 2016

Highlights include:

- Source segregation of waste has been mandated to channelize the waste to wealth by recovery, reuse and recycle
- Responsibilities of generators have been introduced to segregate waste in to three streams (wet, dry and domestic hazardous) and handover segregated wastes to authorized rag-pickers or waste collectors or local bodies.
- Generator will have to pay ‘User Fee’ to waste collector and for ‘Spot Fine’ for littering and non-segregation
- All hotels and restaurants to segregate biodegradable waste and set up or follow a system of collection to ensure that such food waste is utilized for composting / biomethanation.

Read more…..

To access the salient features of the *Solid Waste Management Rules 2016*, click here.

Construction and Demolition Waste Management Rules 2016

Highlights include:

- Every waste generator who generates construction and demolition (C&D) waste shall segregate construction and demolition waste and deposit at collection centre or handover it to the authorised processing facilities
- Large generators (who generate more than 20 tons or more in one day or 300 tons per project in a month) shall submit waste management plan and get appropriate approvals from the local authority before starting construction or demolition or remodelling work,
- Large generators shall have environment management plan to address the likely environmental issues from construction, demolition, storage, transportation process and disposal / reuse of C&D Waste.
- Large generators shall segregate the waste into four streams such as concrete, soil, steel, wood and plastics, bricks and mortar,

To access the salient features of the *Construction and Demolition Management Rules 2016*, click here.

2.1 Key Government Programmes

Swachh Bharat Mission

The aim of the mission is to accelerate the efforts to achieve universal sanitation coverage and to put focus on sanitation. The programme includes elimination of open defecation, conversion of unsanitary toilets to pour flush toilets, eradication of manual scavenging, municipal solid waste management and bringing about a behavioural change in people regarding healthy sanitation practices.

The Union Cabinet has recently approved the Phase II of the Swachh Bharat Mission - Grameen till 2024-25, which will focus on Open Defecation Free Plus (ODF Plus), which includes ODF sustainability and solid and liquid waste management.

To know more about **Swachh Bharat Mission Urban**, click here

To know more about **Swachh Bharat – Grameen**, click here

Swachh Survekshan, Ministry of Housing and Urban Affairs

Swachh Survekshan is an annual survey of cleanliness, hygiene and sanitation in cities and towns across India. The Survey, being undertaken since 2016, covers different components of sanitation related aspects that include segregation of waste at source and processing of waste. In the 2019 Survey, Indore was adjudged as India's cleanest city for the third consecutive year, while Bhopal was named as the 'Cleanest Capital' of India. The Swachh Survekshan 2020 covers over 4370 cities.

Read more

Atal Mission for Rejuvenation and Urban Transformation, Ministry of Housing and Urban Affairs

The Mission focuses on development of basic urban infrastructure in sewerage and septage management in the Mission cities with the expected outcome of Substantial improvement

in coverage and treatment capacities of sewerage. Substantial coverage of sewerage and septage management is the priority sectors under the Mission. At the inception of AMRUT, the sewerage coverage was 31%. By the end of the Mission, it aims to cover 62% households.
Read more

Smart Cities Mission, Ministry of Housing and Urban Affairs
The objective of the Mission is to promote cities that provide core infrastructure and give a decent quality of life to its citizens, a clean and sustainable environment and application of 'Smart' Solutions. Sanitation, including solid waste management, is one of the core infrastructure elements in a Smart City.
Read more

Waste-to-Energy Programme, Ministry of New and Renewable Energy
The objectives of the programme are to:

- To promote setting up of projects for recovery of energy in the form of Biogas / BioCNG / Power from Urban, Industrial and Agricultural Waste and Captive Power and Thermal use through Gasification in Industries
- To promote setting up of projects for recovery of energy from Municipal Solid Waste for feeding power into the grid and for meeting captive power, thermal and vehicular fuel requirements.
- To promote Biomass Gasifier for feeding power into the grid or meeting captive power and thermal needs of rice mills/other industries and villages

Read more

Jawaharlal Nehru National Urban Renewal Mission, Ministry of Housing and Urban Affairs
Jawaharlal Nehru National Urban Renewal Mission (JNNURM), launched in 2005, was a reform driven infrastructure improvement programme that aims to create economically productive, efficient, equitable and responsive cities. Solid waste management is one the thrust areas of the Sub-Mission for Urban Infrastructure and Governance. Under the mission, several solid waste management projects were funded in various cities. This scheme is now succeeded by Atal Mission for Rejuvenation and Urban Transformation.
Read more

3. Technology

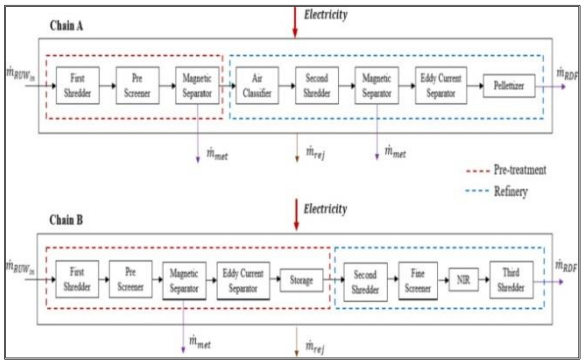
3.1 Municipal Solid Waste

Mechanical Biological Treatment

The Energy 198: 117-325, 1 May 2020

Mechanical biological treatment like AD systems, incineration, vermicomposting etc. are treatment process aims at separating the light and dry fraction of the unsorted waste from the wet one, producing the refused derived fuel and recovering the metal parts. This is an important element of integrated solid waste management system.

Read more….



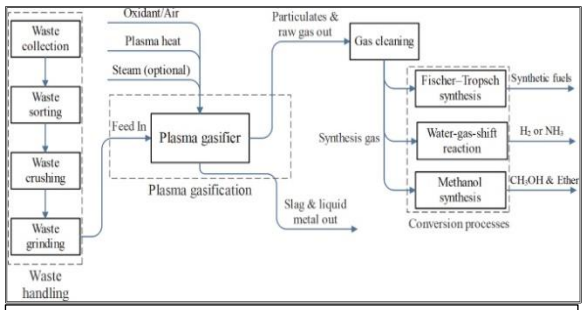
Different chain structures analysed in mechanical biological

Plasma Gasification

Renewable and Sustainable Energy Reviews 116: 109-461, December 2019

Plasma gasification can be a viable technology for converting municipal solid waste (MSW) into value for the circular economy. Plasma gasification can be a suitable technique to achieve zero-waste accumulation, produce renewable fuels, and protect the environment.

Read more…



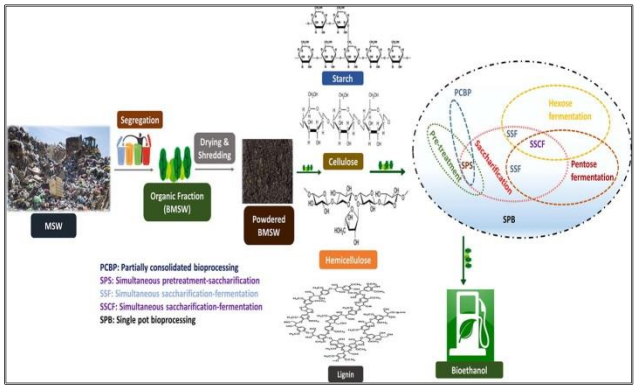
Plasma gasification schematic

Single pot bioprocessing (SPB)

Bioresource Technology 283: 159-167, July 2019

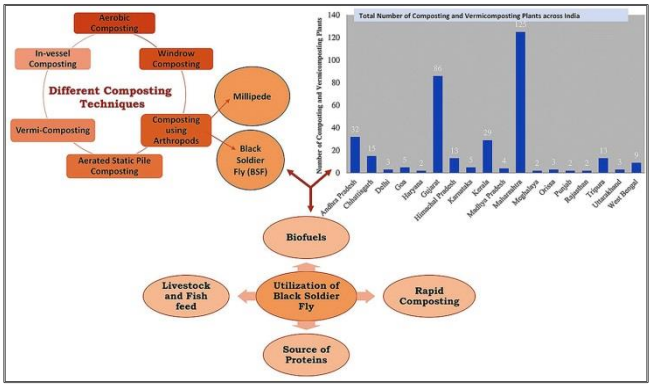
Biogenic municipal solid waste (BMSW) can serve as a solution driven by an effective and simple technology for the production of bioethanol and at same point aid in waste remediation. Single pot bioprocessing i.e., combined pre-treatment and saccharification along with co-fermentation has been employed in this study with an objective to improve the ethanol yield in shorter processing time.

Read more…



Rapid composting techniques

Journal of Environmental Management 227: 189-199, December 2018

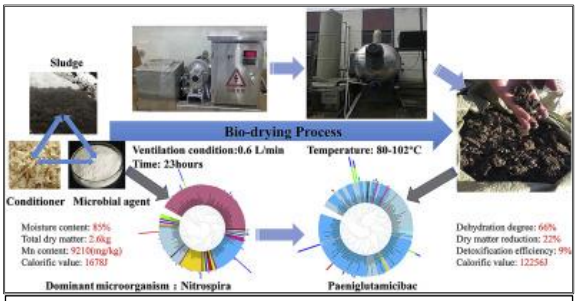


Composting of organic waste is a technique of rerouting discarded materials from dumping sites while obtaining a product at a low cost which is appropriate for the agrarian purpose. By the process of composting, the huge volume of wastes is reduced significantly. This article reviews the recent trends and technologies associated with the process of composting. Utilization of black soldier fly (BSF) larvae can be one of the rapid methods for treatment of biodegradable wastes.

Read more…

Biodrying process

Waste Management 49: 64-72, March 2016



Schematic diagram of biodrying process

Biodrying is an aerobic convective evaporation process which reduces the moisture content of the waste, with minimum aerobic degradation. The biodrying process can be promising for treating mixed municipal solid waste containing large proportion of organic compounds, since high moisture content of the organic materials will increase the wetness of the entire MSW matrix.

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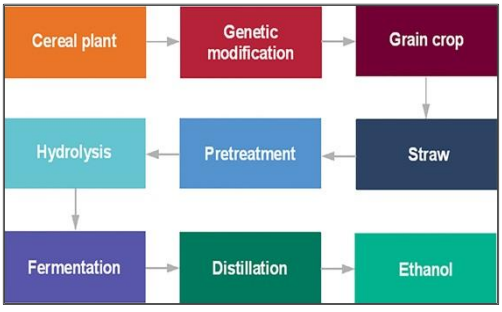
3.2 Agriculture Waste

Genetic modification of cereal plants

Industrial Crops and Products 150: 112-408, August 2020



Genetic modification has been reported as an effective strategy to increase productivity, biomass yields and specific traits of various agricultural plants. It focuses on the progress of different techniques used in genetic modification (transgenesis, cisgenesis mutagenesis and conventional breeding) to genetically engineer plant cell wall.

Read more…

Bioconversion of agricultural waste

International Journal of Recycling of Organic Waste in Agriculture 8: 11–20, 2019

The study established dual inoculation effect of *Eisenia fetida* and *Pseudomonas sp.* with poly lining in the pit as a suitable technology for faster decomposition and effective bioconversion of agricultural waste into quality organic manure.

Read more…

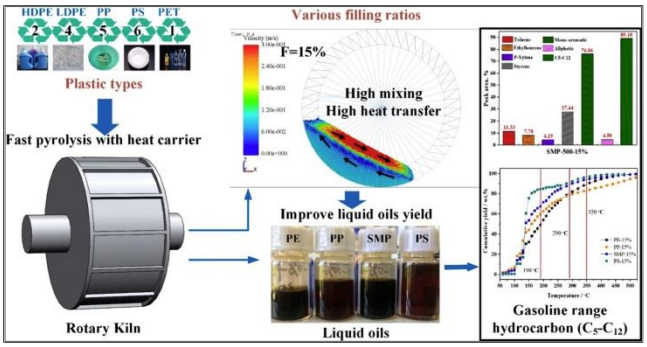
3.3 Plastic Waste

Pyrolysis of plastic wastes with heat carrier in rotary kiln

Fuel Processing Technology 206: 106-455, September 2020

In this study, plastic wastes were pyrolyzed in a rotary kiln to recover liquid oils that could be used as the source of valuable chemicals or fuels. Pyrolysis converts low-grade and non-biodegradable plastic wastes into liquid oils, syngas and char.

Read more…

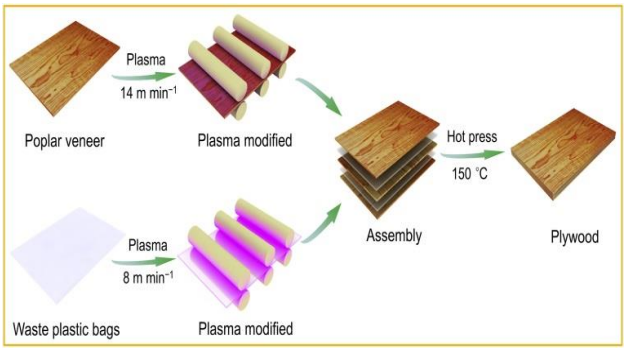


Clean plasma modification for recycling waste plastic bags

Journal of Cleaner Production: 269: 122-196, October 2020

The waste plastic bag was recycled as an alternative to formaldehyde-based adhesives for manufacturing formaldehyde-free plywood. An industrial atmospheric dielectric-barrier-discharge plasma system was used to treat the plastic bag, in order to enhance the interfacial adhesion of the resultant plywood.

Read more…

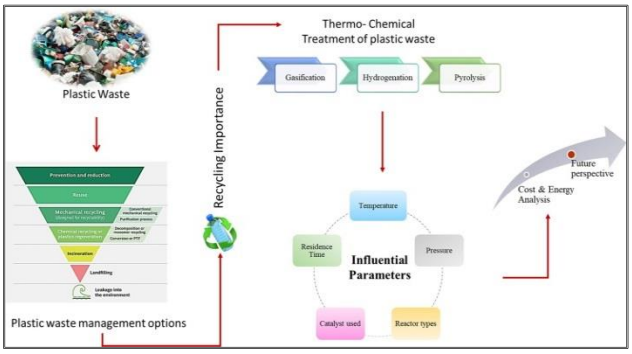


Thermo-chemical biomass conversion

Science of the Total Environment 718: 137-287, May 2020

Thermo-chemical recycling techniques hold more benefits in generating high value added liquid fuels. In this review, the details of municipal plastic waste generation are provided with a brief description of the plastic waste management option and importance of recycling is explained.

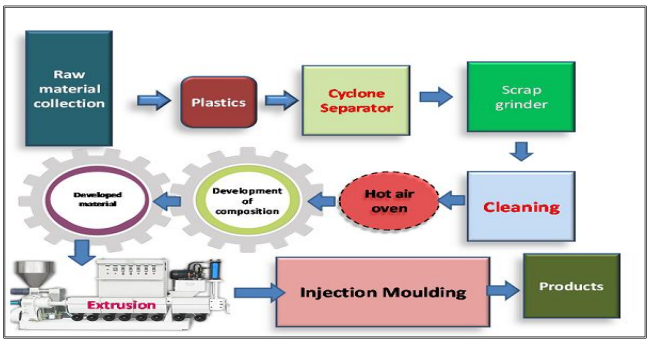
Read more…



Plastic and metal waste recycling technology

Department of Science and Technology, Government of India

Central Institute of Plastics Engineering &Technology (CIPET): [A1] School for Advanced Research in Polymeric materials (SARP), Bhubaneswar developed an eco-friendly viable technology for streamlining of segregation methodology, categorization of plastics waste and value addition of plastics for commercial exploitation.



[Read more…]

Recycling Polystyrene Waste with Citrus Peel Extract

Department of Science and Technology, Government of India

Indian Institute of Technology, Hyderabad has developed a technology to recycle waste polystyrene using agriculture waste (citrus peel extract) and develop it into a non-woven fabric. Polystyrene (e.g. thermocol) is a non-biodegradable material that leads to serious impact on health and environment as a waste. This fabric can selectively absorb oil and are hydrophobic. Therefore it can be used for a wide variety of applications ranging from kitchen napkins, to flexible packaging to oil spillage remediation. The technology is ready to be commercialized and technology transfer is in progress through the start-up company, M/s. Restyro Technologies Pvt. Ltd. in IIT Hyderabad Incubation Centre.

[Read more…]

3.4 E-Waste

Microrecycling

Materials Today Sustainability 9: 100040, September 2020

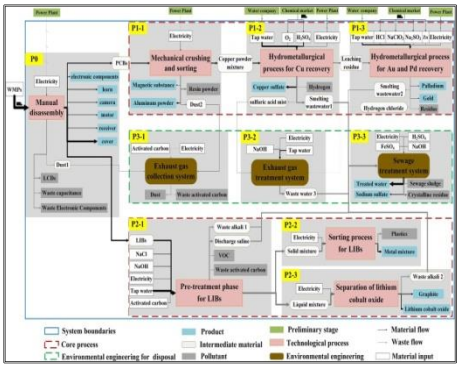
Microrecycling realizes the transformation of materials as an effect of temperature and time, for example, metals, polymers, and ceramics of e-waste separately. Enabling the multiple reactions by selective thermal transformation to achieve the careful synthesis of pure metal alloys, sometimes without melting the metals has placed the fundamentals of the novel pathways to generate metal alloys, nanoceramics, and cleaner gases from waste.

[Read more…]

Hydrometallurgical process for recycling waste mobile phones

Waste Management 111: 41-50, June 2020

A cost-effective method compared with primary mining, is an essential step for maximizing the recovery of secondary resources and minimizing e-waste pollution. The hydrometallurgical process had three characteristics of high



recovery efficiency, significant environmental friendliness and economic feasibility.
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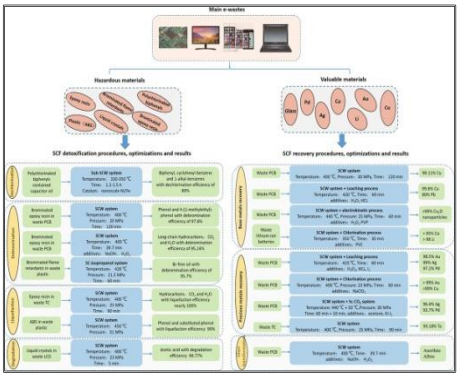
Supercritical fluid technology for e-waste treatment



Journal of Cleaner Production 227: 794-809, August 2019

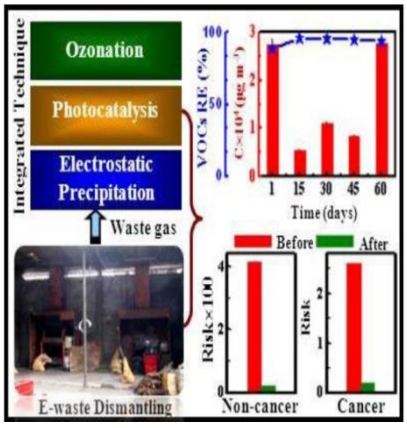
SCF technologies have great advantages in the field of environment, without air or water pollution risks. Supercritical fluid (SCF) is a kind of fluid whose temperature and pressure are higher than its critical state. It has many unique properties. Viscosity, density, diffusion coefficient, solvation capacity and other properties are very sensitive to the changes in temperature and pressure.
Read more…

EMARP framework for refurbishment industries

Journal of Environmental Management 201: 303-308m October 2017

The EMARP framework is specifically designed for refurbishment industries involved in refurbishment of e-waste which mainly includes 'clean' e-waste collected from houses, companies, educational institutions, factories, etc.
Read more…

Advanced oxidation technologies

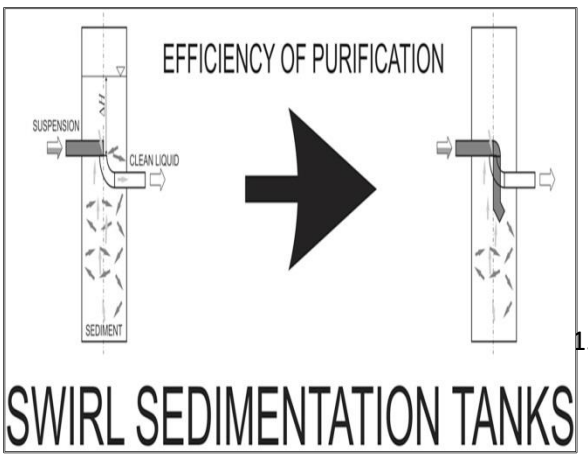


Journal of Hazardous Materials 302: 395-403, January 2016

Advanced oxidation technologies (AOTs), including Fenton oxidation, photocatalytic oxidation, electrochemical oxidation, etc. have emerged as promising VOC abatement technologies. Among these AOTs, photocatalysis (PC) has attracted considerable attention for degrading organics, given its generation of powerful and non-selective oxidant active species.
Read more…

3.5 Waste Water

Swirl/vortex technologies as liquid purification system



Journal of Environmental Management 189: 22-28, March 2017

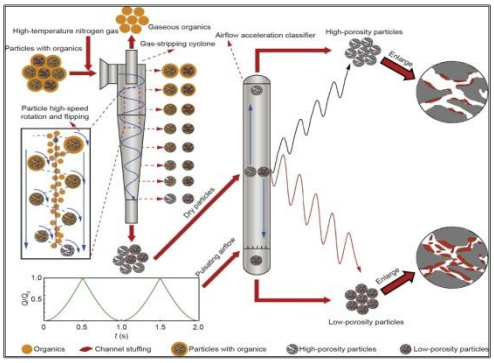
Here discusses the design, evaluation, and application for the use of swirl/vortex technologies as liquid purification system. A study was performed using modified swirl sedimentation tanks. The vortex separators

(OW, OWK, OWR and OWKR) have been studied under laboratory conditions at liquid flow rate from 2.8·10−5 to 5.1·10−4 [m3/s]. The pressure drop and the efficiency of purification of liquid stream were analyzed. The suspended particles of different diameters were successfully removed from liquid with the application of swirl chambers of proposed constructions.
Read more

Separation-and-Recovery Technology for Organic Waste Liquid

Engineering, 4 (3): 406-415, June 2018

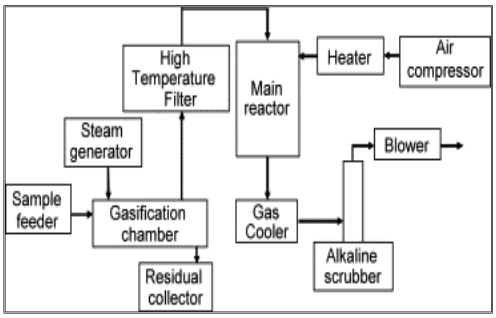
The technological process was developed to recover organic matter from waste liquid by cyclonic gas stripping and classifying inorganic particles by means of airflow acceleration classification.
Read more...



Steam Reforming (SR) Technology

Journal of Physics and Chemistry of Solids 66(2–4): 694-696, 2005

Feasibility study of Steam Reforming (SR) Technology for treating Low-Level Radioactive Organic Liquid Waste (LLROLW) such as fluorinated oils has been performed. Temperature dependences of vaporization for simulated wastes have been studied through the thermo gravimetric method.
Read more

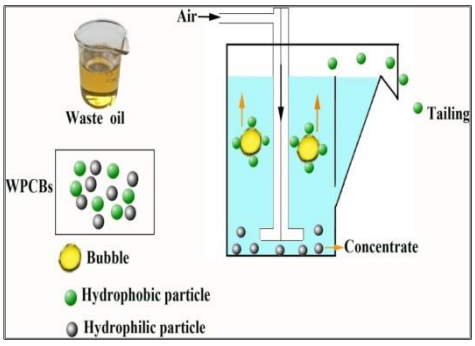


3.6 Metal Waste

Flotation technology with non-ionic renewable collector

Journal of Cleaner Production 255: 120289, May 2020

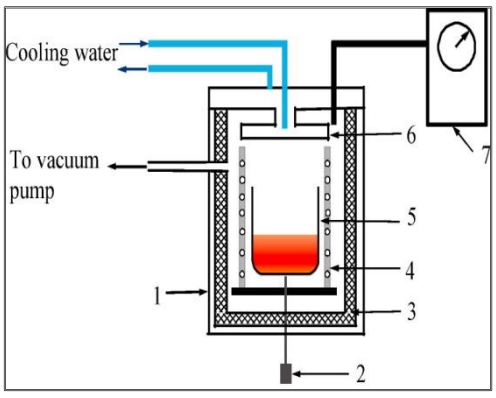
Flotation method was proposed to recover metal from waste printed circuit boards (WPCBs). The flotation mechanism was revealed by functional group composition, which was analysed by infrared spectrometer (FT-IR) and X-ray photoelectron spectroscopy (XPS).
Read more...



New vacuum distillation technology for separating and recovering

Separation and Purification Technology 209: 863-869, January 2019

A new, clean and highly efficient vacuum distillation process is presented for the separation of valuable metals that remain in the waste. Valuable metals in the flotation tailings can be separated and recovered effectively via a two-step vacuum



distillation in which no wastewater or gas is released into the environment.
Read more…

3.7 Nuclear Waste

Pyrolysis to remove hydrogen from an organic nuclear waste

Journal of Hazardous Materials: 123367, July 2020

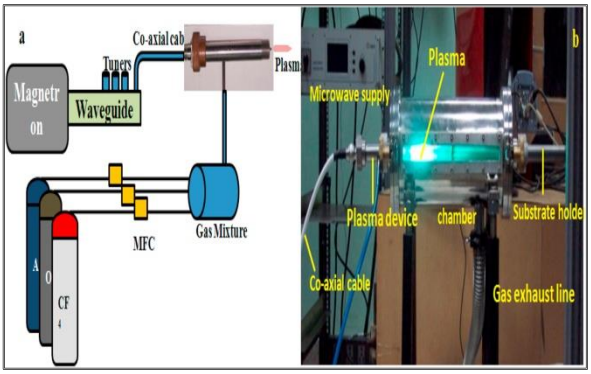
Pyrolysis of polymeric material is a growing technology in many industrial fields. The work deals with the removal by slow pyrolysis of epoxy resin from samples of spent nuclear fuel embedded in this polymer.
Read more…

Wet chemical processing

Journal of Hazardous Materials 362: 368-374, January 2019

To retrieve radionuclides from nuclear waste glass (NWG) a protocol of the wet chemical process to retrieve the radionuclides from simulated NWG has been proposed and demonstrated.
Read more…

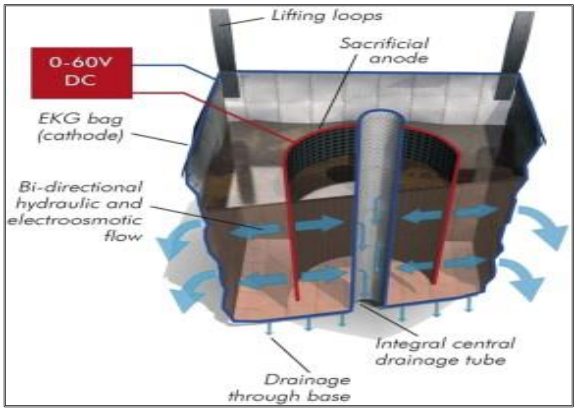
Using non-thermal microwave plasma for nuclear waste management



Environmental Technology & Innovation 12: 219-229, November 2018

In this study we have a prototype, a non-thermal microwave based atmospheric pressure plasma jet (APPJ) device developed & characterized and installed it inside a glove box for solid radioactive waste removal. Parametric optimization studies have been conducted on synthetic solid radioactive wastes.
Read more…

Electrokinetic geosynthetic dewatering of nuclear contaminated waste



Geotextiles and Geomembranes 43(4): 359-362, August 2015

Electrokinetic geosynthetics (EKG) technology provides an alternative dewatering treatment method which reduces the volume of the contaminated waste.
Read more…

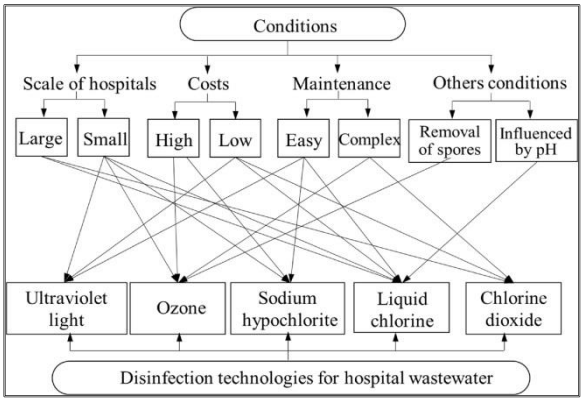
3.8 Medical Waste

Disinfection technology of hospital wastes and wastewater

Environmental Pollution 262: 114665, July 2020

In this study, technologies of different types of hospital wastes and wastewater disinfection have been summarized. Considering the characteristics of various hospital wastes, the classification and selection of corresponding disinfection technologies are discussed.

Read more…

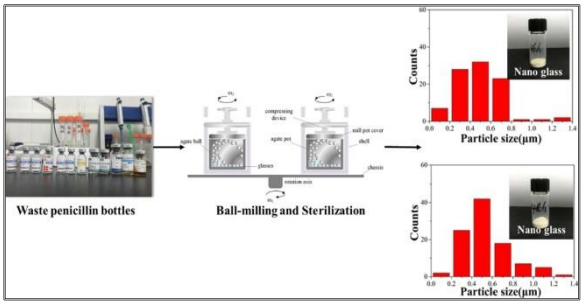


Recovering nano glass from penicillin bottles of medical wastes

Journal of Cleaner Production 229: 632-639, August 2019

This study provided a new and safe technology of recovering nano glass from penicillin bottles of medical wastes. The microorganisms in penicillin bottles were identified by the methods of gram staining and gene sequencing.

Read more…



4. Statistics/Industry Data

What a Waste Global Database, World Bank

What a Waste is a global project to aggregate data on solid waste management from around the world. This database features the statistics collected through the effort, covering nearly all countries and over 330 cities. The metrics included cover all steps from the waste management value chain, including waste generation, composition, collection, and disposal.

Read more

To access *Trends in Solid Waste Management*, click here

Figure 4.1. **Waste Generation Rates: South Asia Region (kg/capita/day)**

Source. What a Waste 2.0: A Global Snapshot of Solid Waste Management to 2050. Urban Development, World Bank, 2018

Central Pollution Control Board

The CPCB collects, compiles and publishes technical and statistical data on state-wise status and inventory of hazardous waste, bio-medical waste, municipal solid waste, and plastic waste.

Read more:

- State wise status of Hazardous waste generation
- National Inventories of Hazardous Wastes Generating Industries & Hazardous Wastes Management in India
- State/UT-wise Status of Hazardous Waste generation in the Country
- Waste Generation In Cities
- Inventory of Bio-Medical Waste Management

IndiaStats

The portal collects, collates and compiles data on various socio-economic parameters including solid waste. Tables include:

- State-wise Bio-Medical Waste Generation in India (2011 to 2018)
- State-wise Solid Waste Generated and Processed in India (As on November, 2018)
- State-wise Total Number of Wards, Collection and Waste Generated under Solid Waste Management in India (As on 31.12.2018)
- State-wise Waste Generation in Urban Areas under Municipal Solid Waste Management in India (As on 31.12.2018)

More on Solid Waste

Solid Waste Management, Open Government Data

Isher Ahluwalia Committee estimated the 20 years investment requirement from different sources for Urban water supply, sewage, solid waste management and storm water based on service level benchmark developed by Ministry of Urban Development.

Read more

E-waste Statistics: Guidelines on Classifications, Reporting and Indicators, United Nations University

In order to improve comparability between countries, a sound measurement framework is proposed that integrates and validates available harmonized statistical data and other non-statistical data sources into e-waste statistics. This measurement framework is presented along with a classification of e-waste.

Read more

Municipal Waste, OECD Environmental Statistics

This dataset presents trends in amounts of municipal generated, and the treatment and disposal method used. The data predominantly covers OECD countries.

Read more

5. Research

RESEARCH TRENDS IN WASTE MANAGEMENT

As a key topic for environmental protection, resource utilization and circular economy, waste management has received considerable attention in the scientific community over the past decades, reflected by the vast peer-reviewed articles on waste management that can be retrieved by accessing research literature databases such as Scopus.

Analyzed parameters included publication output as well as distribution of countries, institutions, source titles, subject category, and authors. 114,661 documents were published over the time period of ten years from 2010 to 2019. From Figure 5.1, it can be observed that there has been an increasing trend in the published documents from 2012 onwards.

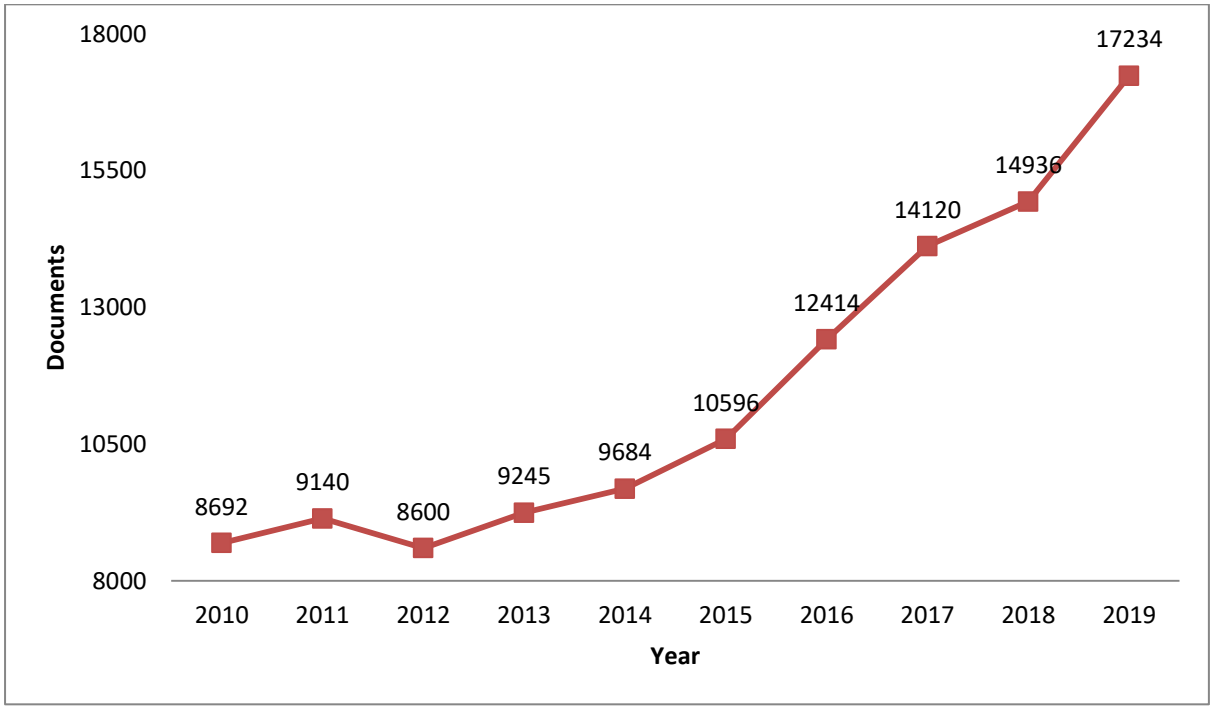


Figure 5.1. **Documents by Year**

Among countries of origin, China has published the maximum number of papers, followed by United States and India (Figure 5.2).

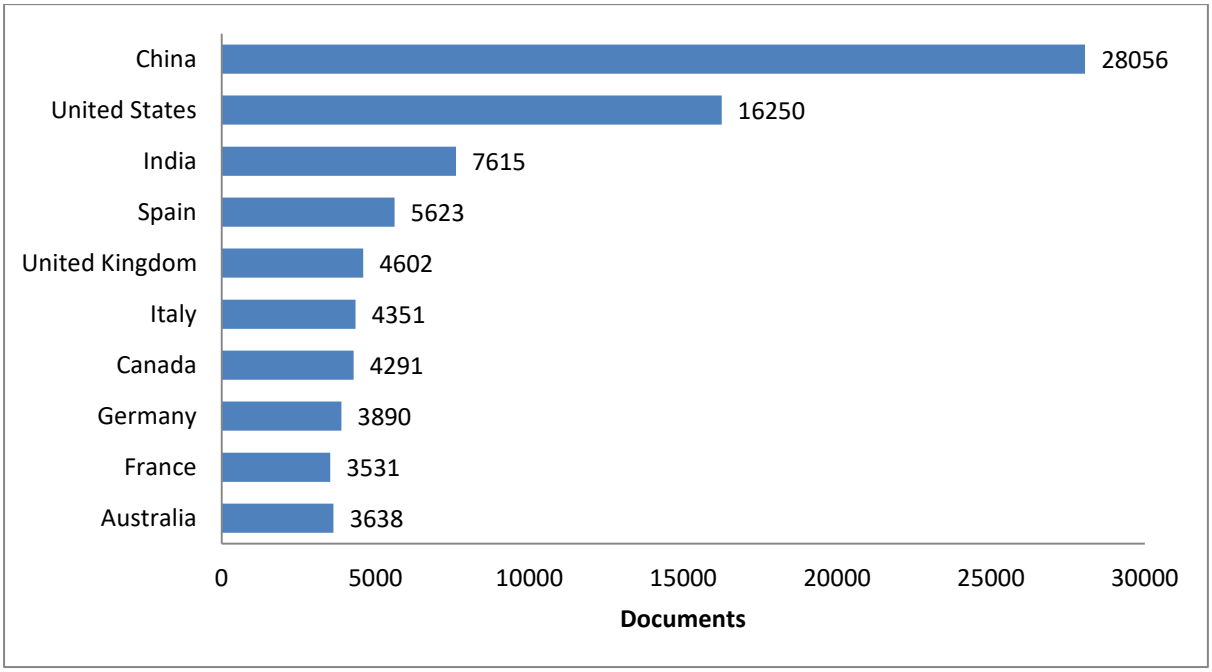


Figure 5.2. **Documents by country (Top ten countries)**

The top three subject areas under which the literature on waste management has been published are Environmental Science, Engineering and Chemical Engineering (Table 5.1).

Table 5.1. **Documents by Subject Area**

Subject Area	No. of documents
Environmental Science	69556
Engineering	26343
Chemical Engineering	19469
Chemistry	16345
Energy	15440
Materials Science	9660
Agricultural and Biological Sciences	8117
Biochemistry, Genetics and Molecular Biology	7256
Earth and Planetary Sciences	6114
Medicine	4910
Social Sciences	4871
Physics and Astronomy	4820
Immunology and Microbiology	4023
Computer Science	3924
Business, Management and Accounting	3360
Economics, Econometrics and Finance	1875
Pharmacology, Toxicology and Pharmaceutics	1651
Mathematics	1462
Multidisciplinary	1143

Decision Sciences	774
Arts and Humanities	347
Health Professions	332
Nursing	194
Veterinary	143
Neuroscience	94
Dentistry	83
Psychology	65
Undefined	3

Of the top ten subject areas, 38% of documents belong to the subject area of Environmental Science, followed by Engineering (14%) and Chemical Engineering (11%) as depicted in Figure 5.3.

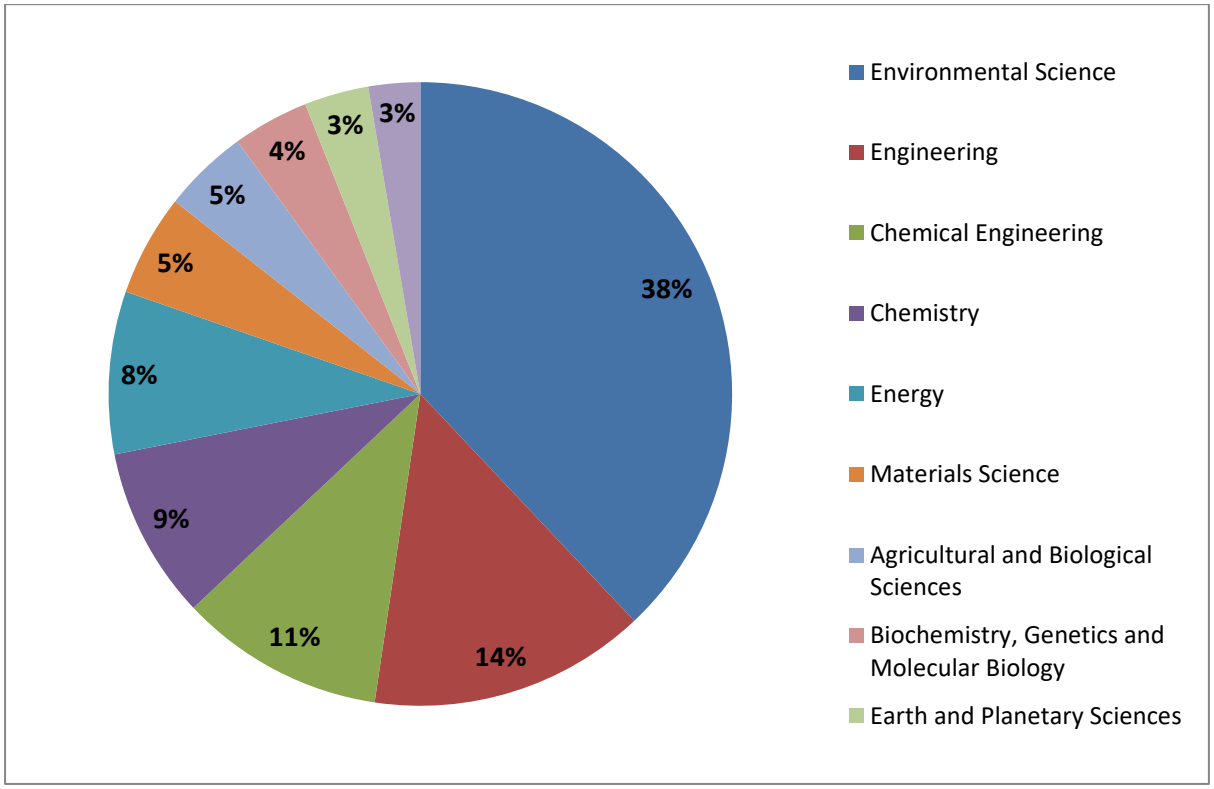


Figure 5.3. **Documents by Top Subject Areas**

The top ten leading journals based on published literature are provided below:

1. Bioresource Technology
2. Waste Management
3. Water Science and Technology
4. Water Research
5. Desalination and Water Treatment
6. Science of the Total Environment
7. Chemosphere
8. Journal of Hazardous Materials

9. Environmental Science and Pollution Research
10. Journal of Cleaner Production

Table 5.2 provides the top ten global funding or sponsoring institutions. It is interesting to observe that funding agencies and foundations of China play a key role in disbursing funds for research in areas of waste management.

Table 5.2. **Top Funding Institutions**

National Natural Science Foundation of China
Fundamental Research Funds for the Central Universities, China
European Commission
National Science Foundation, United States
National Basic Research Program of China
Natural Sciences and Engineering Research Council of Canada
European Regional Development Fund
Brazilian National Council for Scientific and Technological Development
China Postdoctoral Science Foundation
National Research Foundation of Korea

Research Trends in India

In India, an increasing trend of the number of research papers is noticed from 2014 onwards (Figure 5.4).

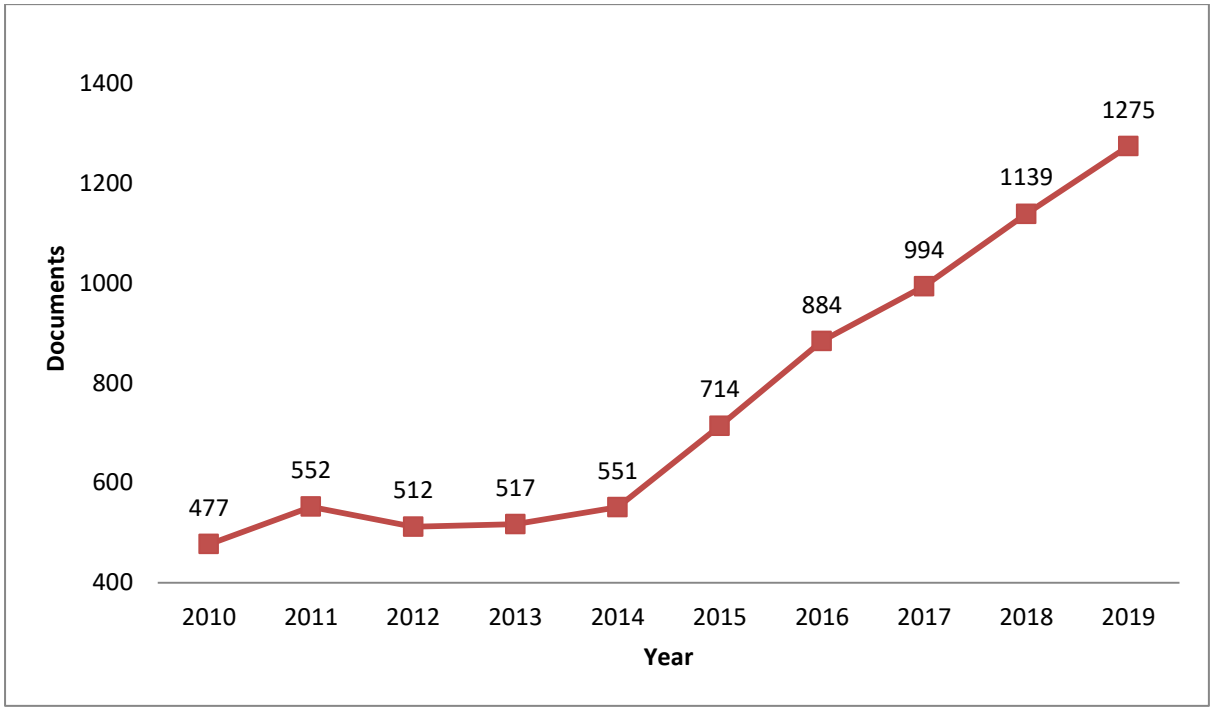


Figure 5.4. **Documents by Year**

The top funding institutions in India based on number of published papers based on research projects are enumerated in Table 5.3.

Table 5.3. **Top Funding Institutions in India**

1.	University Grants Commission
2.	Department of Science and Technology, Government of Kerala
3.	Bangladesh Council of Scientific and Industrial Research
4.	Department of Biotechnology, Government of West Bengal
5.	Council of Scientific and Industrial Research, India
6.	Department of Science and Technology, Ministry of Science and Technology, India
7.	Science and Engineering Research Board
8.	Ministry of Human Resource Development
9.	National Research Foundation of Korea
10.	European Commission

Leading institutions working on the subject domain of waste management comprise research and academic institutions (Figure 5.5). According to the Scopus database, Anna University, Chennai, IIT Roorkee, NEERI, Nagpur are the top three institutions engaged in research on various aspects of waste management.

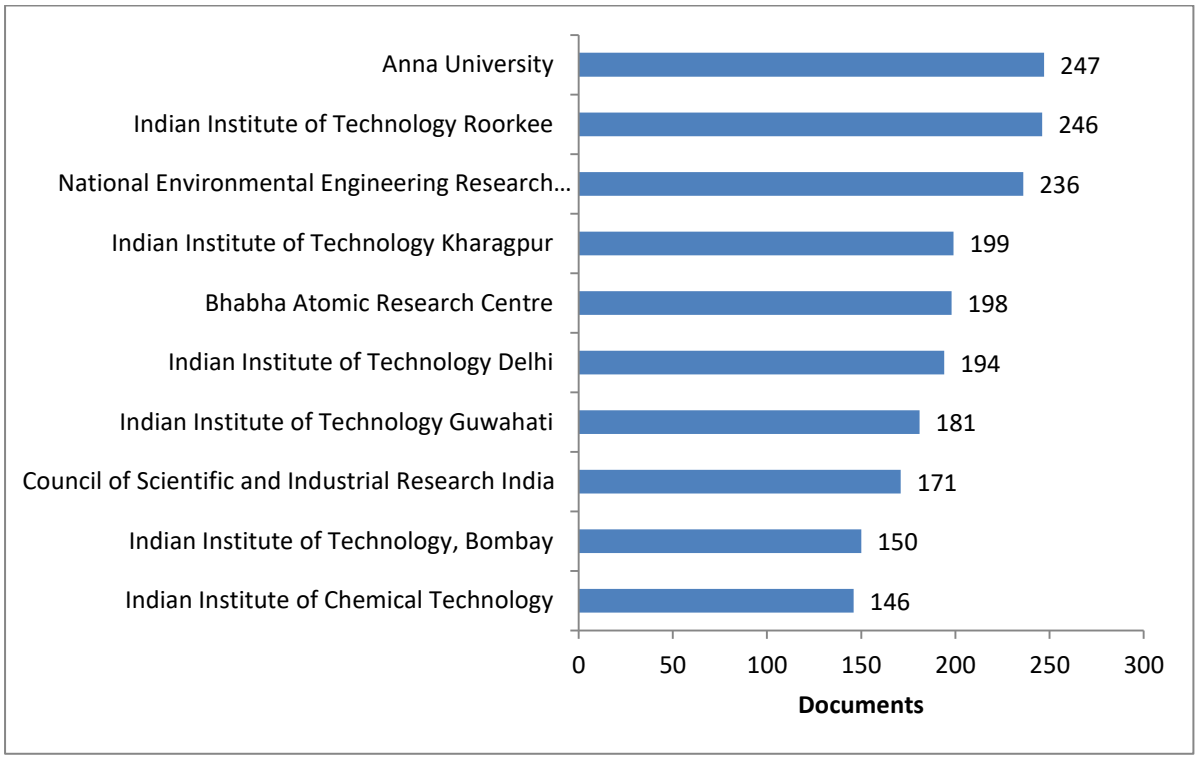


Figure 5.5. **Leading Institutions**

Table 5.4 provides the leading researchers in India who are researching on waste management. Researchers belonging to academic institutions play a key role in the R&D on waste management.

Table 5.4. **Leading Researchers**

Researcher	Affiliation
Venkata Mohan, S.	Indian Institute of Chemical Technology, Hyderabad, India
Ghangrekar, M.M.	Indian Institute of Technology Kharagpur, Kharagpur, India
Kazmi, A.A.	Indian Institute of Technology Roorkee, Roorkee, India
Gogate, P.R.	Institute of Chemical Technology, Mumbai, India
Kumar, S.	National Environmental Engineering Research Institute India, Nagpur, India
Pakshirajan, K.	Indian Institute of Technology Guwahati, Guwahati, India
Garg, A.	Indian Institute of Technology, Bombay, Mumbai, India
Mohapatra, P.K.	Bhabha Atomic Research Centre, Mumbai, India
Rajesh Banu, J.	Central University of Tamil Nadu, Thiruvarur, India
Mohanty, K.	Indian Institute of Technology Guwahati, Guwahati, India

***Note**. This research trend analysis is based on the data retrieved from Scopus database*

RESEARCH RESOURCES

Research Papers | Reports, Books & Reference books | Journals & Periodicals

5.1 Research Papers

Biohydrogen production using kitchen waste as the potential substrate: A sustainable approach
Chemosphere: 129537, 4 January 2021
The paper explores the sustainable feasibility of kitchen wastes to implement as an effective substrate for biohydrogen production through dark fermentation.
Read more…

End-of-life solar photovoltaic e-waste assessment in India: a step towards a circular economy
Sustainable Production and Consumption 26, April 2021
The study undertakes an assessment of the magnitude of the issue in India, using a forecasting model that projects the amount of waste generated by EOL solar PV panels and its balance of system (BOS) using Weibull reliability function for panel failure.
Read more…

Repercussions of COVID-19 pandemic on municipal solid waste management: Challenges and opportunities
Science of the Total Environment: 140693, July 2020
The paper recommends alternatives approaches for MSW treatment and disposal and outlines the future scope of work to achieve sustainable waste management during and aftermath of the pandemics**.**
Read more…

Urban waste to energy recovery assessment simulations for developing countries
World Development 131: 104949, July 2020
In this paper, a quantitative Waste to Energy Recovery Assessment (WERA) framework is used to stochastically analyze the feasibility of WtE in selected cities in Asia. Future policy measures of feed-in tariffs, payments for avoided pollution, and higher waste collection fees are assessed to evaluate if WtE systems can be made self-sustaining investments.
Read more…

E-waste in India at a Glance: Current Trends, Regulations, Challenges and Management Strategies
Journal of Cleaner Production: 122707, July 2020
This paper deals with the strategic interventions conforming existing regulations which are crucial for a sustainable E-waste value chain, secured resources, societal well-being, reduced environmental impacts and overall sustainable development. Furthermore, relevant strategies i.e., eco-product design, circular resource management, extended producer responsibility, polluter pays' principle, life cycle assessment, 4R principle and bioleaching were identified and discussed as a future direction for Indian context.
Read more…

Development of sustainable approaches for converting the organic waste to bioenergy
Science of the Total Environment 723: 138109, June 2020
Present review is concentrated on providing a keen view on the potential organic waste sources and the way in which the bioenergy is produced through efficient conversion processes. Different types of organic wastes used for bioenergy generation and its sources, anaerobic digestion-biogas production and its related process affecting parameters including fermentation, photosynthetic process and novel Nano-inspired techniques are discussed.
Read more…

Prospects of biopolymer technology as an alternative option for non-degradable plastics and sustainable management of plastic wastes
Journal of Cleaner Production 258: 120536, June 2020
In this review, the prospects of biopolymer technology were emphasized to address the issues associated with non-degradability of plastics. In this respect, essential strategies were also discussed further for biopolymers as an alternative option for non-degradable plastics to help establish sustainable management plan for plastic wastes based on standards, certifications, and labeling of biopolymers.
Read more….

Circular economy practices within energy and waste management sectors of India: A meta-analysis
Bioresource Technology 304: 123018, May 2020
Adoption of circular practices within environmental management is gaining worldwide recognition owing to rapid resource depletion and detrimental effects of climate change. The study attempts to ascertain the linkages between circular economy and sustainable development by examining the

role of renewable energy and waste management sectors in circular economy combined with policy setup and enabling frameworks boosting the influx of circularity principles in the Indian context.
Read more…

Inconsistencies of e-waste management in developing nations – Facts and plausible solutions
Journal of Environmental Management 261: 110234, May 2020
The review focus on replacing the traditional and conventional procedures with the futuristic and eco-friendly approaches such as chelation, inducing ionic liquids, integrated processes or hybrid technologies, micro factories, photo catalysis, and green adsorption will substantially harness the current barriers of the e-waste management.
Read more…

Valorization of agricultural waste for biogas based circular economy in India: A research outlook
Bioresource Technology 304: 123036, May 2020
This research paper comprehensively discusses the potential of biogas production from agricultural waste, its upgradation and utilization along with the government initiatives, policy regulations. In addition, barriers that impede the development of an efficient agri-waste to biogas based circular economy, and the future research opportunities to meet the growing needs for agri-waste management, energy production and climate change mitigation are discussed.
Read more…

Industrial solid waste management through sustainable green technology: Case study insights from steel and mining industry in Keonjhar, India
Materials Today: Proceedings, March 2020
This paper primarily focuses on waste management strategies adopted by industries: Iron & steel, mining respectively for cleaner production and sustainable development through effective utilization of solid waste in the construction industry especially in geopolymer concrete.
Read more…

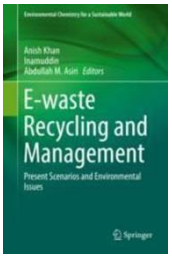
A municipal solid waste indicator for environmental impact: Assessment and identification of best management practices
Journal of Cleaner Production 242: 118433, January 2020
The objective of this study was to develop an aggregate indicator to assess the environmental impact of municipal solid waste management in the small municipalities of the state of São Paulo, Brazil. Additionally, the study aimed at creating a classification of the municipalities considered to identify the best management practices.
Read more…

5.2 Reports, Books & Reference books

The Global E-waste Monitor 2020: Quantities, flows and the circular economy potential
United Nations University, International Telecommunication Union (ITU) & International Solid Waste Association, 2020

The Global E-waste Monitor 2020 provides the most comprehensive overview of the global e-waste challenge, explains how it fits into international efforts to reach the Sustainable Development Goals, and discusses how to create a sustainable society and circular economy. Read more…

E-waste Recycling and Management: Present Scenarios and Environmental Issues



Springer, 2020

Environmental Chemistry for a Sustainable World book series, Volume 33

This book gives up-to-date information and broad views on e-waste recycling and management using the latest techniques for industrialist and academicians. It describes the problems of e-waste generated by all global living communities and its impact on our ecosystems and discusses recycling techniques in detail to reduce its effect as well as proper management of e-waste to save the environment.

Read more…

Food Waste to Valuable Resources: Applications and management

Academic Press, 2020

This book explores new valuable resource technologies, the bio-economy, the techno-economical evaluation of food-waste-based bio-refineries, and the policies and regulations related to a food-waste-based economy.

Read more…

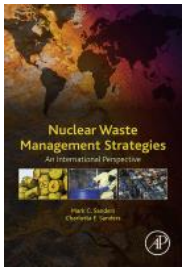
Handbook of Electronic Waste Management: International Best Practices and Case Studies

Butterworth-Heinemann, 2019

The book's authors offer a detailed presentation of e-waste handling methods that also includes examples to further demonstrate how they work in the real world. This is followed by data that reveals the geographies of e-waste flows at global, national and subnational levels.

Read more…

Nuclear Waste Management Strategies: An International Perspective



Academic Press, 2019

This book provides a unique understanding of nuclear waste management technologies and methods available, ensuring that researchers and engineering professionals are equipped with the right knowledge to design, build, implement and improve their own waste management strategies.

Read more…

Waste to Energy: Considerations for informed decision making, 2019

Internationale Zusammenarbeit (GIZ) GmbH, 2019

The overall objective of this report is to provide key considerations to assist decision makers in developing countries when scrutinizing thermal WtE as a waste management option.

Read more…

Plastic Waste Management: Issues, Solutions & Case Studies

Ministry of Housing & Urban Affairs, Govt of India, 2019
This book contains different aspect of plastic waste management including the current scenario, the harmful effect of plastic waste and 3R approach (Reduce, Reuse and Recycle) and resource recovery alternative to deal with plastic menace.
Read more…

Global assessment of municipal organic waste production and recycling
International Solid waste association, 2018
The aim of this report is to update ISWA's knowledge about the amounts of organic waste (excluding purposely grown energy crops and sewage sludge) that are generated annually and those quantities of organic waste that are separately collected and currently composted/anaerobically digested around the world**.**
Read more…

The Global E-waste Monitor 2017: Quantities, Flows, and Resources
United Nations University, International Telecommunication Union & International Solid Waste Association, 2017
This report provides a comprehensive overview of global e-waste statistics, including an overview of the magnitude of the e-waste problem in different regions. The report includes up-to-date information on the amounts of e-waste generated and recycled, makes predictions until 2021, and provides information on the progress made in terms of e-waste legislation.
Read more…..

Waste to Wealth: A Ready Reckoner for selection of technologies for management of municipal waste
Ministry of Housing and Urban Affair, Govt. of India, 2017
This Ready Reckoner on Waste to Wealth is an effort under SBM to put together the available waste processing technologies in a simple way with working case studies for the ULB decision maker's awareness and in aiding them in identifying technologies suiting to their requirements. Read more...

Asia Waste Management Outlook, 2017
United Nations Environment Programme, Asian Institute of Technology, International Solid waste association, 2017
This regional outlook provides an overview of the current status, the current thinking on "state of the art" topics, case studies, and the future of waste management in Asia over the medium term; challenges and opportunities, described through case studies; and recommendations based on technical, strategic, economic, and communication perspectives.
Read more…

Waste-to-Energy Options in Municipal Solid Waste Management, 2017
Internationale Zusammenarbeit (GIZ) GmbH, 2017
A Guide for Decision Makers in Developing and Emerging Countries outlines the different WtE technologies currently applied at the municipal level and their potential role in an integrated waste management system.
Read more..

Municipal solid waste management manual

Ministry of urban development, 2016

This manual on Municipal Solid Waste Management provides guidance to urban local bodies on the planning, design, implementation and monitoring of municipal solid waste management systems. Issues of environmental and financial sustainability of these systems are a critical consideration. The manual clearly defines the planning process to be adopted by urban local bodies for preparing, revising and implementing Municipal Solid Waste Management Plans (MSWM Plans).

Read more

Waste to Resources: A Waste Management Handbook

TERI, 2014

The guidebook provides a detailed overview of urban liquid and solid waste management, construction and demolition debris management, industrial liquid and solid waste (including hazardous and non-hazardous waste streams) management, biomedical waste management in healthcare facilities and e-waste management. The section in the guidebook also deals with the evolution of Acts and Rules in India that deal with pollution control and waste management. The last section of the guidebook provides technology fact sheet covering useful waste treatment and processing technology options, which can not only control pollution, but also ensure maximizing resource recovery from waste.

Read more……

5.3 Journals & Newsletters

Waste Management

Elsevier | Impact Factor: 5.448

The journal covers topics on solid waste generation, characterization, minimization, collection, separation, treatment and disposal, as well as waste management policy, education, and economic and environmental assessments.

Read more…

Waste Management & Research

Sage | Impact Factor: 2.771

WM&R is a fully peer-reviewed international journal that publishes original research and review articles relating to both the theory and practice of waste management and research.

Read more…

Journal of the Air & Waste Management Association

Air & Waste Management Association | Impact Factor: 2.245 (2019)

The journal covers contemporary advances in air quality and waste management science and technology for use in improving environmental protection.

Read more…

Waste Disposal & Sustainable Energy

Springer
Waste Disposal & Sustainable Energy (WDSE) publishes high-quality papers that advance waste disposal and sustainable energy. It broadly encompassed various traditional waste disposal and new sustainable energy sources related topics.
Read more…

Journal of Material Cycles and Waste Management
Springer | Impact factor: 1.974 (2019)
The journal focuses on research in technical, political, and environmental problems of material cycles and waste management; and information that contributes to the development of an interdisciplinary science of material cycles and waste management.
Read more…

Waste and Biomass Valorization
Springer| Impact factor: 2.851 (2019)
The journal dedicated to waste and biomass valorization for sustainable development in terms of safely reusing waste and biomass, the transformation of waste/biomass to valuable materials and energy.
Read more….

6. Case Studies/Best Practices

Transforming urban landscapes of India series, Swachh Bharat Mission (Urban)

Ministry of Housing & Urban Affairs | Government of India

The Swachh Bharat Mission has seen some exemplary success stories of inspiration from all over the country.

- **Transforming urban landscapes of India: Success Stories in Information, Education & Communication (IEC) & Behaviour Change** | 2019
  This report covers the experiences of Ahmedabad, Tiruchirappalli, Punjab, Chhattisgarh, Kerala, Lonavla, Puri, Indore, and Port Blair.
  Read more

- **Transforming Urban Landscapes: 2014-19** | 2019
  This e-book encapsulates the success stories and initiatives taken under the Missions and Programmes of Swachh Bharat Mission (Urban), Pradhan Mantri Awas Yojana - Urban, Smart Cities Mission, Atal Mission for Rejuvenation and Urban Transformation, Deendayal Antyodaya Yojana - National Urban Livelihoods Mission and Heritage City Development and Augmentation Yojana to transform the urban space across the country.
  Read more

- **Transforming urban landscapes of India: Success Stories in Solid Waste Management** | 2018
  The report focusses on the best practices followed in the area of Solid waste management in Ambikapur, Durg, Leh, Mysuru, Navi Mumbai, Visakhapatnam, Bengaluru, Indore and Pune.
  Read more

Tirupati: Solid Waste Management

The pilgrim city, Tirupati, has been ranked as India's best city in solid waste management in the population category of 1 to 3 lakh. The rankings were given as part of Swachh Survekshan 2018 survey conducted by the Ministry of Housing and Urban Affairs. Tirupati has achieved an appreciable growth under the domain of solid waste management; the city has 100% coverage of door-to-door garbage collection in all of its 50 wards. More than 80% of the waste generated in the ULB is segregated into wet and dry categories at the source and 100% of the Bulk Garbage Generators have facility for on-site composting of the waste generated by them.

Read more

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Forecasting municipal solid waste generation using artificial intelligence models—a case study in India

SN Applied Sciences, Volume 1, Article number: 162 | 2019

The paper compares different models of artificial intelligence -- artificial neural network, adaptive neuro-fuzzy inference system, discrete wavelet theory–artificial neural network, discrete wavelet theory–adaptive neuro-fuzzy inference system, genetic algorithm–artificial neural network and

genetic algorithm–adaptive neuro-fuzzy inference system to examine and evaluate their capability in forecasting the amount of garbage being generated. A case example of the city of New Delhi, India, has been used for better understanding of different models.
Read more

Modeling transfer station locations considering source separation of solid waste in urban centers: A case study of Bilaspur city, India

Journal of Cleaner Production, Volume 211 | 2019

The paper proposes an approach for selecting the waste transfer station locations under unsegregated and segregated waste scenarios in an economical manner. The analytical approach is a combination of two basic components, (i) a mathematical optimization model for the overall cost of municipal solid waste management; and (ii) tools of a geographic information system for creating the dataset of the mathematical model. The proposed approach has been verified by applying on city of Bilaspur, India.
Read more

Innovative partnerships with informal workers to recover plastic waste, in an inclusive circular economy approach, Pune, Maharashtra

Sustainable Cycles (SCYCLE) Programme, UNU-ViE | 2018

Management of recyclable waste in Pune, India follows a hybrid model involving informal workers and is widely considered a success story in this sector. One important factor in understanding this achievement is the city's history of informal workers' rights movements and civil society participation. This case study retraces plastic waste streams in the city of Pune, identifies contributions by informal economy workers to the recovery, sorting and recycling of plastic waste and provides policy insights that aim to harness the environmental benefits of a more inclusive and productive waste management model.
Read more

Case Study of Mumbai: Decentralised Solid Waste Management

Procedia Environmental Sciences, Volume 35 | 2016

This paper explores the scale at which different institutions/communities have taken efforts to successfully manage their waste. This paper looks at examples from Municipal Corporation of Greater Mumbai and Thane Municipal Corporation. The city interacts with all its stakeholders to manage the waste effectively. The nexus between the government agencies, technology, recyclers, citizens/residents, waste pickers create the circle for effective waste management of the city in a centralised and/or decentralised manner.
Read more

7. Commercial Perspective

The global waste management market size is expected to reach $530.0 billion by 2025 from $330.6 billion in 2017, growing at a CAGR of 6.0% from 2018 to 2025. By 2025, the waste management market size in India is projected to be worth ~$15 billion growing at an annual growth rate of 7 per cent. The waste management market in the country is segmented by:

- Waste type - Industrial Waste, Municipal Solid Waste, Hazardous Waste, E-waste, Plastic Waste, and Bio-medical Waste
- Disposal method - Landfills, Incineration, Dismantling, and Recycling
- Type of ownership - Public, Private, and Public-Private Partnership

The Indian waste management industry offers huge potential, as only 30% of the 75% recyclable waste is being recycled currently. Shortage of proper policies for collection, disposal, and recycling and the lack of efficient infrastructure are few of the many reasons leading to poor waste management in the country. According to the Central Pollution Control Board, less than 15% of the municipal solid waste generated is processed or treated.

The informal sector has a very important role in waste materials reuse and recycling. The informal sector is characterized by small-scale, labour-intensive, largely unregulated and unregistered low-technology manufacturing or provision of materials and services. Many start-ups are coming up with innovative ideas to manage wastes, as well as convert them into valuable resources. Various private companies are playing an active role in the waste-management ecosystem and bringing more environmental friendly and ethical waste management techniques. These include 3R Management, ComePost, Veolia, Ecocredible, Kankyo Cleantech, and others. Opportunities such as usage of IoT technologies, digital applications, and usage of big data are expected to revolutionize the solid waste management industry. Major players operating in the bio-medical waste management market include Synergy Waste Management Pvt. Ltd, Biotic Waste Solutions Pvt. Ltd, GreenTech Environ Management Pvt. Ltd, Medicare Environmental Management Pvt. Ltd, SMS Water Graca BMW Pvt. Ltd, Ramky Enviro Engineers Ltd, and others.

Resources

Business Models for the Circular Economy

OECD | 2018

Circular business models serve to reduce the extraction and use of natural resources and the generation of industrial and consumer wastes. They represent the key activities required to transition to a more resource efficient and circular economy. Resource recovery models recycle waste into secondary raw materials, thereby diverting waste from final disposal while also displacing the extraction and processing of virgin natural resources.

Read more

Circular Economy in India: Rethinking Growth for Long-Term Prosperity

Ellen MacArthur Foundation | 2016

The report has estimated that implementing that a circular economy path to development in India could yield over $624 billion (approx. INR 47 crore lakh) per annum in material savings by 2050—a benefit equivalent to 30% of India's current GDP. This conclusion rests on the economic analysis of three focus areas that are vital to the Indian economy and society -- cities and construction, food and agriculture, and mobility and vehicle manufacturing.
Read more

Waste Management Market
Allied Market Research
As per the data released by the World Bank, in 2018, the global municipal solid waste generated in 2016 was 2.1 billion tons, and is expected to reach approximately 3.40 billion tons by 2050. The report presents an extensive analysis of the current & emerging waste management market trends and dynamics in the global waste management market. *[Access requires subscription]*
Read more

India Biomedical Waste Management Market, By Service (Recycling & Disposal), By Treatment Site (Offsite), By Region (South, West, North & East), Competition, Forecast & Opportunities, 2024
TechSci Research | December 2019
By 2024, the Indian bio-medical waste management market is expected to reach $ 39 million. The report aims to analyze and forecast the market size of the Indian bio-medical waste management market. The report classifies and forecasts the market based on type of service, treatment site and regional distribution.
Read more [Priced]

Private sector and entrepreneurs involved in waste management sector

- 20 Most Promising Waste Management Companies- 2018 | SiliconIndia | May 2018
  Read more
- 20 Most Promising e-Waste Management Companies -2018 | SiliconIndia | May 2018
  Read more
- Leading Waste Management Companies in India | Green World Investor | June 2018
  Read more

8. Past and ongoing Projects of TERI/Other organizations

Project title	**Waste to Energy (W2E)**
Commissioned by	GIZ, Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, Germany (BMU), Government of Germany
Executing agency	Ministry of Environment and Forest, Government of India Nashik Municipal Corporation, Maharashtra, India
Project duration	2009 to 2017
Project summary	The W2E project in Nashik facilitates interaction and cooperation between the various stakeholders - from planning levels to implementation levels. A pilot model for a sustainable business concept for the combined treatment of septage and organic solid waste to produce clean energy by bio methanisation (co-fermentation) has been established in the city of Nashik.

Read more

Project title	**Development and Management of Waste NAMA (Nationally Appropriate Mitigation Action) in India**
Commissioned by	GIZ, Government of Germany
Executing agency	TERI
Project duration	2020 to 2014
Project summary	The project team will audit all 125 housing societies located in Goa within the city limits to assess the implementation of the Solid Waste Management Rules, 2016, the Plastic Waste Management Rules, 2016, and the Construction & Demolition Waste Management Rules, 2016. The project has adopted the city of Panjim for pilot demonstration of better waste management practices. The other town chosen for the pilot demonstration is Varanasi in Uttar Pradesh. NAMA is a global mechanism to help developing countries chose actions most suitable to their local conditions, with waste being a major contributor to increasing GHG emissions.

Read more

Project title	**Assessment of the value chain of plastic straws generated with used beverage cartons**
Commissioned by	Tetra Pak India Pvt Ltd
Executing agency	TERI
Project duration	November 2019 to May 2020
Project summary	The study was conducted in three major cities of India, Delhi in North, Mumbai in West and Bangalore in South. This study involved understanding

	the perception of waste generators and waste collectors on the fate and recyclability potential of straws attached to UBCs and identify barriers in collecting these straws for recycling. This study further involved interactions and analysis to understand the percentage of straws getting collected and reaching large scale dealers.
Read more	

Project title	**Independent Assessment of Waste Management System and Sanitation Infrastructure in NDMC area**
Commissioned by	New Delhi Municipal Corporation
Executing agency	TERI
Project duration	2019
Project summary	The objective of the study was to conduct an independent audit for monitoring of waste management systems services in NDMC area as a third party and identify gaps and deficiencies in the system along with providing recommendations for addressing gaps; to help NDMC in improving the existing waste management system. This audit also aids in understanding the scenario of waste management in all wards of NDMC and help them in planning future actions. Hence ward wise outputs have also been given in annexures for ULB to undertake corrective actions.
Read more Related information	

Project title	**Reducing short lived climate pollutants from solid waste sector in India**
Commissioned by	Climate and Clean Air Coalition, ABT Associate
Executing agency	TERI
Project duration	November 2017 to May 2018
Project summary	In partnership with Climate and Clean Air Coalition TERI implemented a project to reduce Short-Lived Climate Pollutants (SLCPs) under the CCAC's Municipal Solid Waste Initiative in India. The mandate of the project was to develop work plans for two cities in India to help formulate priorities in managing waste, reducing SLCP emissions, and establishes an Indian city network under the CCAC- Waste initiative for building capacities and helping in reduction of SLCPs from the municipal solid waste sector.
Read more	

Project title	**Rethink Plastic: UNEP-TERI joint initiative in Mumbai region**
Commissioned by	UNEP
Executing agency	TERI
Project duration	Nov 2019
Project summary	On 4th March 2019, the Government of Japan and the United Nations

	Environment Programme (UNEP) declared a collaborative effort to enhance the knowledge and information for developing countermeasures against marine plastic litter in Southeast Asia and in India. Supported by UNEP, the project titled 'Promotion of countermeasures against marine plastic litter in Southeast Asia and India' is being implemented along the Ganges River Basin in Haridwar/Rishikesh and Allahabad, and along the Yamuna River Basin in Agra. As part of this initiative, TERI will steer a public campaign named as Rethink Plastic in Mumbai to raise awareness about plastic pollution, its impacts, and ways to manage plastic pollution and motivate communities to reduce consumption of single-use plastic.

Read more

Project title	**Plastic Waste Management Programme**
Commissioned by	UNDP
Executing agency	HCCBPL and HUL
Project duration	2018
Project summary	United Nations Development Programme (UNDP) India, in partnership with Hindustan Coca-Cola Beverages Private Limited (HCCBPL) and Hindustan Unilever Limited (HUL) is building on existing systems to reduce the impact of plastic waste on environment in India. The partnership promotes collection, segregation and recycling of all kinds of plastics to move towards a circular economy.

Read more

Project title	**Independent Assessment of Waste Management System and Sanitation Infrastructure in NDMC area**
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Project duration	2019
Project summary	The objective of the study was to conduct an independent audit for monitoring of waste management systems services in NDMC area as a third party and identify gaps and deficiencies in the system along with providing recommendations for addressing gaps; to help NDMC in improving the existing waste management system. This audit also aids in understanding the scenario of waste management in all wards of NDMC and help them in planning future actions. Hence ward wise outputs have also been given in annexures for ULB to undertake corrective actions.

Read more

9. Current Developments

PMC launches pilot project for recycling thermocol waste. Pune Municipal Corporation (PMC) has joined hands with SWaCH cooperative and K K Nag Pvt Ltd to launch a sustainable thermocol (Polystyrene) recycling initiative in the city. The project named 'Recycole' is being implemented with the help of waste-picker cooperative SWaCH.

IIT Madras to develop online platform for e-waste management. IIT Madras is developing an online platform called e-Source to tackle e-waste by linking various stakeholders in the formal and informal sectors. 'e-Source' will be an exchange platform that will serve as an online marketplace for waste electrical and electronic equipment and facilitate a formal supply chain between various stakeholders (buyers and sellers).

Top performers in biomedical waste management. Himachal Pradesh, Chandigarh, Delhi, Puducherry and West Bengal have been adjudged the top performing states in a comparative evaluation made by CPCB regarding the implementation of the Biomedical Waste Management Rules, 2016. These states/UTs have a total score of 21 out of 24 according to a report submitted by the CPCB before the National Green Tribunal. The CPCB identified 12 key performance indicators to assess states with respect to effectiveness in monitoring, ensuring compliance and implementation of the Biomedical Waste Management Rules, 2016.

Data sourced from the Ministry of Environment Forests and Climate Change between June 2020 and June 2021 showed that the highest waste burden was incurred in Maharashtra, Kerala, Gujarat, Tamil Nadu, Delhi, Uttar Pradesh and Karnataka.

Generation of COVID-19 waste seven months since June 2020	
Maharashtra	5367 tonnes
Kerala	3300 tonnes
Gujarat	3086 tonnes
Tamil Nadu	2806 tonnes
Uttar Pradesh	2502 tonnes
Delhi	2471 tonnes
West Bengal	2095 tonnes
Karnataka	2026 tonnes

India generated 33k tonnes COVID-19 waste in 7 months. According to the data received from state pollution control boards, since June 2020, all states and union territories have generated 32,994 tonnes of COVID-19-related biomedical waste which is being collected, treated and disposed of by 198 common biomedical waste treatment facilities.

NCL develops tech to convert biomedical waste to plastic. The research by NCL, Pune is based on a system of autoclaving biomedical waste. Face masks and PPE suits were burnt earlier. Now this new recycling system will allow plastic products to be made from the bio-medical waste. Small particles of plastic are made after a recycling process and then converted into various products.

IIT Guwahati develops method to turn industrial waste into chemicals. Researchers at Indian Institute of Technology (IIT), Guwahati, have formulated efficient "pincer" catalytic systems that transform industrial or biomass wastes into valuable chemicals. According to the team, tiny amounts of these "pincer catalysts" repeatedly convert large amounts of industrial waste such as glycerol into lactic acid and hydrogen. Such catalysts also efficiently convert bioethanol, a low-energy density fuel, into high-energy density butanol.

Revision 3 of the guidelines was issued to incorporate norms on segregation of general solid waste and biomedical waste.

Uttarakhand govt starts process of setting up six plants for generating electricity from solid waste. These plants will be set up in Roorkee, Rudrapur, Kashipur, Haldwani, Rishikesh and Kotdwar. A biogas plant should be set up with the help of the Indian Oil Corporation in Haridwar and a waste-to-energy plant in Roorkee. An action plan should be prepared for the upcoming plants in Haldwani, Kashipur, Rishikesh, Rudrapur and Kotdwar. Along with making the action plan, monitoring should be done in all the municipal bodies for proper waste segregation, making compost, and other activities for proper solid waste management.

South Delhi Municipal Corporation gets Rs 43 crore for dust, waste management. To implement dust combating measures and augment waste management facilities, South Delhi Municipal Corporation has received the funds from the Centre under the urban development fund (UDF) scheme for the current financial year. The fund will be utilised for strengthening and resurfacing damaged roads at 12 places, with the expected cost to be around Rs 20 crore. Regarding the development of 15 decentralised waste treatment plants and laying pipelines at different places, Rs 7 crore has been allocated.

Safety training to COVID-19 waste handlers and sanitation workers. CPCB has released *Revision 3* of the Guidelines for Handling, treatment and disposal of waste generated during treatment, diagnostics and quarantine of COVID-19 patients. It also addresses the issue of safety of waste handlers and sanitation workers associated with healthcare facilities, local bodies and Common Biomedical Waste Treatment Facility in handling of waste generated from quarantine centres, healthcare facilities and households with COVID-19 patients.

Bio-waste spikes. With discarded PPE kits, masks, gloves and items used to treat COVID-19 patients collecting by the minute in hospitals, the risk of this biomedical waste infecting sanitation workers has gone up. Biomedical waste in hospitals per bed daily has gone up from 500 gm in normal times to 2.5 to 4 kg per bed per day during COVID pandemic. The number of treatment units for such waste in the country has stayed at around 200.

Delhi. Delhi is generating 11 tonnes of coronavirus-related waste every day, according to CPCB.

Karnataka. The state is generating about 3000 kg biomedical waste daily and paying more than nine times what it used to, to dispose of and incinerate a kg of biomedical waste earlier. Bengaluru's Victoria Hospital campus, where 299 COVID-19 patients are housed, pays Rs 65 to dispose one kg of COVID-19 waste as against Rs 7 per kg of biomedical waste that it used to pay before the pandemic.

Kerala. As per the data available with Indian Medical Association Goes Eco-friendly (IMAGE), the COVID-19 biomedical waste in Palakkad waste treatment plant has increased from 698 kg on March 19 to 4715 kg on May 31. In total, Kerala has produced 14,8,707 kg of COVID-19 waste from 82 centres. While Malappuram has seen the highest quantity of COVID-19 waste generated at 22,055 kg, Thiruvananthapuram has collected 19,241 kg and Ernakulam 18,945 kg.

COVID-19 Biomedical Waste Tracking App. CPCB has started an app to record all biomedical waste being generated from hospitals. CPCB is regulating biomedical waste by daily online tracking of the waste generated and disposed of by coronavirus testing laboratories, waste generators and disposal facilities. All testing laboratories, waste generators and disposal facilities have to upload real-time

data related to COVID waste. The platform will provide real time data of each unit involved in COVID-19 waste submission through the app.

Source. The Times of India, May 22, 2020 | The Times of India, May 24, 2020 | The Times of India, June 2, 2020 | The New Indian Express, June 2, 2020 | The New Indian Express, June 9, 2020 | Deccan Herald, June 21, 2020 | India Today, June 25, 2020 | The Times of India, August 10, 2020 | Hindustan Times, August 12, 2020 | The Economic Times, October 12, 2020 | Business Standard, November 16, 2020 | Hindustan Times, January 11, 2021 | The Tribune, February 5, 2021 | Waste Management World, July 27, 2021 | Hindustan Times, August 25, 2021 | The Hindu Business Line, August 31, 2021 | Indian Express, September 8, 2021

10. Events

March 10-11, 2022
3rd World Conference on Waste Management 2022
Virtual
https://wastemanagementconferences.com/

December 1-4, 2021
11th International Conference on Sustainable Waste Management & Circular Economy and IPLA Global Forum 2021
Kolkata, India
https://www.iswmaw.com/data/Brochure_11th%20IconSWM-CE%20&%20IPLA_R1_10062021.pdf

November 25-26, 2021
Waste & Resource Management Summit 2021
Virtual
https://greenco.in/wastemanagement2021/

September 2-3, 2021
International Conference on Circular Economy, Management and Industry 4.0 leading towards Sustainability
https://bvimsr.org/wp-content/uploads/2020/12/International-Conference-on-Circular-Economy-Management-and-Industry-4.0-leading-towards-Sustainability_Final_compressed.pdf

August 5-6, 2021
ICWRR 2021: 15. International Conference on Waste, Recycling and Reuse
Montreal, Canada
https://waset.org/waste-recycling-and-reuse-conference-in-august-2021-in-montreal

August 4-6, 2021
3rd Sustainable Waste Management Conference

Virtual
https://www.aiche.org/ifs/conferences/sustainable-waste-management-conference/2021

More events at:
https://conferenceindex.org/conferences/waste-management
https://waset.org/waste-management-conferences