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SOLID WASTE MANAGEMENT IN POST-DISASTER SITUATIONS

National Institute of Disaster Management
(Ministry of Home Affairs, Government of India)

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Solid Waste Management in Post-Disaster Situations

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कार्यकारी निदेशक

Rajendra Ratnoo, IAS
Executive Director

सत्यमेव जयते

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FOREWORD

Disasters cause substantial damage across the world and create large volumes of various categories of waste. Mismanagement of such wastes not only affects the response operations but recovery of the affected areas also. Further, effective waste management is essential to ensure conservation of natural resources. Safe handling, treatment, removal and management of disaster waste are therefore important areas of concern which shall require an early action, within immediate response as well as also in relief and rehabilitation programmes. Currently, disaster management practices in our country do not pay significant consideration to the waste management issues during/after disasters.

Natural hazard events are projected to increase in many regions due to growing human activities, combined with increase in vulnerability, climate change and global warming. Therefore, challenges of recovery from these disasters will remain at the forefront for an unforeseeable time. Not only natural hazards but also human-induced disasters such as urban fires and industrial/chemical accidents pose a challenge of disposal of the hazardous waste in a responsible manner so that it has the least adverse impact on the environment. It will not be out of the context to mention that waste is not waste unless it is 'wasted'. Hence, the first priority in any 'waste management' approach should be based on 'resource recovery'. At this

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juncture, we may not have many options for full adoption of this approach in a post disaster scenario, given the volumes of wastes, time constraints and other competing priorities. However, I am confident that promoting green innovation and market-driven solutions can help transform waste into environmentally efficient solutions.

This paper has attempted an extensive literature review of international guidelines and practices available in the area of disaster waste management. Also, a two-day national consultation (virtual) was organized by NIDM during 11 and 12 November 2021 for in-depth discussions and deliberations on this pressing matter. Subject experts and practitioners from international agencies, central government, state governments, humanitarian organizations, academicians and researchers had contributed significantly through consultation.

Drawing lessons from the review study and through the deliberations by leading experts during national consultation and extensive literature review, we have been able to produce the present paper in the form of final outcome, which recommends the urgent need of a disaster waste management framework in India.

(Rajendra Ratnoo)

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Senior Consultant(Resilient Infrastructure)]
NIDM

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Abbreviations

ADB	Asian Development Bank
ATI	Administrative Training Institute
BWMR	Biomedical Waste Management Rules
C&D	Construction & Demolition
CAHO	Consortium of Accredited Healthcare Organization
CEPT	Centre for Environment Planning & Technology
COP	Conference of Parties
CPCB	Central Pollution Control Board
CSOs	Civil Society Organizations
DM	Disaster Management
DRR	Disaster Risk Reduction
DWM	Disaster Waste Management
DWMCP	Disaster Waste Management Capability Plan
EIA	Environmental Impact Assessment
EPA	Environment Protection Act
ESF	Emergency Support Function
FEMA	Federal Emergency Management Agency (United States)
FWM	Flood Waste Management
GIS	Geographical Information System
GIZ	Gesellschaft für Internationale Zusammenarbeit
GMDC	Gujarat Mineral Development Corporation
GoI	Government of India
GPS	Global Positioning System
GSDMA	Gujarat State Disaster Management Authority
HDPE	High Density Polyethylene
IDP	Internally Displaced Person
IL&FS	Infrastructure Leasing & Financial Services Limited
IoT	Internet of Things
IRS	Incident Response System
M&E	Monitoring and Evaluation

MoEFCC	Ministry of Environment, Forest and Climate Change
MoHUA	Ministry of Housing and Urban Affairs
NATECH	Natural Hazards Leading to Technological Disasters
NDMA	National Disaster Management Authority
NDRF	National Disaster Response Force
NGO	Non-Governmental Organization
NGT	National Green Tribunal
NIDM	National Institute of Disaster Management
NIUA	National Institute of Urban Affairs
NLSIU	National Law School of India University
OCHA	Office for the Coordination of Humanitarian Affairs
PCB	Polychlorinated biphenyls
PRO	Producer Responsibility Organization
RDF	Refuse Derived Fuel
RIKA	Resilient Innovation Knowledge Academy
RMC	Ready Mixed Concrete
SBM	Swachh Bharat Mission
SBM (R)	Swachh Bharat Mission, Rural
SBM (U)	Swachh Bharat Mission, Urban
SDG	Sustainable Development Goal
SDRF	State Disaster Response Force
SFDRR	Sendai Framework for Disaster Risk Reduction
SOP	Standard Operating Procedure
SWM	Solid Waste Management
TSS	Temporary Storage Site
UNDP	United Nations Development Programme
UNDRR	United Nations Office for Disaster Risk Reduction
UNEP	United Nations Environment Programme
UNFCC	United Nations Framework for Climate Change
UNIDO	United Nations Industrial Development Organization
USEPA	United States Environmental Protection Agency
WHO	World Health Organization
WMS	Waste Management System

EXECUTIVE SUMMARY

Disasters generate large quantities of unexpected solid waste. Management and safe disposal of solid waste becomes complicated and usually takes a long time after disasters. This waste affects the existing solid waste collection and disposal systems severely. In most of the cases, solid waste management systems collapse due to the abrupt addition of massive amount of waste produced due to a disaster. Presence of solid waste in the living environment and contamination of surroundings (air, water, land etc.) expose the affected communities to the risk of direct or indirect contact with the waste leading to public health issues like risk of a disease outbreak. Various other challenges such as delay in rescue and relief efforts, mixing of multiple streams of waste and pilferage of hazardous waste create unprecedented situations that need to be managed after any disaster. Scientific management of solid waste after disasters requires technical expertise and handling throughout its process from collection to final disposal. Yet, this area remains under-emphasized, especially in the Indian context. Hence, the present paper is an attempt to draw focus on the issue of managing solid waste in post-disaster situations in the context of India and to prepare conclusions, recommendations and way forward for managing wastes during and after the disasters.

Our global commitments for dealing with the most pressing concerns of contemporary times- the Sustainable Development Goals 2030, the Paris Agreement for Climate Action and the Sendai Framework of Disaster Risk Reduction (2015-2030) prioritize waste management as an essential component for achieving their respective strategic objectives. They involve prevention and reduction of the generation of waste along with promotion of innovation, technology and infrastructure for reuse, recycle, recovery, scientific treatment and sustainable disposal of waste. In this backdrop of our international obligations, solid waste management in post-disaster scenarios becomes more significant.

The present study has carried out a comprehensive review of literature on solid waste management including guidelines, policies and documents developed by international agencies and national governments. The Institutional Framework for Solid Waste Management in Indian context has been studied in order to understand the existing waste management system as well as to find out if there are provisions that shall help in dealing with the issue of solid waste during and after disasters in India. Besides this, the paper reviews waste management processes adopted during major disasters such as the Great East Japan Earthquake 2011, Bhuj Earthquake 2001, Srinagar floods 2014, Nepal Earthquake 2015 and Kerala floods 2018. Good practices of Delhi and Maharashtra for managing Construction and Demolition (C&D) waste and chemical waste respectively, have also been reviewed. The literature review and case studies give insights about practical challenges and institutional lacunas for Solid Waste Management in the aftermath of disasters.

In order to understand the challenges and issues related to post-disaster solid-waste management from the perspective of international organizations, state governments, technical experts and other important stakeholders, a two-day national consultation on *"Challenges and Solutions for Utilizing and Safe Disposal of Solid Waste generated in Post-Disaster Scenario"* was organized by NIDM during November 2021. A panel of domain experts had deliberated upon the safe disposal and management of solid waste generated in the aftermath of disasters. These experts from varying backgrounds ranging from public and private sectors, civil society organizations, international organizations, academics institutions presented their research findings and field experiences. The consultation had four technical sessions highlighting key topics viz. Overview and Challenges associated with Solid Waste Management in Post-disaster Situations; Plastic Waste Generation due to Disasters and Innovations and Technologies available for Recycle – Reuse of Plastic Waste in an Environmentally Friendly Manner; Debris Waste Management after disasters and Hazardous Waste Disposal generated due to Industrial Disasters, Fires and Health Facilities.

Throughout the panel discussions and from literature and case studies, a strong consensus for creating a disaster specific solid waste management plan and guidelines for India has emerged. It is important so as to institutionalize a proactive approach towards disaster waste management which is usually left to reactive and ad-hoc solutions. A rational and carefully planned disaster waste management framework is the need of the hour. Hence, at the end of this study, a suggestive and illustrative plan for the Post Disaster Solid Waste Management has been modeled on the basis of lessons learnt and gaps analyzed throughout this study. The framework recommends solid waste management operations within the larger context of disaster management cycle and phases. The emergency and other post disaster operations are as strong as the existing 'peace-time' infrastructure and practices; hence, an integrated and resilient solid waste management framework has been envisaged that involves a cyclical approach to pre-disaster contingency plan, post-disaster emergency operations and long-term recovery.

The subject solid waste management in post-disaster situation requires a healthy discourse involving technical and expert consultations at national level as well as participation in transboundary and intergovernmental partnerships harnessing the global and regional goodwill. This would herald a new chapter in the arena of disaster risk management and resilience in India thereby, moving closer to building a *'Culture of Disaster Resilience'*.

CHAPTER - 1

INTRODUCTION

1.1 Background

Disasters happen every year and their frequency and impacts have greatly increased in recent decades. India is prone to various natural hazards such as earthquakes, floods, tsunamis, cyclones, landslides and man-made disasters like fire and industrial accidents. Disasters are projected to increase in many regions due to growing exposure of human activities, combined with increasing vulnerability and the effects of climate change and global warming. Millions of tonnes of debris and other wastes are generated due to natural hazard events and anthropogenic disasters every year.

Disasters cause substantial damage and generate a large volume of waste. Disasters can generate 5 to 15 times the annual waste usually in a given community (Reinhart & McCreanor, 1999). The devastating Nepal Earthquake (2015) created 10 million tonnes of waste (Govt. of Nepal, 2015), the Haiti earthquake (2010) generated an estimated 23-60 million tonnes of debris (Booth, 2010), 20 million tonnes debris was generated due to Sichuan earthquake (2008) in China (Taylor, 2008) and about 15 million tonnes of waste was generated in Kobe earthquake, Japan (1995) (Hirayama et al., 2009). In India, after the Kerala floods (2018) about 35,717 metric tonnes of waste was collected as of two weeks from the disaster (Jacob, 2018) and Srinagar floods (2014) threw up 85,157 metric tonnes of municipal waste and garbage i.e., six times higher than normal rate for the city to clear (Ashiq, 2014). During the COVID 19 pandemic, India generated 56,898 tonnes of biomedical waste in one year (June 2020- July 2021). During the second surge of COVID-19 (April-May 2021), a 46% increase in COVID 19 related medical waste was recorded (Centre for Science & Environment India, 2021).

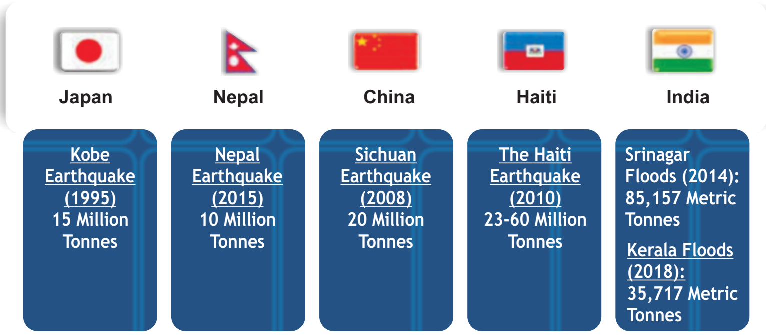


Figure 1.1: Quantum of waste generated due to different disasters

Disaster waste acts as an obstacle for rescue, relief and reconstruction operations post disasters. It threatens public health and greatly impacts the living environment (UNEP/ OCHA, 2013). The large quantities of debris produced during disasters endanger life of the people trapped under it, block access to roads and drainage channels. It overwhelms the existing solid waste management facilities and forces communities to use unsustainable disposal options.

Within this context, solid waste management and disposal has emerged as a critical issue while responding to any disaster. Therefore, it becomes imperative to manage the waste generated by disasters in order to facilitate early response, reconstruction and recovery and to maintain public health by preventing spread of infectious diseases, contamination of air, water and land as well as to encourage a safe living environment for all.

1.2 Statement of the Problem

Disasters create large volumes of waste and its mismanagement can affect both the response and long-term recovery of disaster-affected areas. Managing disaster waste is much more difficult because the construction wastes and municipal wastes are mixed together and sometimes it becomes challenging to separate them at the site during response and recovery phases. Management of solid waste after disasters is further complicated due to risk of leakage of hazardous waste into the environment, lack of equipment and trained manpower at local level. Solid waste management also forms a considerable chunk of financial burden after a disaster. According to a 2007 estimate by FEMA in the United States of America, after Katrina Hurricane around 27% of disaster recovery cost was incurred on waste management operations (Brown et al., 2011). At the same time, solid waste management in a post-disaster scenario also presents opportunities for reusing and recycling of the waste, as it may contain valuable material like concrete, steel, timber as well as organics for composting. These materials can be utilized as either a source of income or reconstruction material, and reduce burden on natural resources that might otherwise be harvested for reconstruction. Thus, safe handling, removal and management of solid wastes in post-disaster situation are important issues in disaster response and recovery that require a proper framework and system for operationalization.

1.3 Objectives

The objectives of the present paper are as follows:

I. To conduct review of the relevant documents, guidelines and case studies available globally and nationally.

II. To assess the gaps and challenges for managing solid waste in post-disaster situations in the context of India.

III. To prepare conclusions, recommendations and way-forward for managing solid wastes during and after the disasters.

1.4 Methodology

I. **Review of Literature:** The present study is an outcome of extensive literature review of guidelines and case studies available on post-disaster solid waste management globally and nationally. A comprehensive literature review has been carried out in two parts, in order to understand solid waste management (SWM) issues, challenges and strategies in post-disaster scenarios.

In the first part, guidelines developed by the international agencies such as United Nations Environment Programme (UNEP), World Health Organization (WHO), United Nations Development Programme (UNDP) and the Governments of the United States of America (USA), Japan, Thailand and Australia have been reviewed. To understand the Indian scenario, review of existing national level guidelines/rules/policies on SWM such as Environment Protection Act (1986), SWM Rules (2016), National Action Plan on Municipal Solid Waste (2016) by Central Pollution Control Board (CPCB), Ministry of Environment, Forest and Climate Change (MoEFCC) and provisions under Swachh Bharat Mission (SBM) 1.0 and 2.0 by Ministry of Jal Shakti and Ministry of Housing and Urban Affairs (MoHUA) has been done.

In the second part, case studies from Nepal, Japan, Kerala, Uttarakhand, Jammu & Kashmir (J&K), Delhi and Gujarat have been reviewed. Also, best practices and innovative solutions developed by various organizations towards developing sustainable solutions for waste management have been reviewed.

II. **Identification of Domain Experts from various Organizations:** A list of experts was developed (after desk review and discussions with relevant organizations), as per details given below:

- **National and State Organizations:** National Disaster Response Force (NDRF); National Institute of Urban Affairs; Uttarakhand State DM Authority; Srinagar Municipal Corporation; DM Department, Government of Tripura and Maharashtra State Fire Service.
- **UN Agencies and International Organizations:** World Bank, United Nations Environment Programme, United Nations Development Programme, and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ).
- **Academic Institutions:** Centre for Environmental Planning & Technology, Ahmedabad, Gujarat; Kyoto University, Japan; Tribhuvan University, Nepal and Sardar Vallabhbhai National Institute of Technology, Surat, Gujarat.

- **Other Stakeholders:** M/s Price Water House Coopers Pvt. Ltd, M/s Infrastructure Leasing & Financial Services Limited (IL&FS), M/s Global Safety Institute, USA, M/s Recykal, M/s Ramky Reclamation and Recycling Limited, M/s Life-givers Professionals and Consortium of Accredited Healthcare Organizations (CAHO).

The experts from the above-stated organizations participated as resource persons in the National Consultation organised by NIDM wherein they made presentations on the respective work being carried out by them or their organization.

III. **National Consultation on "Challenges and Solutions for Safe Utilization & Safe Disposal of Solid Waste Generated in Post Disaster Scenario":** The two-days National Level Consultation (in virtual mode) was organized for collection of data, case studies and experiences from various organizations on the relevant topics. The consultation was hosted on 11th and 12th November 2021 on Webex Platform of NIDM. The consultation was divided into 4 technical sessions viz.

- **Technical Session 1:** Overview and Challenges associated with Solid waste Management in Post-disaster Situation.
- **Technical Session 2:** Plastic Waste Generation due to Disasters and Innovation & Technologies available for Recycle - Reuse of Plastic Waste in an Environmentally Friendly Manner. This session was conducted in collaboration with the UNDP.
- **Technical Session 3:** Debris Waste Management after Disasters- Challenges & Solutions.
- **Technical Session 4:** Hazardous Waste Disposal generated due to Industrial Disasters, Fires and Health Facilities.

The invited experts from diverse backgrounds presented the case studies based on their field work, research and experience. These sessions were organized at an open platform and each technical session was attended by about 70-80 participants (average). The session-wise proceedings of the National Consultation are available at NIDM portal *i.e.* www.nidm.gov.in and live proceedings are available at YouTube NIDM live channel. The summary of the consultation is covered in Chapter 4.

Gap identification, Conclusions and Recommendations: The information gathered through the literature review and presentations made by the domain experts were analyzed and accordingly challenges and lessons learned have been identified in context of the Indian situation. Recommendations and way forward have been prepared from the learnings derived from the review of case studies and the guidelines and presentations made during the national consultation.

1.5 Scope and limitations

The study attempts to identify the issues, challenges and solutions for safe utilization or disposal of the solid waste generated by human and natural hazard induced disasters. Due to lack of availability of structured data on solid wastes generated during disasters in the public domain, the study is largely based on the existing published literature and information collected through consultations with subject experts.

1.6 Relevance of the Paper

The Sustainable Development Goals (SDGs) 2030 address the issue of solid waste through SDG 11 (sustainable cities and communities) and SDG 12 (responsible consumption and production) improving consumption patterns with specific targets of prevention, reduction, reuse and recycling of all waste in a sustainable manner (United Nations, 2015). Solid waste also has direct or indirect bearing on other SDGs like SDG 3 (good health and wellbeing), SDG 6 (clean water and sanitation), SDG 9 (industry, innovation and infrastructure), SDG 13 (climate action) and SDG 15 (life on land) and on commitments under Paris Agreement for climate action mandating reduction in emissions (from dumpsites and landfills) and conserving energy through circular economy (reuse and recycling). The Sendai Framework for Disaster Risk Reduction (SFDRR) and SDG 9 (industry, innovation, and infrastructure) also place a high priority on resilient critical infrastructure (UNISDR, 2015) (UNDRR,2020), which includes a disaster waste management system that can both withstand the shock of disaster events and serve well in post-disaster operations. This paper will guide towards formulating the guidelines for handling and safe disposal of the solid waste and debris generated after disasters which causes risks to human health and environment.

1.7 Structure of the Paper

The paper is divided into five chapters. First chapter provides an introduction, statement of the problem, objectives, methodology and scope and limitations of the present study. The second chapter discusses the definitions, terminologies, elements of waste management, types of waste occurring due to disasters and approaches for handling post-disaster solid wastes. The third chapter provides a review of documents and guidelines available at international, national and state levels and presents case studies from various disasters. This chapter also identifies key gaps and issues in the existing SWM system and its appropriateness for managing disaster waste in the Indian context. Fourth chapter provides summary of discussions held during the four technical sessions of National Consultation held on 11th-12th November 2021. This complements and further strengthens the findings of chapter 3. The fifth and the last chapter summarizes the paper and suggests recommendations and way forward.

CHAPTER - 2

APPROACHES FOR HANDLING OF POST-DISASTER SOLID WASTE

2.1 Background

The intensity and frequency of natural hazardous events such as floods, landslides, earthquakes and cyclones are evidently increasing in the world and the Indian subcontinent is no exception. When these disasters occur, large amounts of waste are generated due to damage of both the natural and man-made environment. Natural hazards like earthquakes, floods, cyclones, and forest fires; human-induced disasters like hazardous chemical spills, explosions, and gas leaks; and occasionally a combination of anthropogenic and natural consequences, like the collapse of buildings and infrastructure can produce massive amounts of mixed waste, including building debris, fallen trees, and hazardous waste. Inefficient or ineffective management of clean-up efforts following a disaster often result in a slow and capital-intensive recovery of a community making them vulnerable to environmental health issues as well. The health, safety and environment are all at risk from disaster trash (WHO, 2018). Effective implementation of post – disaster waste management will smoothen the process of recovery of communities and their surrounding environment. Identifying non-biodegradable and hazardous wastes that have the potential to cause long-term environmental damage is the most critical post-disaster issue.

The present chapter discusses relevant definitions of solid wastes, types of wastes, solid waste management, and various methodologies used in various guidelines, books and articles.

2.2 Concepts and Terminologies

The word "waste" is defined as unwanted and unusable materials and is regarded as a substance that is of no use, which mainly includes wastes from our houses, wastes from schools, offices, *etc.* and wastes from industries and factories. The common terms, concepts and functions related to solid waste management (SWM) and elements of Solid Waste Management are represented in Table 2.1 and Table 2.2 respectively.

Table 2.1: Concepts and Terminologies related to Solid Waste Management

Terminology	Definition
Solid Waste	All discarded and thrown away solid and semi-solid wastes arising from human and animal activities. These may be classified as municipal wastes, industrial waste and hazardous waste or any garbage or refuse, sludge from a wastewater treatment plant, water supply treatment plant, or air pollution control facility and other discarded material, resulting from industrial, commercial, mining, and agricultural operations, and from community activities.

Terminology	Definition
Municipal Waste	Wastes produced by residential, commercial and public services sectors that are collected by local authorities for treatment and/or disposal in a central location.
Industrial Waste	Industrial waste is the waste produced by industrial activity which includes any material that is rendered useless during a manufacturing process such as that of factories, mills, and mining operations.
Hazardous waste	Hazardous waste is a waste with properties that make it dangerous or capable of having a harmful effect on human health or the environment.
Bio-Medical Waste	Biomedical waste is defined as any waste, which is generated during the diagnosis, treatment or immunization of human beings or animals, or in research activities pertaining thereto, or in the production or testing of biological symptoms
Solid Waste Management	Solid waste management is defined as the discipline associated with control of generation, storage, collection, transport or transfer, processing and disposal of solid waste materials in a way that best addresses the range of public health, conservation, economic, aesthetic, engineering, and other environmental considerations.
Zero Waste	As described by United Nations Environment Programme (UNEP), zero waste is shorthand for efforts to reduce, reuse, redesign and recycle, to throw away less by making better use of what humanity produces and to design products that don't end up as waste, especially after just a single use. The benefits of zero waste include clean seas and fresh air, fertile soils, sanitary cities, resilient economies and sustainable extraction.
Circular Economy	It is a new way of creating value, and ultimately prosperity. It works by extending product lifespan through improved design and servicing, and relocating waste from the end of the supply chain to the beginning. (UNIDO, 2017)
Resource Recovery	Resource recovery is a process that involves extracting valuable materials and resources from waste streams, often referred to as the "circular economy." Resource recovery aims to reduce waste, minimize environmental impacts, and create economic and environmental value by recycling, reusing, and repurposing materials and resources that would otherwise be discarded as waste (World Bank, 2007).

Source - *Compiled from various published sources*

Table 2.2: Elements of Solid Waste Management

Elements	Characteristics
Waste Generation	It refers to waste creation by individuals, households, industries, businesses or any other entity. Waste generation includes all discarded materials, whether or not they are later recycled or disposed of in a landfill.
On-site Handling of Waste	It means handling of waste (separation, storage, collection, reusing or recycling, processing or preparation for final disposal) until the waste is collected.
Waste Collection	It is the procedure whereby waste is taken from designated sites/locations and loaded into vehicles for transport to a treatment or disposal area. This usually includes preliminary sorting and storage. Waste collection is done with the purpose of removing waste from its location.
Waste Transfer and Transport	It refers to the movement of waste from one place (usually place of origin) to another (place of destination).

Elements	Characteristics
Waste processing and recovery	It refers to the treatment of waste after collection and before final disposal. It usually includes volume reduction, segregation, recycling, physical/ chemical/ biological treatment, resource recovery, etc.
Disposal	Disposal is the final stage of waste management. It involves activities aimed at the systematic disposal of waste materials in locations such as landfills or waste-to-energy facilities.

Source: Central Pollution Control Board, 2016 and Solid Waste Management Rules, 2016

2.3 Solid Wastes Generated in Post-Disaster Scenario

Waste generated due to consequences of the disasters, can broadly be categorized as primary waste viz. debris, vegetative waste and carcasses, generated as a consequence of the event and secondary waste viz. food packets, water bottles, excreta and medical waste generated due to relief efforts. The quantity, composition and characteristics of these waste depend on the type and location of a disaster. For e.g., floods generally produce vegetation, mud, silt, slurry; earthquakes generate construction and demolition waste; fires generate ash, charred materials and metals whereas chemical/industrial accidents generate hazardous or radioactive waste (UNEP/ OCHA, 2013).

Table 2.3 provides a glimpse of types of solid wastes generated due to various disasters. It clearly identifies the five types of waste (broadly) generated due to disasters i.e., collapse structures, natural debris, hazardous and biomedical waste, plastic waste and municipal waste. Table 2.4 may be referred for composition of the wastes.

Table 2.3: Common Types of Wastes (debris) Generated due to various Disasters

Types of Disasters	Wastes (debris) Generated due to Disasters				
	Collapsed structure waste	Natural Debris	Hazardous Waste	Plastic Waste	Municipal Waste
Earthquakes/ Building Collapse	X	X	X	X	X
Landslides	X	X	X	X	X
Floods	X	X	X	X	X
Tsunamis	X	X	X	X	X
Forest fires		X			
Urban fires	X	X	X	X	X
Avalanches	X	X			
Cyclones	X	X	X	X	X
Industrial Disasters and other accidents			X	X	

Source - Compiled from various published sources

Table 2.4: Types of Solid Waste Generated and its Composition

Types of Wastes	Composition
Collapsed Structure Waste	Construction waste including concrete, steel, wood, clay, pipes, wires and tar elements from damaged/destroyed buildings and infrastructures caused due to building collapse or demolition of the structures. Parts from the power and telephone grids such as electrical poles, wire, electronic equipment, transformers; parts from water and sewage distribution systems.
Natural Debris	Sand, clay, mud, trees, branches, bushes and tree leaves.
Hazardous Waste	Chemicals, nuclear, radio-active materials, damaged vehicles and metals (cars, buses, bicycles and boats), pesticides, cleaners, paint, varnish, solvents, dyes, toxic gases, batteries, rubbers, electrical equipment, fly ash, smoke and coal and biomedical / health waste
Plastic Waste	Plastic water bottles, packaging material, polythene bags, containers, baskets etc. Relief supplies (plastic packaging, bottles, containers etc.) also generate this waste at camps and temporary settlements.
Municipal Waste	Garbage, food, paper, textiles, leather, wood, glass, metals, cleaners, sanitary waste in septic tanks and other household and relief camps wastes

Source - Compiled from various published sources

2.3.1 Disaster-Specific Solid Wastes

A. Earthquake

During an earthquake, structure collapse can lead to floor slabs collapsing on top of each other, trapping huge amounts of large debris waste (building materials, boulders, steep, iron and other construction material waste) in between them. This may lead to challenges such as sorting out hazardous waste like asbestos from non-hazardous waste such as general building rubble during response phase. Collapsed buildings may also overlap across streets, blocking access for the

Figure 2.1: Collapsed buildings and structures after the Bhuj (Gujarat) Earthquake, 2001; Source: 2DayHistory.com

search, rescue and relief operations. Quantities of waste during an earthquake are high as compared to other disasters since components of buildings eventually become waste.

B. Tsunami

Strong tsunami waves can cause widespread damage to the infrastructure leading to the spread of debris over a large area. Debris generated due to tsunamis often gets mixed up with the local soils, trees, bushes and other loose objects like vehicles. This complicates the segregation and handling processes of waste.

Figure 2.2: Debris generated from the Indian Ocean Tsunami (2004);
Source: The Hindustan Times

C. Landslides

Common waste generated by landslides includes damaged structures' waste, charred wood waste, downed trees, mixed waste, metals, C&D materials.

Figure 2.3: Uttarakhand Landslide Debris, 2016;
Source: Times of India

Figure 2.4: Debris caused due to a landslide incident that happened at a road connecting Dehradun and Mussoorie, following heavy rainfall in Dehradun (Tuesday, Aug. 11, 2020); Source: PTI

D. Floods

Floods damage the structural integrity of infrastructure causing extensive damage to the buildings leading to spread of debris. Floods can also create molds and cause rotting of materials made of wood such as timber. Waste often gets mixed with hazardous materials such as household cleaning products or electronic goods. Floods may further bring mud, clay and gravel into the affected areas which can create massive hindrance in the relief and recovery operations after the flood water recedes. Sometimes these materials get mixed up with the hazardous materials which require further assessment before the final dumping process.

E. Cyclones

Strong winds of a cyclone can tear the roofs off the buildings which causes the walls of the houses to collapse. These strong winds can destroy brick or concrete walls. Poorly constructed houses and huts can get folded under the roof tops. Waste generated by the cyclones can spread across open lands, streets, and marketplaces etc. This waste may include roofing materials, small items and dust carried by the wind. Mixing of these waste materials with asbestos may cause serious problems. Sometimes massive cyclones throw the ships and boats on the shore of oceans. Removal of these massive waste further requires specialized waste management. Vessels which sink in harbours during cyclones need to be removed too. Electric and telephone grids, transformers containing oil and Polychlorinated Biphenyls (PCBs) may get damaged due to cyclones.

Figure 2.5: Plastic Waste and debris generated due to Kerala Floods (2018);
Source: PTI

Figure 2.6: Wastes generated in Sundarbans region after Cyclone Yaas (2021),
Source: Japan times

F. Wastes Generated due to Industrial Accidents, Fires and Forest Fires

Industrial hazards and fire accidents produce hazardous waste, gases, dust and fly ash. The hazards encountered are fire, explosion, toxic release and environmental damage. The waste generated due to these hazards create a range of solid waste more or less similar to other hazards (Table 2.3). On the other hand, major generators of industrial solid wastes are the thermal power plants producing coal ash, the integrated iron and steel mills producing blast furnace slag and steel melting slag, non-ferrous industries like aluminum, zinc and copper producing red mud and tailings, sugar industries generating press mud, pulp and paper industries producing lime and fertilizer and allied industries producing gypsum. The majority of industrial waste comes from three types of industries: metallurgy, non-metallurgy, and food processing industries. The waste may differ from industry to industry according to the raw materials used, the manufacturing processes, and the product outlets, but these kinds of wastes can be categorized into three forms: solids, liquids, and gases (JeyaSundar et al, 2020). Forest fires usually produce a huge amount of ash and particulate matter into the atmosphere.

Figure 2.7: Explosion at a fireworks factory, Virudhunagar, Tamil Nadu, February 12, 2021;
Source: Deutsche Welle

G. Other Events

The disastrous events such as conflicts, terrorist attacks, rail and road accidents, air strikes and accidents result in damage of key strategic installations, industries and residential areas resulting in the generation of hazardous and solid waste.

Figure 2.8: Debris after Hyderabad Bomb Attack, 2013,
Source: The Livemint

2.4 Environmental Impacts

Disposing of waste has huge environmental impacts and can cause serious problems. Some waste will eventually rot and in the process, it may smell, or generate methane gas, which is explosive in nature and contributes to the greenhouse effect. Badly managed landfill sites may attract vermin or cause litter. Incinerating waste also causes problems, because plastics tend to produce toxic substances, such as dioxins, when they are burnt. Gases produced from waste incineration may cause air pollution and contribute to acid rain, while the ash from incinerators may contain heavy metals and other toxins. Table 2.5 and Table 2.6 provide causes and impacts of disaster waste on the environment.

Table 2.5: Cause - Effect Relationship of Disaster Waste on the Environment

Causes	Effects
Uncollected building rubble from damaged buildings	Waste tends to attract more waste since the site is already considered a dumping site.
Dumping in inappropriate areas and/or proliferation of scattered dump sites	Sites too close to settlements, especially from hazardous materials. Destruction of valuable land. Impacts on drinking water supplies and damage to valuable fisheries. Increase in disease vectors (flies, mosquitoes, rats, etc.). Risk of waste piles collapsing. Risk of fires. Risk of cuts from sharp materials, including used syringes
Collapse of municipal solid waste services, including possible loss of experienced waste managers	Lack of collection service and uncontrolled dumping of waste
Uncontrolled dumping of healthcare waste from hospitals and clinics	Serious health risks to local populations including the spread of disease and infection, for example from used syringes; odour problems.
Asbestos sheet exposure in collapsed structures or in re-use of asbestos for reconstruction	Health risks associated with inhalation.
Food Waste in Landfill	As waste decomposes it releases methane gas. Methane is a greenhouse gas which is significantly more potent than carbon dioxide.
Irresponsible Waste Disposal	It can result in air pollution, land pollution and could also cause numerous health conditions.

Source: Compiled through various sources

Table 2.6 Types of Hazardous Wastes and Associated Risks

Types of hazardous waste	Common Risk
Toxic Wastes	Death, illness, chronic health effects and diseases such as cancer, respiratory issues, genetic disorders, birth defects etc.
Reactive Wastes	Chemically unstable and react violently with air or water. They cause explosions or form toxic vapour and might cause immediate fire hazards.
Infectious wastes	Bandages, used needles, and other waste materials from clinics, hospitals or biological research facilities can spread infections such as HIV, hepatitis etc.
Radioactive Wastes	Radio-active materials emit ionizing energy which can persist in the environment for many thousands of years before fully decaying. Decomposition of radioactive substances is not under control of local municipal organizations but under engineering tasks separate from other forms of hazardous - waste management.

Source: Hazardous Waste Management Rules, 2016

2.5 Solid Waste Management and Treatment Methods

Solid Waste Management (SWM) is one of the many priorities that agencies must manage in various stages of disaster management. Early disposal and management of large -scale debris caused due to disasters is essential to protect human health, reduce injuries and minimize or prevent environmental impacts. It involves advanced thought, planning and coordination among individuals at various levels of government and the private sector with experience and expertise in waste management (Agarwal, Chaudhary & Singh, 2015). The key to efficient waste management is to ensure proper segregation of waste at source and to ensure that the waste goes through different streams of recycling and resource recovery. The reduced final residue is then deposited scientifically in sanitary landfills (Lahiry, 2017).

In recent times, the necessity of solid waste treatment has been highlighted and there has been a noticeable progress to achieve sustainability. Some of the current practices are as follows:

- **Segregation of Waste at Source:** In some urban centres, solid waste is collected from each doorstep by workers working in the informal sector for a collection fee and they gain additional income from sale of recyclables.
- **Use of Solid Waste for Energy Generation:** There has been technological advancement for processing, treatment and disposal of the solid waste. Energy-from-waste is a crucial technique of SWM because it not only reduces the volume of waste from disposal but also helps in converting the waste into renewable energy and organic manure. Waste may be converted into energy in a number of

ways- gasification, pyrolysis, anaerobic digestion, landfill gas recovery etc.

- **Reduction of load on Landfill Sites:** Installation of waste-to-compost and bio-methanation plants would reduce the load of landfill sites. The biodegradable component of India's solid waste is currently estimated at a little over 50 per cent. Bio-methanation is a solution for processing biodegradable waste that remains underexploited.
- **Upgradation of Recovery Centres and Facilities:** There is also an urgent need to re-imagine and upgrade a significant number of resource recovery centers and material recovery facilities, particularly in densely populated urban areas. These facilities should be capable of handling substantial volumes, ranging from 10 to 60 metric tonnes. Furthermore, there is a pressing requirement for increased mechanization and the use of appropriate technologies to enhance economic and ecological efficiency in the waste sorting and recycling processes. It's essential that these innovations also prioritize the dignity and health of the workers employed at these sites, ensuring safe and sustainable working conditions.

2.6 Principal of Reduce, Reuse, Recycle and Recover

With modern day technologies, produced solid wastes can be manageable through the four "R" principle. It refers to Reduce, Reuse, Recycle and Recover.

- **Reduce** represents less use of non-biodegradable components which are harmful for the environment such as plastics.
- **Reuse** stands for using the non-biodegradable components over and over again to decrease the manufacturing of these harmful substances.
- **Recycling** process is basically a part of the reusing process. This helps to recycle the non-biodegradable waste to create another useful component rather than going to any landfill as a waste.
- **Recover** means to convert waste into resources such as energy (heat, electricity) through waste-to-energy processes.

2.7 Conclusion

The present chapter has briefly discussed the different terminologies and concepts which are frequently used in this document. The chapter has highlighted the types of wastes generated due to various disasters and possible options which are available to treat solid waste. It is clear that the quantities and types of waste being produced due to disastrous events need special focus and long-term solution. Hence, careful examination of literature and identification of gap areas is an important aspect before suggesting a post-disaster solid waste management framework. In order to understand the different approaches, guidelines, the next chapter would focus on the review of policies and case studies available nationally as well as globally.

CHAPTER - 3

REVIEW OF GUIDELINES AND CASE STUDIES

Disaster waste is a recurring issue that needs to be managed throughout the post disaster timeline- be it during the immediate aftermath (during rescue and relief operations), short (relief and response) or long term (recovery and reconstruction) operations. Efficient and systematic management of waste is a critical factor for successful and cost-effective disaster recovery (Brown et al., 2011). For this purpose, many agencies, organizations and governments have been developing plans and guidelines as a roadmap for post-disaster waste clean-up. This chapter attempts to review internationally published plans and guidelines for disaster waste management along with global and domestic solid waste management case studies from post-disaster scenarios. For this purpose, the chapter has been divided into two sections. The first section attempts to give a detailed review of national and international guidelines envisioned for guiding waste management policy, programmes, projects and humanitarian field practices. Second section contains case studies of current practices in the context of different disasters.

3.1 Review of International and National Guidelines for Post-Disaster Solid Waste Management

Multiple global organizations and governments have published Disaster Waste Management (DWM) guidelines with a vision of improving practices globally. A few of them are as follows:

Table 3.1: Disaster Waste Management Guidelines

S.No.	Name of Guidelines	Organization	Year
1.	Disaster Waste Management Guidelines	UNEP/OCHA	2013
2.	Technical Note 7: Solid Waste Management in Emergencies	WHO	2013
3.	Guidance Note on Debris Management	UNDP	2015
4.	Guidance Note Municipal Solid Waste in Crisis and Post- Crisis Situation	UNDP	2015
5.	Flood Waste Management (FWM) Guidelines for Bangkok	National Institute for Environmental Studies, Japan	2015

S. No	Name of Guidelines	Organization	Year
6.	Disaster Waste Management Contingency Plan and Guidelines	South Australia	2018
7.	Sphere Handbook	Sphere International	2018
8.	DWM Guidelines for Asia and the Pacific	Ministry of Environment, Japan	2018
9.	Best Practices for Solid Waste Management: A Guide for Decision Makers in Developing Countries	United States Environmental Protection Agency (USEPA)	2020

3.1.1 International Guidelines

Under this section, selected guidelines have been reviewed in congruence with the case studies presented in the national consultation (refer Chapter 4) for their adaptability, diversity, applicability, scope and coverage.

A. Disaster Waste Management Guidelines by United Nations Environment Programme (UNEP)/United Nations Office of Coordination of Humanitarian Affairs (OCHA), 2013

Disaster Waste Management (DMW) guidelines in their ambit cover solid as well as liquid waste generated from disasters except human or animal dead bodies and excreta. These guidelines intend to mitigate public health risk from contact with waste, create ease for relief and reconstruction efforts, prevent environmental degradation, promote reuse and recycling of waste material and share waste management knowledge with government authorities, NGOs, relief and humanitarian organizations *etc*. Table 3.2 summarizes the action plan for DWM proposed under UNEP/OCHA guidelines.

Table 3.2: Phase-wise Actions Plan for Disaster Waste Management proposed under the UNEP/OCHA Guidelines

Phases	Purpose	Operations	Output
PHASE 1 Immediate (0-72 hours)	Identification of immediate concerns and priorities after the disaster; preliminary estimation of waste quantity and composition; assessment of risk from hazardous waste in the living environment	Appropriate disposal of waste, create access for search and rescue operations, segregation of hazardous and biomedical waste.	Identification of primary waste concerns and actions to address them.

Phases	Purpose	Operations	Output
PHASE 1 Short-term (post 72 hours)	Rapid Assessment; integrated management of waste from Internally Displaced Persons (IDP) camps and general household waste by general SWM services present locally.	Status of waste management, identification of segregation and disposal sites, assessment of local capacities and requirement for external assistance	
PHASE 2 Medium-term	Continuation of assessment and collection of data related to waste quantity, composition, local capacities and lacunas and identification of exit strategies.	Establishment of temporary storage sites for waste collection and transportation of waste. Guidance to local authorities for solutions to reduce impact of waste	Data for preparing DWM programme for recovery phase.
PHASE 3 Long-term	Implement DWM programme designed in Phase 2; Monitoring and Evaluation (M&E) and handover of an improvised DMW system to the local authorities.	Stakeholder engagement and communication for implementation of plan. Procurement of required equipment or machinery, training of workers and operators	A complete and holistic addressal of the DMW Plan.
PHASE 4 Contingency Planning (Pre-disaster planning)	To bridge gap between all the phases during response, recovery and reconstruction	Predefined responsibilities of authorities and stakeholder engagement; Communication planning; Debris removal strategy; Identification of potential waste storage sites; Inventory management; Planning for recycling and reuse.	A contingency plan with pre-identified risks, capacities and strategies to deal with waste in case of any hazardous event.

Source: UNEP/OCHA, 2013

The above guidelines seek to establish sustainability of the disaster waste management operations through a rational exit strategy and smooth handover of a disaster resilient waste management project to the public, private or community bodies in a given setting.

B. Disaster Waste Management Guidelines for Asia and the Pacific, Ministry of Environment, Japan 2018

The present guidelines provide a holistic coverage of all DWM processes and actions (short term and long term and before, during and after disasters) with an attempt to cover all types of wastes that can be generated in a disaster with an exclusive focus on the Asia-

Pacific region. They also outline a unique approach of integration of the DWM plan with the Disaster Management (DM) cycle, involving planning for waste for each phase of disaster *i.e.*, preparedness, rescue, response, recovery and reconstruction with emphasis on pre-disaster planning as the most integral activity upon which the entire DWM planning and implementation depends. It is a handy guide for action giving planning and action guidance as well as practical cases and examples from the Asia Pacific region. The different components of the DMW Plan proposed by the Government of Japan is given in Table 3.3.

Table 3.3: Components of Disaster Waste Management Plan as per the Government of Japan

Component of DWM Plan	Time of Activation	Purpose	Activities
Contingency plan (CP)	Pre - disaster	To specify what, who, when and how to do and proceed with waste when disaster event breaks	Estimation of waste generated, identification and assessment of the current system and capacity in waste management as well as crucial activities and resources like temporary storage sites, organization of workforce, on-site traffic planning, segregation and recycling facilities etc.
Implementation Plan (IP)	During and post disaster	To compile response policies using the contingency plan, specify the actions for waste disposal during disaster	Establishing DWM clusters, opening temporary storage sites, hiring workers for clean-up, segregation and sorting of waste, waste treatment and recycling etc.
Risk Deduction Plan (RDP)	Post - disaster	To create risk reduction counter measures in the DWM Plan	Reducing potential waste that may be generated during the disaster event.

Source: Ministry of Environment, Government of Japan, 2018

C. Guidance Note on Debris Management- United Nations Development Programme, 2015

The above document intends to give guidelines to the UNDP's Country Offices in various parts of the world and to support national, state and local authorities for debris management in the aftermath of a disaster. This guidance note covers only post-disaster debris from damaged or demolished buildings, natural materials and places focus on debris management. The document also places focus on gender empowerment- through participation of women in all stages of waste management projects as active stakeholders, emergency employment, equal pay for equal work etc. The guidelines are broadly given in two phases i.e., planning and implementation phase. The important components of the guidelines are as given below.

Components of Debris Management Plan given by UNDP are as follows:

- **Situational Analysis:** It would be conducted for detailed understanding of institutional, economic and social context for which the project is to be designed and implemented.
- **Damage Assessment:** It gives an understanding about the impact of disaster, urgent requirements, risks and capacities (infrastructure, institutional, human and financial) through observation, initial estimation and data review, local survey and official statistics.
- **Development of a Programme Strategy and Result Framework:** The strategy outlines the objectives of the project, approach and the key deliverables it aims to provide. For e.g., development of small disposal and temporary storage sites for sorting and processing of debris near or at the demolition site (to avoid high transportation costs) which can then be sent to processing or disposal sites. The strategy also outlines the results framework along with the clear objectives of operations, *e.g.,* removal of debris, economic revitalization, number of jobs created and people trained, *etc.*
- **Identifying and Mitigating Risks:** This component provides a unique feature *i.e.*, risk assessment framework for the project itself, which includes identification of risks, which could be political, security related (law and order), financial, environmental and cascading disasters. It also provides, suggestions for mitigation of these risks through capacity building, resource mapping, partnership development, conducting environmental impact assessment and developing standard operating procedures *etc.*
- **Management and Funding Arrangements:** The concerned government is made responsible for the successful implementation of the project and UNDP along with other stakeholders can provide its support. This guidance note also provides for various potential funding partners that can be approached for timely resource mobilization.
- **Monitoring and Evaluation:** This component provides a framework through various monitoring systems such as verification vouchers, e-ticketing systems, electronic debris tracking system through which each and every operation and activity can be tracked and accounted for. It also highlights the use of technologies for tracking and monitoring-such as Geographical Information

Systems (GIS) for tracking and mapping of progress of debris clearance and removal operations, using Cash for Production modality by linking payment of salaries of workers with output and using local communities or NGOs as monitoring partners.

- **Communication Strategy:** This clear and responsive communication strategy has been given for, a strong public information and broadcasting measure such as public website that can disseminate information on roles and responsibilities of stakeholders, progress status of various activities and operations, short term employee vacancies for debris management, *etc*. Regular reporting, coordination and consultation with government and local authorities is a must for creating a project that can sustain in the long term.
- **Implementation Plan:** The UNDP guidelines provide a detailed implementation plan for the project, which details out:
  - » different checklists for different phases of implementation (identification of area, debris removal, staging, segregation, storage, recycle and reuse)
  - » techniques of accelerating project implementation
  - » enumerating key government strategies and responsibilities for debris management
  - » implementation through community engagement and participation
  - » capacity building and training for communities to create permanent resources locally,
  - » information, communications and relationships (between stakeholders) management

D. Solid Waste Management in Emergencies (Technical Note 7), Technical Notes on Drinking Water, Sanitation and Hygiene in Emergencies: World Health Organization, 2013

These technical guidelines deal with management of waste generated from emergencies and relief operations during and in short-term after disaster, with an objective of preventing public health risk from direct or indirect contact with waste. The key components of the guidelines are as follows:

- Prior assessment of context and situation before starting the operations- such as estimating waste quantity, its type, existing waste disposal system, its coping capacity after the disaster and organization of authority, responsibilities and availability of resources.
- Removal of waste to facilitate rescue and relief operations.
- Employing community members/ groups in clean up tasks both to give them agency and source of income.

- Safety and protection of workforce - vaccination, protective clothing and equipment against potential disease outbreaks.
- Collection of waste in communal storage bins, its transport depending on the type and quantity of waste, disposal at already existing disposal sites or setting up temporary sites like communal pits. Camp waste to be managed either on-site or by establishing large disposal sites away from camp.

E. Best Practices for Solid Waste Management: Guide for Decision Makers in Developing Countries, United States Environmental Protection Agency (USEPA), 2020

The USEPA has developed a guide for national, state and local authorities, Civil Society Organizations (CSOs), field practitioners, private sector and citizens in developing countries to improve their SWM infrastructure and practices within their given physical, socio-economic and political context and landscape. The guide paints quite vivid scenarios of best practices around the world through multiple case studies and real time examples illustrating problems and their possible practical solutions to help decision makers design and evaluate their strategic options. The EPA has developed an approach of 'Waste Hierarchy' (refer Figure 3.1) for prioritizing solid waste management actions. This hierarchy ranks waste management strategies in order of preference (from most to least) on the basis of their environmental sustainability.

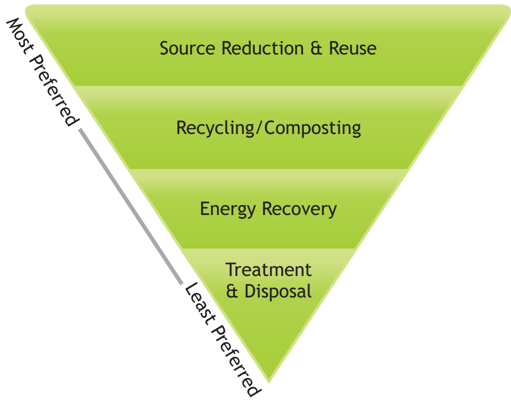


Figure 3.1: Waste Hierarchy, Source: EPA, 2017

Table 3.4: Key Features of USEPA Guide for Decision Makers on Solid Waste Management

Components	Objectives	Actions and Best Practices	Key considerations
Stakeholder Engagement	Identification of stakeholders, communication and engagement with them	Contract negotiations, shareholdings and their specific roles, public consultation	Involvement of public-private sector partners, academic institutions, NGOs, informal sector, and community.
Planning Systems	Planning for SWM systems	Identification and assessment of resources, waste management needs	Integration of disaster waste planning into existing regulations

Components	Objectives	Actions and Best Practices	Key considerations
		and objectives, evaluation of viability of all possible waste management options, implementation strategy (timeline, specific actions), M&E tools.	pertaining to solid waste and disaster risk reduction
Economic Considerations	Funding of SWM action and operations	Cost estimation, exploring internal or external avenues of funding, assessing financial feasibility of project, budgeting, financial contracts etc.	Extended Producer Responsibility- eases the burden of financing SWM operation on public (taxes). It may designate the producers to compensate for waste operations for the goods, products they produced.
Waste Characterization	Categorization of different waste streams, identification of special waste from the waste stream	Basis of differentiation- sources, quantity, composition	Special wastes that may be hazardous or may pose risk to the living environment. e.g.: E-waste, Bio-medical waste, industrial or chemical waste etc.
Prevention and minimization	Reducing waste generation	Using fee or penalties for use of plastics, minimizing use of disposable products etc.	Cost effectiveness, conservation of resources, lesser emissions etc.
Separation, collection and transportation	Primary and secondary collection, segregation and transportation	Assessing waste composition for segregation, deciding waste storage and collection locations, design and maintenance, transfer stations, collection and transport vehicles	Door to door or communal collection of waste, massive involvement of informal sector especially during segregation of waste and deriving recyclables and reusables
Recycling	Source of income, easing of burden on new/virgin resources, reduction in waste disposal	Strategic planning, understanding the recycling stream, identification of recyclables during collection, separation, treatment, processing and re-utilization of the recycled waste to manufacture new products	Informal sector involvement, health and safety of workers at all stages and regulation of working conditions for them

Components	Objectives	Actions and Best Practices	Key considerations
Dumpsite management	Assessing appropriateness of strategy for dumping- open dumping, controlled dumping, sanitary landfilling	Identifying locations, improving operation at open dumpsites, converting them to controlled dumpsites, planning for closing of dumpsites	Sanitary Landfilling to control and mitigate potential contamination of ground , water or air- bottom lining of the landfill, leachate collection and treatment and covering landfill.
Energy Recovery	Waste to energy conversion from the non-recyclable waste, reduction of dumping operations	Combustion, co-processing to be exercised in tandem with source reduction and recycling strategies	Capital investment, education and training of staff

F. *Flood Waste Management (FWM) Guidelines for Bangkok (Thailand), 2015*

The FWM guidelines are based on extensive research based on Thai and Japanese FWM which includes perspectives from public management, administrative and technical engineering aspects. The structure on which the FWM system is based, is known as Incident Command System (ICS). In Bangkok, each district is allotted a separate facility for collection of flood waste and transportation of it to the temporary storage sites (an accessible site during a flood situation). The phase-wise action plan outlined for FWM in Bangkok is given in Table 3.5.

Table 3.5: Phase-Wise Action Plan Outlined for Flood Waste Management in Bangkok

Category	Phase-wise Action plan for Flood Waste Management			
	Mitigation Phase (Normal Time)	Preparedness Phase	During Flood Phase	After Flood Phase
Organizational Strengthening	• Allocation of responsibilities to each department • Training and Workshops	• Constitution of task forces • Training and Workshops	--	• Provide information on waste collection process • Secure public sanitation
Communication with Stakeholders	• Post-flood assistance to the affected community • Inter-connection amongst different	• Meetings with stakeholders • Inclusion of private companies	• Providing information on waste collection and separation. • Secure public	• Update flooding information to waste transfer stations. • Update

Category	Phase-wise Action plan for Flood Waste Management			
	Mitigation Phase (Normal Time)	Preparedness Phase	During Flood Phase	After Flood Phase
	stakeholders • Awareness about SWM with residents		sanitation. • Coordination with EOC (Emergency Operations Centre)	information on damages. • Re-estimate flood waste amount
Data Collection and Analysis	• Making a list of TSS (Temporary Storage Sites) • Estimation of possible flood-waste quantity and composition. • Pre-count of availability of equipment and vehicles. • Possible type of waste generation maps	• Check the condition of selected TSS	• Gathering latest data • Collection of latest inundation maps • Latest information on evacuation, damage to housing and other infrastructure. • Estimation of flood waste amount.	--
Preparation/ Updating of the Plan	• Preparation of guidelines for SWM during a flood. • Guidelines for residents.	• Reviewing the plan	• Revision of FWM plan along with the field situation	• Revising FWM plan according to actual situation
Plan Execution	--	• Prevent flood impact on regular waste management system • Secure FWM resources • Adaptively plan for the implementati on of FWM • Develop coping capacity of the public	• Set up temporary sites • Preparation of SW transportation vehicles • Estimation of budget	• Prepare cost estimation • Manage TSS • Manage waste transfer station • Close TSS to secure the area to its original condition Collect scattered wastes from flooded houses and transfer them to waste

Category	Phase-wise Action plan for Flood Waste Management			
	Mitigation Phase (Normal Time)	Preparedness Phase	During Flood Phase	After Flood Phase
		• Improve vulnerability conditions		collection stations. • Transfer them to the final disposal site. • Keep records of each FWM activities. • Review of FWM plan for future use. • Improve WMS during regular times to avoid risks during floods.

G. Disaster Waste Management Capability Plan (DWMCP) and Guidelines by Government of South Australia, 2018

The DWMCP is one of the four parts of the South Australian State Emergency Management Plan prepared to define the roles and responsibilities, associated key activities/ projects/programmes with them and the agencies responsible for their execution and implementation of management of waste generated by a disaster during preparedness, response and recovery phases. It also provides a list of agencies and organizations responsible for implementation of the Waste Management Plan.

The Guiding Principles behind the Disaster Waste Management Capability Plan (DWMCP) are as follows:

- To strengthen local communities through training programmes on waste management and incorporating DWMCP in local emergency management arrangements.
- To ensure safety of the environment and minimize the risks to public health.
- To incorporate sustainable resource management in DWMCP.
- To clarify the roles and responsibilities, activities involved, agencies/timely response institutions.
- To ensure the availability of skilled labour, equipment, timely response, smooth logistics and transportation beforehand.

- To encourage the economy, creation of jobs and recycling/reuse practices through implementation of DWMCP.

The DWM guidelines provide a phase-wise responsibility for waste management. The key roles during the preparedness phase are creating tools and resources and maintaining them, planning at zone-level, dissemination of information to the public, assessing the legislations and regulations and assigning specific roles and responsibilities. For the response and recovery phases, the plan delineates the roles of all the institutions/state governments/people/communities involved corresponding to the various types of activities in these phases. It further recommends the state government to set up an advisory support as a guiding tool for effective waste management and an operational support for a smooth and coordinated implementation of activities. The DWMCP is further accompanied by practical guidance on managing waste after a disaster viz. DWM Guidelines, given in the box below.

Disaster Waste Management Guidelines by Southern Australia, 2018

It entails the best practices for the waste management of all types of waste, especially the solid waste (including non-hazardous, hazardous and medical waste) generated due to natural hazards, during the emergency phase. The guideline document is divided into two parts viz. general guideline and technical guidelines.

The guidelines provide a step-by-step guide for the people involved in DWM. Steps that are to be followed for an effective post-disaster waste management are as follows:

- Planning an initial assessment to find out issues in waste management *e.g.*, estimation of the volumes of waste, identification of the ownership *etc*.
- Identification of support - advisory and potentially operational support
- Supervising the support provided.
- Conducting an in-depth assessment for an exact understanding of issues related with Disaster Waste Management (DWM).
- Working out long-term support for waste management by assessing the potential of communities to manage issues related to waste management or to identify waste volumes, with the help of stakeholders involved. If possible, state governments may be requested to address the problems of the affected communities.
- Planning a DWM programme for the support which must include the objectives, activities and timelines to meet the objectives of community recovery.
- Strictly supervising the implementation of the programme till it finishes checking arrangements such as coordination of resources, monitoring progress, regularly assessing the situations related with disaster waste.

- Evaluation of the end results of the Disaster Waste Management plan.

The technical guidelines assist people in managing waste of varied nature and characteristics from pick-up to drop and their processing. These guidelines provide technical advice on managing the above-mentioned waste through various phases such as on-site handling, their transportation, creating temporary storage facilities, and recycling.

Source: Compiled from DWM Guidelines, Govt. of South Australia, 2018

3.1.2 National Guidelines

Under this section, selected guidelines have been reviewed to understand the existing SWM guidelines in India. This section will also attempt to find out the gap areas, which may direct towards need to develop guidelines for DMW.

A. Waste management Rules and Guidelines by Ministry of Environment, Forests and Climate Change (MoEFCC) under Environment Protection Act, 1986

Waste management is a multi-ministerial and multi-departmental subject. From planning to the execution, multi-level coordination has been envisaged in the national, state and local framework. The MoEFCC along with CPCB acts as the nodal agency for the majority of waste management activities at the centre under the Environment Protection Act (EPA), 1986 (NLSIU & MoEFCC, 2019). Other ministries and departments including Ministry of Commerce & Industry, and Ministry of Housing & Urban Affairs (MoH&UA), Ministry of Chemicals & Fertilizers and Ministry of Agriculture will participate in regulation, planning, coordination and implementation of waste management in their respective areas of jurisdiction. At state level, State Pollution Control Board and even more importantly at local level, Urban Local Bodies (ULBs) and Panchayati Raj Institutions (PRIs) are entrusted with handling waste management operations.

Under the ambit of the umbrella legislation of the EPA, 1986, MoEFCC has provided for various sets of rules and guidelines depending on the nature and type of waste as highlighted in the table below.

Table 3.6: Existing Rules and Guidelines on Waste Management in India

Rules	Scope	Purpose
Manufacture, Storage and Import of Hazardous Chemicals (MSIHC) Rules, 1989	Multi- Accident Hazard (MAH) units dealing with manufacture, storage, import or associated use of hazardous chemicals	• Identification of MAH units, preparation of on-site emergency plan. • Estimation of dispersion of leakages, its size etc.

Rules	Scope	Purpose
Chemical Accidents (Emergency Planning, Preparedness, and Response), Rules, 1996	MAH Units	• To establish criteria for identification of MAH units, formation of crisis management hierarchy.
Solid Waste Management Rules, 2016	Solid Municipal Waste	• Scientific disposal of SW-collection, segregation, treatment, disposal, recovery, reuse and recycle.
Hazardous and other Waste Management Rules, 2016	• Hazardous waste posing health and/or environmental risks • 'Other waste' such as paper, metal scraps, tyres, used electronics that can be reused or recycled	• Scientific management of hazardous waste in sequential order from collection to safe disposal. • Recovery of energy from waste using co-processing technique that uses waste as supplementary resource for energy.
Hazardous Waste (Management Handling and Transboundary Movement) Rules, 2019	Hazardous waste brought into India for recycling and reprocessing	• For alignment with Basel Convention on Control of Transboundary Movements of Hazardous Wastes and its Disposal.
Biomedical Waste Management Rules (BWMR), 2016	Human and animal anatomical waste, treatment apparatus like needles, syringes, bandages etc.	• Scientific disposal of BWMR through on-site segregation, collection, transportation, treatment etc.in an environmentally sound and sustainable manner.
Plastic Waste Management Rules, 2016	Plastic Waste	• Classification, segregation, recycling and/or phasing out of different categories of plastics.
E-Waste Management Rules , 2016	Electronic and electrical waste (laptops, phones, ACs, CFLs etc.)	• To establish Extended Producer Responsibility, Manufacturer, dealer, refurbisher, Producer Responsibility Organizations (PROs) as stakeholders to manage and track e-waste throughout its life cycle.

Rules	Scope	Purpose
Construction and Demolition Waste, 2017	Building, road, construction sector waste	Collection, segregation and disposal of waste along with noise and dust management, reutilization of C&D material.

Source: Compiled through multiple sources

The above guidelines provide detailed insights about the scientific methods of collection, segregation and disposal of the waste and define responsibilities of various stakeholders for its management. However, responsibilities of the concerned institutions for planning and managing the large-scale waste generated due to disasters or accidents need mention in the existing guidelines. For more clarity, few of the important existing rules and guidelines are reviewed below.

B. *Solid Waste Management Rules, 2016*

The MoEFCC revised and notified the SWM Rules in April 2016, replacing Municipal Solid Waste (Management and Handling) Rules, 2000. The new rules have extended beyond the municipal jurisdiction to urban agglomerates, census towns, industrial townships, areas under Indian Railways, airports, *etc*. The rules suggest waste generators to segregate waste at source into three categories- wet (biodegradable), dry waste and domestic hazardous waste. The rules aim at recycling, reuse and recovery of dry waste, and utilization of wet (organic) waste for composting or bio-methanation. Waste generators are mandated to pay user fees to the collector and spot fine in case of littering and flouting of the segregation mandate. It suggests that informal waste collectors(ragpickers) should be integrated in the formal system of waste management by the State. Criteria for setting up of landfill sites and their operation has also been given by the rules. For non- recyclable high calorific waste, as an alternative to being disposed of in landfills, provisions have been made to use that waste for energy generation either through co-processing in cement or thermal power industry or to be used in and as Refuse Derived Fuel (RDF) in industries. Material Recovery Facilities or secondary storage facilities where ragpickers/waste collectors can sort and separate waste are to be set up by local authorities. Throwing, burning or burying waste in open public spaces, drains or other water bodies by waste generators has been prohibited (Singh, 2020). The SWM Rules, 2016 focus on day-to-day management of waste and do not provide any guidance on management of large-scale disaster induced waste.

C. *National Action Plan for Municipal Solid Waste by CPCB, 2016*

I. The National Action Plan was drafted in accordance with the SWM Rules, 2016 on the order of NGT (National Green Tribunal). This plan is a suggestive outline for the states/union Territories and cities/towns, so that they can draw their own respective SWM plans and strategies. This action plan covers development, operation and implementation of the waste disposal plan at state and local (municipal) level.

II. The plan suggests the states to follow waste management policy based on the hierarchy, given in Figure 3.2.

- **Waste prevention or minimization**
  Composting, bio gas production, cattle feed etc.
- **Waste utilization**
  Material Recovery Facility (MRF)- segregation and recovery of material from waste
- **Waste Recycling**
  Reprocessing, reuse and recycling of waste (paper, metal, wood etc.)
- **Waste Processing**
  Treatment of waste before disposal
- **Waste-to-Energy**
  Bio-gas, biofuel, heat etc.
- **Landfilling**
  To be kept as last resort

Figure 3.2: Hierarchy for the Waste Management Policy
Source: Central Pollution Control Board, Ministry of Environment, Forest and Climate Change, GoI

III. The plan gives a region/cluster-based approach for common waste processing and disposal facilities. It suggests that common waste management facilities be set up for the clusters. These clusters can be divided on criteria such as spatial area, distance, quantity of waste generation, transportation and logistical ease. *e.g.* smaller towns can together form a cluster or a big city may form a cluster in itself. Each cluster may also have diverse facilities ranging from waste treatment, recycling, co-processing and Refuse Derived Fuel (RDF).

IV. Based on population and the quantum of waste generated by the states or cities, they are required to make their respective SWM Plans. The National Plan suggests the components of these action plans (collection, transportation, logistics, disposal, partnerships, *etc.*) depending on the quantity of waste generated (>500, 100-500, 50-100 and <50 tonnes per day). The implementation of action plans is to be monitored at State, district and municipal level.

D. Solid Waste Management under Swachh Bharat Mission by MoH&UA

The "Swachh Bharat Mission" (SBM) has played an important role as an inclusive improvement policy and paradigm shift (Ghosh, 2016) in the scenario of SWM in India. The focus of SBM is on creating awareness and providing community driven sanitation systems so that implementation of solid and liquid waste management initiatives can be economical and efficient. It aims at promoting ownership at the grass root level and community involvement at all stages to target sustainable waste management. From 2017, SBM's major campaign focused on waste segregation at source, door-to-door collection, enhancement of the waste processing capacity of plants and increase in capital investment (Henam & Agarwal, 2017). Solid Waste Management under SBM is categorized under two missions *i.e.*, Solid Waste Management under Swachh Bharat Mission Gramin (SBM (G)) by the Ministry of Jal Shakti and Solid Waste Management Plans under SBM Urban (SBM (U)) for urban areas by MoH&UA.

The SBM (G), in its first phase focused on rural sanitation coverage, however, during the second phase of SBM(G), the focus was broadened to ensure effective solid and liquid waste management. The SBM (U) focused upon strengthening of municipal SWM planning. It emphasized on segregation of solid wastes at its source, utilizing the principles of 3 "R" - (Reduce, Reuse and Recycle) in a scientific way to process various types of municipal solid waste. The SBM (U) 2.0 guidelines emphasized on SWM, which covers the need for the possible ways of efficient collection and transportation of solid waste along with special focus on processing every kind of waste.

3.2 Review of Case Studies

This plan discusses the selected case studies from India and other countries to understand issues and gaps with respect to management of solid waste in the post-disaster scenarios.

A. Nepal Earthquake 2015

Context and Background: Two earthquakes measuring on 7.8 and 7.3 on Richter scale rocked the Himalayan region of Nepal on April 25 and May 12, 2015 respectively. According to estimates of the Nepal Government, around 10 million tonnes of debris waste was generated from 14 districts (UNEP/ IETC, 2015).

Removal of Solid Wastes/ Debris: For removal of debris, the community participated and at many places spearheaded all the removal and reconstruction processes (Khanal et al., 2021). The local people removed debris manually (Lauritzen, 2018) which led to mixing of waste (Khanal et al, 2021) that created further issues. During the initial phase, housing materials, bricks and scrap materials were collected but due to random and haphazard disposal of debris, recycling and reuse of this collected debris remained largely unorganized (Lauritzen, 2018).

Utilization of Debris: A study found that 57.96% of debris collected was utilized in the reconstruction activities (Khanal et al 2021) but this was done without processing the C&D waste (Lauritzen, 2018).

Challenges: Lack of necessary resources, technology and lack of adherence to proper safety measures (REA, MOEST, 2015) (Khanal et al, 2021), lack of relevant policies (Memon, 2016) and pre- disaster strategic planning (Poudel, 2019), dearth of trained manpower and sufficient finances (Memon, 2016; Lauritzen, 2018) along with poor communication and transportation challenges due to damaged or blocked roads (Lauritzen, 2018).

B. East Japan Earthquake and Tsunami, 2011 (NATECH Event)

Context and Background: NATECH stands for Natural Hazards leading to Technological Disasters. In 2011, an earthquake (9.0 Mw) in Japan led to a Tsunami which further led to a nuclear accident. This case study is important as the radiological and nuclear waste was added in the category of disaster waste for the very first time.

Management of Solid Waste: The east Japan earthquake left approximately 28 million tonnes of debris in its wake in the three prefectures of Miyagi, Iwate and Fukushima which would normally have taken at least a decade to clear but Japan made an ambitious 3-year master plan completing the final treatment and disposal of debris by March 2014 (Ide, 2016). This plan focused on recycling and reusing maximum materials as Japan lacked the required area under landfills to dispose such enormous quantity of waste. The cities managed waste on their own and a few small towns transported their waste to bigger cities as they lacked the institutional setup and other important facilities. The emphasis was given on reuse, pre-treatment and intermediate treatment before final disposal. Private stakeholders were engaged in the waste management process (Ide, 2016).

The management of the waste was based on the approaches of segregation of recyclables/non-recyclables and their storage. This included collection of waste, its transfer from the primary temporary storage sites to the secondary temporary storage sites for intermediate treatment (crushing, separation) converting waste into reusable reconstruction material and finally transfer of recycled and residual material after treatment (Ide, 2016).

Combustible waste (wood chips, paper) separated from the waste was then incinerated and followed by removing impurities from the resultant exhaust gas as per safe environmental norms. Granulated solidification of incineration ash was performed by mixing it with incombustibles, cement and insolubilizing agent. The resultant granulated solidification materials were utilized for earth filling during reconstruction. Other recycled and treated material was also used for the embankment and backfilling in public reconstruction projects (Ide, 2016).

Strengths of the Management:

- The usual practice of incineration of the waste and its reuse to make commercial products like cement and fly ash products, was applied to the waste which carried radioactive properties (Nagasaki, 2015).
- As a result of the disaster, waste management infrastructure development was given emphasis as many of the cities lacked incineration facilities (Henam & Sembyal, 2019).
- Earlier Japan had city waste management policy but after this disaster, it integrated the national and prefecture plan as cities were unable to manage the massive amount of waste on their own (Ministry of Environment, Japan, 2018).
- The on-site segregation of the waste was done with a clear focus to assess and understand the waste type and composition to aid preparedness for similar future disasters.
- According to the Japanese Ministry of Environment (2014), 88% of waste was recycled in Iwate and Miyagi. This is because of multiple methods such as multi-stage separation (rough, rotating, wind, magnetic and manual separation, *etc*. were used to separate recyclable material using heavy machinery, contributing to the increase in recycling ratio. Many local people were also employed for manual sorting and separation to identify and classify waste.
- During the treatment process, it was ensured that the radioactivity concentrations and radiation dose in the waste were measured.
- Capacity building programme was undertaken to educate the community (Ide, 2016).

Challenges:

- The unprecedented nature and intensity of the disaster blindsided and overwhelmed the existing system and it nearly collapsed (Oskin, 2017).
- Japan had legislations for waste management for different disasters since 1948 with focus on public health, sustainable society and environment protection but

there was no legislation prepared for the NATECH event till then (Ministry of Environment, Japan, 2018).

- As the Tsunami caused the mixing of the radioactive waste with other debris, it made the whole debris radioactive and toxic and this mixing of debris with the radioactive waste proved to be a blind spot for the government.
- Transportation of waste was carried out without any planning for transport and storage of radioactive waste (Ministry of Environment, Japan, 2018).
- The radioactive waste that made its way to the sea posed a challenge of locating the waste and its collection .

C. Plastic Waste Management, Kerala Floods 2018

Context and Background: After the Kerala floods during August 2018, plastic waste accumulated in the living environment was a major contributor to the post disaster waste as it was regurgitated back during the floods (Prabhakaran, 2021). Huge piles of plastic waste were strewn all over (across roads, bridges and agricultural land). Eg: tonnes of plastic waste also even washed into the Idukki Hydel reservoir, Periyar river banks (Raman, 2018) and the Malayattoor-Kodanad bridge in Ernakulam (Jayarajan, 2018).

Leftover waste from the relief material (packaging material, plastic bags and wrappers) piled up and added to the woes of the state. Post-floods, the state capacity to manage the waste, was compromised as it wasn't even in the position to manage 8- 10 thousand tonnes of waste generated in the normal course of events (Singhal, 2018). The volunteers during their clean-up of houses left heaps of plastic and e-waste on the roadsides (Devasia, 2018).

Management of Waste: Civic bodies were entrusted with the SWM but as they were burdened with more immediate concerns like rescue, damage assessment, and relief distribution (Ghosh & Gokhale, 2018), the Kerala State cabinet delegated the waste management over to private firms with technology to process and recycle the waste (Devasia, 2018) like Clean Kerala Company, Kerala Enviro Infrastructure Limited (Sumithra, 2019), and Green Worms (Singhal, 2018). Suchitwa Mission (technical arm of the Local Self Government department), was the nodal agency for assisting cities and local bodies for waste management (Chauhan & Raghuram, 2018) and Local Self-Government Department also roped in Kudumbashree workers and Haritha Karma Sena volunteers for collection of the waste and handing it over to the collection facility and then to the Clean Kerala Company.

State Government issued guidelines to segregate biodegradable waste, directed local bodies to find godowns for temporary storage of solid waste that was later sent to recycling centres within and outside the state (Jacob, 2018). The local bodies also opened collection centres for solid waste management but at multiple rural locations, a massive amount of waste (without segregation) was transported in lorries and dumped in empty plots.

Multiple isolated initiatives were undertaken; police, truck owners association, voluntary groups and organizations took up initiatives to dispose of plastic waste themselves by collecting, sorting and transporting waste to identified recycling centres (Jacob, 2018). *'Recycle Kerala'* was pioneered by a Bengaluru tech-professional to divert plastic waste away from landfills or water bodies and towards recycling companies. Trucks that carried relief material from Bengaluru to Kerala carried plastic waste on their return to deposit it to the recycling centres in Bengaluru. This project received massive support from authorities, volunteers (around 5,000) and the community (Karelia, 2018).

Challenges:

- Lack of adequate vacant space to store and segregate the waste collected.
- The process of collecting and segregating the waste was moving at a very slow pace (Devasia, 2018).
- Waste was even dumped back into the river to clear road for transportation, *e.g.*: the Malayattoor-Kodanad bridge in Ernakulam (Jayarajan, 2018).
- Roping in private entities, negotiating contracts, amending procedures and finalizing approvals in post-disaster situation delayed the response (Devasia, 2018).
- Limited re-cycling facility in Kerala- segregating plastic from other waste and transporting it to companies outside Kerala for disposal.

D. Good Practice for Construction and Demolition Waste Management, Delhi

Context: Delhi being a metropolitan city generates a higher amount of daily C&D waste and management of this waste is not less than disaster -induced debris management.

Management of Waste: Delhi is using recycling and reusing processes to get rid of its waste (Banerjee, 2015). Delhi has four plants working for C&D waste recycling *i.e.*, Burari (2000 tonnes per day), Ranikheda (1000 tonnes per day), Mundka (150 tonnes per day) and Shastri Park (1000 tonnes per day). In this way, Delhi is recycling 4150 tonnes of C&D waste per day, which is higher than the daily generated C&D waste *i.e.*, 3900 tonnes (Singh, 2021). C&D recycling plants use waste to produce Precast Foamed Concrete (PFC) slabs, pre-cast tiles and paver blocks, kerbstone, RMC (Ready Mixed Concrete) and for sand manufacturing (Bansal et. al., 2014; Singh, 2021).

The Strength of the Recycling and Reusing Techniques:

- Sand recovers (from the wet processing of C&D waste) will reduce the sand mining from river banks as a sustainable solution.
- Formation of Recyclable Concrete Aggregates (RCA) which is a good replacement of natural aggregates.
- Formation of the granular sub-base, recycling and reuse techniques reduce pressure on landfills (Bansal et. al., 2014; Aytekin & Mardani, 2021).
- Recyclers use mist generators and sprinklers for the dust settlement to combat the PM 2.5 and PM 10 generated from the recycling of C&D waste (Singh, 2021).

Challenges:

- Based on the IS:456, IS:1343, or IRC:112, the use of aggregates other than that retrieved from the natural sources is not permitted, this leads to no use of the recycled aggregates (Bansal et. al., 2014).
- Need of revision and modification in municipal bye laws for the use of the recycled aggregates in concrete construction.
- The demand and usage of the recycled products is lesser, in order to overcome this issue users of the recycled products should be given some incentives to promote recycled product use.
- Production of recycled aggregates with comparable properties to natural aggregates recovered from the C&D waste is currently at a very low level in India (Bansal et. al., 2014).

E. Good practices for disposal of industrial waste generated due to fire or industrial disasters- A case study of Maharashtra Industrial Development Corporation (MIDC)

Context and Background: Maharashtra Industrial Development Corporation (MIDC) is responsible for establishment and development of industries and management of industrial disasters in Maharashtra. Fire is a consistent threat in chemical and petro-chemical industries which may be due to the risk of uncontrolled exothermic reactions, fire runaways, negligence, mechanical issues, design or equipment failure, operational errors, heat transfer, maintenance and inspection deficiencies, inadequate supervision and training, *etc*. (Kidam & Hurme, 2012).

Management of Industrial Solid Hazardous Waste by MIDC:

- Most commonly used disposal methods for solid waste include dumping on land (mostly simple home waste), dumping in water (sewerage treatment plants), then controlled soil landfills are created specially by ploughing into the soil in the

MIDC areas for dumping of hazardous solid waste depending on the type of waste (the waste may remain in these landfills for upto 50 years). Incineration method is used to dispose of the waste from which recovery or reuse of materials is not an option.

- The solid waste disposal process includes - identification of the waste at the source, transport to the recovery site and examination of the contents of solid waste at the site. The physical segregation of chemicals is done and depending upon the nature of chemical, an antidote is used to neutralize the chemical or sometimes, other methods are used to stabilize the heavy metals. Scrubbers are used for the segregation process. Segregated material is then treated and disposed. But if chemical/ gases cannot be treated, they are incinerated. Heat generated from the incineration process is used for power generation.
- As per the CPCB guidelines for solid waste disposal, MIDC carries out a systematic operation of direct landfilling- through a drainage system running to and from Effluent Treatment Plant in order to prevent environmental damage. Also, regular monitoring of air, groundwater and soil is done to ensure compliance with prescribed guidelines.
- During the monsoon, the secured landfill is covered with high density polyethylene films to prevent the penetration of water and subsequent groundwater contamination. Prior to accepting any hazardous waste, a Comprehensive Analysis Report (CAR) is taken from the waste generator and for every hazardous waste consignment, fingerprint analysis is done and compared with CAR and then the disposal pathway is finalized. Monitoring of all the landfills after their closure is also carried out.
- Certain hazardous waste may contain toxic and heavy metals which have to be treated properly (as per guidelines by CPCB) with specific chemicals and binders to prevent leaching before disposal in landfills. This treatment includes solidification and stabilization process *i.e.*, immobilization of toxic material by binding with cement, fly ash, hydrated lime and other specialized chemicals which can then be safely disposed of in landfills. In the state of Maharashtra, three such areas have been designated: Taloja Industrial Area in Navi Mumbai, Ranjangaon in Pune and Butibori in Nagpur.
- The MIDC has also adopted the plasma gasification process as a sustainable model for waste decomposition and energy generation at two of its facilities currently.

F. Bhuj, Gujarat Earthquake, 2001

Context: An earthquake (epicentre near Bhuj in Kutch region) measuring 7.9 on the Richter scale rocked the western state of Gujarat in India on 26th January 2001. There was unprecedented level of devastation caused to life and infrastructure. Out of the 181 talukas (subdivision of a district), 42 talukas were severely affected. 70 percent of houses in 442 villages in the five most severely affected districts were destroyed (Mishra, 2004). Around 348, 729 houses were completely destroyed whereas 751, 0886 houses were damaged (Earthquake Summary Fact Sheet, Fiscal Year (FY) 2001 - India, 2001).

Management of Waste- Due to the massive volume of debris generated and the costs associated with its clean up, the authorities faced what looked like an insurmountable task at the time. An initial assessment by the World Bank and Asian Development Bank in March 2001 estimated the quantity of debris at 10- 20 million metric tonnes in urban and 15-30 million metric tonnes in rural areas. The immediate priority was to cut the concrete, remove the rubble and rescue people trapped under debris. Removal of debris also became an immediate priority for making navigable routes for the vehicles to reach the affected for rescue and relief operations.

A systematic approach towards debris removal was undertaken only after a few days. Debris removal of completely demolished buildings was prioritized at main urban sites. Controlled demolition of unsafe buildings was also carried out. Multiple departments and authorities joined this effort in Bhuj city and its rural areas- Roads and Buildings department, Irrigation department, local police, Gujarat Mineral Development Corporation (GMDC), Surat Municipal Corporation, Gujarat Ship Breaking Association, the Army and Kandla Port Trust along with Reliance industries and private contractors. Assistance in the form of personnel and equipment also came from other state governments like Maharashtra and Haryana (Mishra, 2004). The following table gives the quantity of debris removed by respective agencies/ authorities calculating to a cumulative figure of approximately 109 Lakh metric tonnes of debris that was cleared post the disaster.

Table 3.7: Quantities of Debris removed by the Local Authorities after Gujarat Earthquake, 2001

S.No	Agency	Debris removed (Lakh MT)
1.	Roads and Buildings department	20.48
2.	Irrigation department	18.72
3.	Kandla Port Trust	4.06
4.	Drought relief work	20.48
5.	Government buildings	4.66
6.	Village committees/ panchayats	40.41
	TOTAL	**108.81**

Source: Mishra, 2004

The clearance work was first initiated for roads and public places with the help of heavy equipment organized or subsidized by the Government and large industrial enterprises. In the interior of city and rural areas where the narrow lanes prevented large vehicles to enter, debris removal and collection were done by the people manually. Gujarat State Disaster Management Authority (GSDMA) initiated rubble removal relief works that employed local people in emergency works temporarily and paid them Rs. 40 per day especially in the rural areas like Kutch village (World Bank & ADB, 2001). Here, debris removal process was utilized as a strategy for the revival of the economy in the state through livelihood generation. A programme of removal of debris through village committees was undertaken when even after months of the earthquake, debris was still found lying in some villages (Mishra, 2004). For the process of debris removal, over 1,700 excavators and bulldozers and 2,800 trucks were used (World Bank & ADB, 2001). During the reconstruction, material recovered from the debris was reutilized in road construction, filling of low-lying areas, erecting embankments and boundaries in fields to check soil erosion etc.

Challenges- The entire establishment at the State and Centre was shook by the sudden devastating impact of the earthquake which generated colossal volume of debris to be cleared in its wake (World Bank, 2001). This earthquake happened when India was yet to institutionalize a disaster management framework through a legislation which was done later in 2005 in the form of Disaster Management Act, 2005. The paradigm shift from a reactive to proactive approach in disaster management had not happened yet, in fact, this disaster acted as an impetus in this direction especially in the state of Gujarat and then later at national level too. Hence, at the time, lack of preparedness along with lack of rules, regulations and guidelines for estimation and assessment of debris and the cost associated with its removal led to haphazard coordination and management. Lack of readily available equipment like concrete breakers, gas cutters and bulldozers (Mishra, 2004) and trained operators immediately in the aftermath of the disaster, further delayed rescue and debris removal. Waste was either removed earlier during the rescue/ relief operations or was later left unattended to be dealt by people or during the reconstruction phase. There were no standardized guidelines for waste removal for the community to follow. Hence, a lot of concrete and rubble waste was dumped in open grounds, road sides, lake sides and river banks while removing the debris as people thought that extracted material could be sold or reused (Misha, 2004).

G. Sikkim Earthquake 2011

Background: On 18th September 2011, a strong earthquake of 6.8 magnitude jostled the North Eastern state of Sikkim along with its surrounding states and countries (Chakraborty, Ghosh, Bhattacharya, & Bora, 2011).

How was it managed: The earthquake caused multiple landslides in the area owing to the steep angle of the mountain slopes. According to the data from post-earthquake surveys, the poorly built, multi-storied buildings were relatively damaged more (Rajendran, Rajendran, Thulasiraman, Andrews, & Sherpa, 2011). The collapsed buildings and landslides post the earthquake generated the majority of the waste that included mud, cement mortar, and flat or sloping roofs constructed of galvanized iron sheet, thatch, reinforced cement concrete, and reinforced brick concrete or wood (DMMC, 2012). Locally, rescue operations began by removal of debris manually with the help of local uniformed forces. Volunteer groups were formed with the help of local people for managing the wastes generated after the earthquake (NIDM, 2012).

The NDRF forces along with the local, national and international NGOs came forward to create an Inter-Agency group and funding plan for relief work along with waste management programmes for reconstruction and restoration (Khanna, Verma, & Khanna, 2012).

Challenges: The major problem faced after the earthquake was connectivity issues. Total 1196 new landslides were recorded (Martha, Govindhraj, & Kumar, 2015) which destroyed most parts of NH 31 connecting the state with the plains of West Bengal. Many villages were disconnected from the State capital Gangtok, which caused a delay in supplies and relief works (NIDM, Sikkim Earthquake 2011 - A Roadmap for Resurrection, 2011). The NDRF was only able to reach the disaster site after more than 24 hours of the event. Due to the absence of quick deployment of response force and equipment, the response was considerably delayed. Due to lack of awareness and haphazard collection and clearance, the debris waste was not separated (Khanna, Verma, & Khanna, 2012).

H. Srinagar, Jammu & Kashmir Floods, 2014

Context and Background: Kashmir was hit with massive devastating floods in September 2014. This proved to be one of the worst flooding events to have hit the region in almost 60 years. After the flood waters receded, tonnes of garbage, silt, mud and slurry, rotten food items, sewage waste, collapsed buildings laid bare on roads and streets, blocking lanes and drains. The process of cleaning of homes, offices and other buildings also added to the woes of the authorities. Waste amounting to 1051 metric tonnes (5 times the usual quantity) was gathered daily after the floods (Ashiq, 2014). Risk of a disease outbreak from carcasses of dead cattle and animals, presence of rodents, *etc.* also loomed large after the floods.

Management of Waste: Srinagar Municipal Corporation (SMC) launched *'Mission Clean Srinagar'* and undertook the waste removal operation on a war footing. Special task groups of around 3000 officials including officers, engineers, technicians, field staff and temporary sanitation staff were formed and duties like cleaning and sanitation, animal carcasses removal, disinfection and deodorizing were assigned. 85,157 metric tonnes of waste was collected through 17,836 truck trips. Over 5000 employees worked 'round the clock'. Hundreds of heavy construction machines such as JCBs, bulldozers, trucks and loaders were used to collect and remove the waste. Landfill site at a dry elevated location at Achan, Saidapora developed by J&K Economic Reconstruction Agency with funding from Asian Development Bank (ADB) was chosen for landfilling (Qasba et al., 2021).

Strengths: Strategic location of landfill site at a dry elevated location to prevent its inundation. This site (accommodated 85,000 Kg of post floods waste) was monitored through computerized weighing bridge, registration and tracking of movements of loading/ unloading trucks. All the workers and officials were immunized against Tetanus and Hepatitis B to ensure their safety. Community was engaged through social media, procurement of satellite phones communication sets, walkie-talkies and fixed communication sets from army and police was done for establishing communication when routine communication channels broke down post floods (Qasba et al., 2021).

Challenges: The SMC central office, sub offices, ward offices and transport yard were inundated and hence, they were not fit to be used as operation rooms for cleaning drive immediately after the floods. Breakdown of communication channels and vehicles for transportation also created delays and issues for the response (Qasba et al., 2021).

3.3 Identification of Gaps and Issues

From the review of the guidelines and the case studies, the following gaps and issues have been identified in the context of India's post-disaster SWM approach:

- India does not have any specific and targeted rules or guidelines for institutionalization of a robust DWM ecosystem.
- The existing SWM guidelines, although, outline various methodologies for normal or peace times, but they do not envisage any possible provisions for a post-disaster scenario. There are several existing guidelines for management of waste, however, none of them provide concrete guidelines on management of large-scale disaster-induced waste. This creates a huge gap for prompt, swift and proactive rescue, relief, and response operations in the short-term. In the medium and long-term, the management of disaster waste, sustainability of its processes and disaster recovery itself are seriously thwarted.
- As seen from the above case studies of Bhuj Earthquake (2001), Srinagar Floods (2014) and Kerala Floods (2018), it is evident that India has ad-hoc solutions for dealing with disaster waste that are triggered only after a disaster occurs. It means that even though GoI has shifted to a proactive approach for managing disasters, the area of the management of solid waste generated in disasters still requires adequate consideration by policymakers towards adopting a proactive strategy rather than a reactive approach.

- The case studies indicate that this tends to create an unsustainable and unorganized situation post-disaster as people begin the clean-up process on their own in the absence or delay of organized efforts. Sometimes the solid waste is left unattended for long period of time after the disaster. This results in further mixing of waste, increased risk to health from infectious and hazardous waste, degradation of environment and so on.
- Due to large scale waste generation, sorting and segregation of waste at source is either not done or is done in a non-uniform and haphazard manner due to lack of standardized processes, guidelines and awareness amongst people. All these issues create risk to the health of the workers ,environment and long term recovery .

3.4 Key Guiding Principles for Preparation of the Guidelines

The review of the above guidelines and other relevant documents, highlighted certain areas or components that form the core guiding principles for preparation of the existing guidelines on DWM. These principles and components have been consolidated below:

- Pre-disaster **contingency planning** has been observed to be an essential component for better preparedness and thereby, a better response and recovery. Planning for the entire disaster waste flow: removal, storing at temporary sites, separation and sorting, treatment, reuse and recycling before the actual disaster strikes as a measure of preparedness. Prevention and mitigation measures are other important aspects, which are to be part of contingency planning.
- Disaster Risk Reduction and long-term development approach focusing on the principle of *'build-back-better'* (structurally as well as non-structurally) in order to create resilient solid -waste infrastructure and communities.
- Preservation of the living environment by reducing health and environmental risks by prioritizing treatment of infectious and hazardous waste. Health and safety of the all- affected community as well as personnel working in DWM especially during the cleanup of hazardous substances is essential.
- Promotion of implementation of the ***4R (Reduce, Reuse, Recycle and Recovery)*** strategies. Recycling of waste to be encouraged as it reduces waste to be disposed of and at the same time provides additional income and resource material.
- **Building of local capacities** through trainings for improving the skill levels of public authorities, waste management workforce and citizens. Also, enhancement of technical capacities through better equipment, machinery or plants, training of people who can efficiently operate them and financial self-

sufficiency in order to ensure continuation of waste management systems during and after disasters.

- **Local factors and risk assessment** form the basis for assessing appropriateness or need of developing alternatives for any strategy, framework or activity.
- **Stakeholder engagement** involving identification of stakeholders in a given context, differentiating and delegating roles and responsibilities, knowledge sharing, networking and regular communication between multiple stakeholders, *etc.* is essential for a coordinated action plan to work.
- Efficient management of operations and support to local institutions (through fund or manpower) to capacitate them is crucial for effective solid waste management post disasters.
- Involvement of affected communities at each and every step of the waste management process.
- Provision of regular communication and information flow to the public, reporting to local authorities and building cooperation between citizens and authorities through public hearing and/ or consultation on contingency plan.

3.5 Lessons Learnt

It is apparent that SWM is a massive undertaking that requires systematic planning and implementation, even more so due to the element of risk and urgency created by disasters. Hence, we require an '*Integrated Disaster Waste Management Framework*'. The framework would recognize the requirement of a single SWM system that not only functions well during normal (peace) times but can also withstand a disaster event and perform the waste management Emergency Support Function (ESF) smoothly and effectively during any emergency or disaster. This integrated DWM framework includes a well thought out contingency plan along with DWM guidelines that aim to build and strengthen pre-existing SWM systems as well as provide for waste management throughout the DM cycle (in all phases from preparedness to recovery).

3.6 Conclusion

The review of guidelines and case studies have shown gaps under the existing SWM framework of India in comparison to other countries in the area of SWM in post-disaster situations. There is a need to develop a DWM specific plan and guidelines for institutionalization of waste management in post-disaster scenarios. In order to support the findings of literature review and for expert guidance from the field, a national consultation was organized, wherein the domain experts had participated. The outcomes of the consultation are discussed in the next chapter.

CHAPTER - 4

NATIONAL CONSULTATION OUTCOMES

The two-days National Level Consultation *"Challenges and Solutions for Safe Utilization and Disposal of Solid Waste in Post-disaster Situations"* was organized by NIDM on 11 and 12 November 2021. The overarching objective of the workshop was to understand the issues related to the solid waste in Post-disaster Situations and to learn from the guidelines, case studies and solutions available nationally, internationally and from local agencies for utilization, treatment and early disposal of the different wastes. The consultation was organized under the four technical sessions, titled as Technical Session 1: Overview and Challenges associated with Solid Waste Management in Post-disaster Situation; Technical Session 2: Plastic Waste Generation due to Disasters and Innovation & Technologies available for Recycle - Reuse of Plastic Waste in an Environmentally Friendly Manner; Technical Session 3: Debris Waste Management after Disasters-Challenges & Solutions and Technical Session 4: Hazardous Waste Disposal generated due to Industrial Disasters, fires and health facilities. About twenty-five experts from diverse backgrounds were invited to present their case studies based on their field works, research and experience. These interactive sessions were organized at an open platform and each technical session was attended by about 70-80 participants (average) from government organizations, non-governmental organizations, private sectors and academic institutions. The proceedings were relayed live at YouTube (NIDM live). The present chapter gives session-wise details of the key challenges and conclusions drawn from the presentations made under the national consultation.

4.1 Technical Session 1: Overview and Challenges associated with Solid Waste Management

This Technical Session (TS) focused on challenges and issues associated with SWM in Post-disaster Situations which began with the keynote addresses from NIDM and National Disaster Response Force (NDRF). Experts from NIDM, UNEP, World Bank, Kyoto University, Uttarakhand DM Authority and Jammu & Kashmir shared their experiences through different case studies, research and practical experiences.

The key discussions and challenges presented during the first technical session were as follows:

- Any single event of disaster can create a huge amount of debris that can take several years to be removed from the disaster site. It is the first and foremost challenge of post-disaster solid waste management at the disaster affected sites.
- There are issues related to coordination, governance, capacity and funds for

immediate removal and disposal of debris. Delay in debris removal generally creates delay in kicking-off the search and rescue operations during the response phase and result in serious injuries, casualties and other losses.

- State governments need to have a proper mechanism for handling post-disaster waste, which is generally large in quantity and existing landfill sites are already filled with routine waste.
- The debris management and disposal are expensive for cities which lack institutional setup, skill set, expertise, and financial settings. It is important for these cities to work towards future disaster solid waste handling.
- Post disaster clean-up is complex and time consuming as disaster waste is usually mixed type of waste which makes it very challenging.
- Global scenario of disaster SWM was explained through the case studies of catastrophic events that occurred in Fukushima (Japan) and Uttarakhand (India). The case study on East Japan Earthquake and Tsunami (EJET) 2011 indicated that the back-and-forth movement of water caused the mixing of the debris inland as well as in the ocean. The radioactive waste from the Fukushima accident mixed with the other waste. The Debris Management and Disposal cost a lot to the cities which had no institutional setup, skill set, expertise and financial settings. Japan had no plan for the transportation and storage of radioactive waste and it was a great challenge for them.
- For the management of EJET 2011 and for handling future disasters, Government of Japan developed a post-DWM policy at the national, state and regional level while earlier it was only for the state level. The planning and management was focused on reuse, retreatment and intermediate treatment and emphasized on integrated SWM with 3Rs.
- The case study of Uttarakhand indicated that the

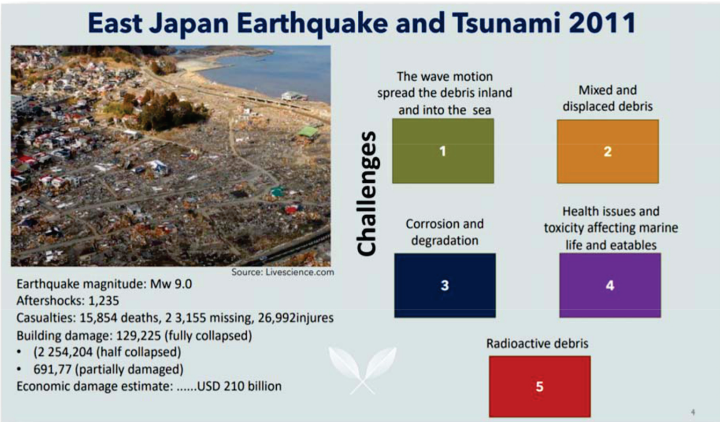


Figure 4.1: East Japan Earthquake and Tsunami, 2011[1]

[1]Source: Illustrative slide from presentation made by Dr. Ranit Chatterjee during the National Consultation on the topic 'Debris Management from NATECH events- Case study of Japan'

Steps taken by Japan

- The role of managing the disaster waste was shared by national, perfecture and local governments
- Identification of type of hazard linked wastes

Source: Ministry of the Environment, 2018

Figure 4.2: Disaster Waste Management in Japan[2]

state was devastated due to unprecedented rainfall, floods and landslides during the year 2013. It was one of the largest rescue operations in the world where more than 1 lakh people were rescued. The disaster led to huge devastation caused by overflowing rivers in the areas of Kedarnath, Rudraprayag and Dharchula. Vehicles were buried under the debris, muck debris was deposited around the villages, roads were damaged and blocked due to boulders, highways were washed out, debris from collapsed buildings of the hospitals and schools could be seen all around.

Recommendations:

- Disaster waste should be handled carefully because wastes of varied characteristics, such as hazardous waste, building collapse debris and vegetative debris, get intermixed and pose a severe threat to health.
- Firstly, segregate the debris according to the type and quality (determine the geotechnical properties), followed by identifying the potential use of debris. *e.g.*, utilization of debris as construction material and as an ingredient in any specialized manufacturing process.
- In debris disposal, the pre-planning stage is important. It involves carefully selecting the muck disposal site (non-productive land), with the help of land use/land cover maps.
- In the planning stage, the planners should focus on topographical, hydrological, geological and geotechnical investigations; educating the contractor; incorporating the cost of debris transportation; and preparing disposal sites.

[2]Source: Illustrative slide from presentation made by Dr. Ranit Chatterjee during the National Consultation on the topic 'Debris Management from NATECH events- Case study of Japan'

- Under the debris disposal plan, the mapping of settlements and infrastructure in proximity of the proposed dumping site and monitoring the dumping sites and future use of dumping sites such as developing parks would be important.
- The selection of the debris disposal site should consider the parameters like cost effectiveness, absence of ground or surface water, scope of afforestation works, quantity of mucks *etc*.
- The mitigation measures include biological measures and engineering measures. Debris slope should be protected by the geotextile and geogrid under the biological measure while in compaction measures, compaction, retaining structures, drainage measures, and subsurface water should be considered.
- Local capacity to handle the solid waste should be developed.

4.2 Technical Session 2: Plastic Waste Generation due to Disasters and Innovations & Technologies available for Recycle - Reuse of Plastic waste in an Environmentally Friendly Manner

The TS- 2 on *"Plastic Waste Generation due to Disasters and Innovations & Technologies available for recycle-reuse of Plastic Waste in an Environmentally Friendly Manner"* was organized in collaboration with UNDP, India. Experts from UNDP, NIDM, GIZ, M/s Ramky, Reclamation and Recycling Ltd, M/s Recykal, M/s PWC, M/s IL&FS and Uttarakhand State Disaster Management Authority had participated in the session.

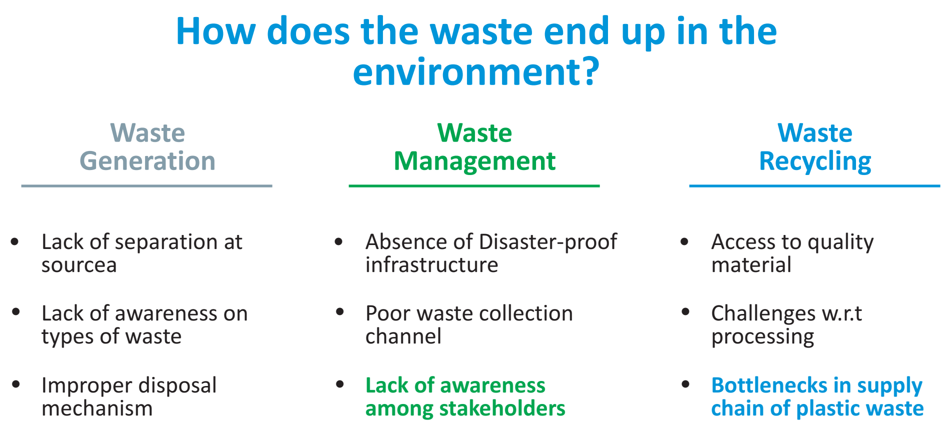


Fig. 4.3 Process of Waste Management[3]

[3]Source: Illustrative slide from presentation made by Ms. Kamna Swami during the National Consultation on the topic 'Management of Plastic Waste after disasters - Issues and Solutions'

The key discussions and challenges presented during the session are as follows:

- Plastic waste comes under the dry waste components. As per statistics, about 50 percent of the plastic waste is single use plastic and only 9 percent plastic is being recycled in the world.
- Plastic waste which is discarded in water bodies, dumping sites and open environment always comes back on the ground due to floods, rainfall and other events. One of the major reasons for the urban flood situation getting worse, is obstruction in drainage systems due to accumulation of discarded plastic. After floods in Kerala, 60 lakh bottles and 400 kgs of plastic were collected in the state.
- An inefficient plastic waste management system creates negative impacts on the environment such as spread of infectious diseases, blockage of drains and loss of biodiversity due to pollution.
- During disaster response operations, relief materials are distributed to the disaster survivors, which are normally packed in plastic, causes a huge generation of plastic waste.
- In India, Urban Local Bodies (ULBs) are mostly responsible for the collection of plastic waste in the city. There are other stakeholders such as NGOs and private organizations that play an important role in the entire waste value chain. Waste management depends on the severity of the disaster. It has been observed that the cities which have a robust recycling process, perform better in critical conditions.
- Countries which are very much prone to disasters such as Japan have robust planning techniques and infrastructure. Use of modern technology such as robots, earth observation applications and other emerging technologies are increasingly being developed and adapted for Disaster Management. Furthermore, these technologies are being used to enhance the efficiency and effectiveness of first responders' aid through advanced technology -based disaster response and relief aid.
- Unmanned Aerial Vehicles (UAVs), also known as drones, are progressively being deployed in emerging disaster situations. This is because drones are portable, reliable, and increasingly affordable. Most importantly, their application in combating disasters is becoming imperative. Moreover, drones are being incorporated in rapid situational awareness with mapping technology and imagery of affected areas. As such, drones are helping firefighters to identify hot spots and assess property damage in inaccessible areas.

Recommendations:

- There is need to practice "reduce, reuse and recycle" the plastic waste in general, which will result in lesser plastic waste generation after disasters as well. It was emphasized that plastic waste should be collected at source, segregated and recycled. Eco-friendly materials instead of single use plastic should be promoted during post-disaster relief operations.
- Material recovery facilities to manage plastic waste, debris-clean-up devices, debris sweepers and sea-bins are needed to remove plastics and other wastes carried into water bodies.
- Use of drone and robot technology, digital innovations and GPS based monitoring systems to detect and monitor plastic waste which gets accumulated during disaster situations.
- Strengthening the governance system in line with centre and state rules for plastic waste management is needed.
- Encourage the role of public-private partnerships for proper treatment and disposal of plastic waste. There is a need to inculcate appropriate behaviour amongst communities for management of solid waste and disasters.
- There is a need to promote sustainable waste management practices to reduce plastic leakage. An Integrated Waste Management System needs to be practised in India, which shall have components of management of disaster induced waste.

4.3 Technical Session 3: Disaster Waste Management After Disasters-Challenges and Solutions

The TS 3 focused on challenges and issues associated with debris and building collapse waste. The session had presentations from the experts from NIDM, Tribhuvan University, Nepal, Municipal Corporation, Jammu & Kashmir, NIUA, CEPT, IL&FS and Govt. of Tripura.

The key discussions and challenges presented during the session are as follows:

- The Nepal Earthquake of 7.8 magnitude in 2015 completely destroyed 4,91,602 private buildings, partially damaged 2,69,653 buildings and more than 7,500 official buildings. This produced approximately 18.85 cubic meters of debris all over Nepal.
- Lack of clear rules, technical equipment, financial resources and management for disaster waste management.

Disaster waste

- **Mw 7.8 Gorkha Earthquake-2015. Nepal had severely damaged buildings producing massive amount of debris.**
- **491.620 private building were completely damaged. 269.653 were partially damaged. 7.532 schools and 1,100 health facilities damaged (Ranjitkar and Upadhyay, 2015)**
- **Approximately 18.85 cubic meters of debris remain accumulated in various parts of 31 quake hit district.**

Fig. 4.4 Debris after Nepal Earthquake, 2015[4]

- Post-flood sanitation, waste handling, collection and disposal are a few major challenges for any city. Huge piles of garbage including the municipal waste, plastic and carcasses create risk of outbreak of epidemic(s) and other water or air borne infections. Former Municipal Commissioner of Srinagar during his presentation highlighted that thousands of structures were damaged and the river Jhelum overflowed blocking the National Highway flooding almost 77% of the total area including official and lifeline buildings. Huge piles of waste were scattered around the city, causing fear of epidemic outbreak needing disinfection on an immediate basis. Post-disaster flood management operations involved collection and disposal of 85,157 metric tonnes of waste material. The damage was restored in the span of 10 days and several heaps of debris were shifted to proper dumping areas. The process of disposal became one of the success stories for disposal of solid waste after disasters.
- The NIUA representative indicated that Delhi being a capital city, does not have any correlation between DM and SWM. Delhi falls under the seismic zone IV and V, which makes it prone to earthquakes and almost 60% of unauthorized settlements are vulnerable to damage. Other challenges could be posed by the narrow lanes in accessing large size debris waste in case of collapse of structures. Ghazipur

[4]Source: Illustrative slide from presentation made by Dr. Basanta Raj Adhikari during the national Consultation on the topic 'Utilization of Debris in Reconstruction Program- A case study of Nepal Earthquake 2015'

(Delhi) landfill site is as big as 40-50 cricket stadiums, which can lead to vector borne diseases and groundwater contamination. The presence of such a huge landfill site is the cause of disaster in itself. Hence, the management strategies for such big cities can be developed with these statistics to handle the solid waste in post-disaster situations.

- Cricket Stadium size approx. 20,000 sq meter i.e 5 Acres
- Ghazipur (70 Acres)-5x14 (i.e. 14 Cricket stadiums)
- Okhla (35 Acres)-5x7 (i.e. 7 Cricket stadiums)
- Bawana (40 Acres)-5x8 (i.e. 8 Cricket stadiums)

- IHC Areas - 9 Acres i.e.
- Ghazipur = (almost 8 IHC campuses)
- Okhla - (almost 4 IHC campuses)
- Bawana = (4-5 IHC campuses)

Figure 4.5: Landfill sites of Delhi[5]

Recommendations:

- Large amount of solid waste in disasters can be dealt with by the waste removal programme, which can be as follows: 1-15 days (Rescue phase); 1month to 1 year (during recovery phase); 6 months to 5 years (reconstruction phase).
- In the long-term, large landfill sites cannot be options as they threaten the environment and can give rise to vector-borne diseases and groundwater contamination.
- Earthquake debris is normally C&D waste, which provides a scope for researchers and C&D waste recycling industries to come up with new innovation in the field for the future. Rules for segregation and grading of C&D waste, implementation of guidelines for reuse and mandatory use of C&D waste through capacity building and workshops is required.
- The recycling process of C&D materials has four stages: collection of waste, transportation to the processing sites, recycling and finally recovery of aggregates.

[5]Source: Illustrative slide from presentation made by Ms. Madhuri Singh during the National Consultation on the topic 'Management of Construction and demolition waste in Building Collapse- Planning and governance issues'

- Systemic waste removal programmes need to be taken into consideration for the future incidents.

4.4 Technical Session 4: Hazardous Waste Disposal Generated due to Industrial Disasters, Fires and Health Facilities

TS - 4 involved a discussion on issues and challenges due to the disposal of hazardous waste generated due to industrial disasters, fires and health facilities. Experts from MIDC, Maharashtra Fire Services, Life Givers Professionals, CAHO, NIT Surat, UNDP and other renowned organizations, shared their views through presentations on the topic.

The key discussions presented during the session are as follows:

- In current times, the disposal of hazardous and bio-medical waste is an issue of concern in India. Some of these materials are non-biodegradable and often lead to waste disposal crisis and environmental pollution. Management of hazardous waste such as toxic metals, fungicides and pesticides should be as per the existing guidelines.
- Dismantling of massive hazardous containers and disposal of their waste, dumping of sludge containing rust into nearby landfill areas, ignition of racked out buried sludge on exposure of sunlight (an exothermic reaction as the sludge is pyrophoric) are some of the exigent challenges. Practices such as landfilling of hazardous waste or solid waste causes environmental pollution in long-term.
- Impact on public health due to the waste generated post-disasters was discussed.

Recommendations:

- Reuse of waste generated due to industrial accidents and fires will conserve the natural environment by reducing pollution.
- Several strategies to handle the fire hazards in post disaster situations such as liquid disposal arrangements, direct land filling, solidification and stabilization and plasma gasification were identified.
- Fly ash based angular shaped coarse aggregates can be a replacement to natural stone aggregates for development and construction works.
- Use of advanced technologies such as drones and robots for waste monitoring and waste segregation should be encouraged.

4.5 Key Takeaways:

After the detailed deliberations, key takeaways were identified, which are given in brief below:

- The consultation helped in creating an understanding about the different kinds of solid wastes generated due to different disasters that may broadly include debris, plastic, building collapse, municipal waste, fly ash, sand, silt, dust, chemical and bio-medical waste.
- It was observed through various presentations that the existing SWM system is already burdened with day-to-day management of the waste. There is a need to strengthen the SWM system both for normal (peace time, day-to-day) as well as disaster situations. Therefore, an integrated system of Solid Waste Management that can sufficiently cater to all usual as well as contingent needs is required.
- There is a need for careful consideration of governance, planning and financing while managing the disaster waste. Several guidelines, case studies and other documents are available worldwide which need to be taken into account during the preparation of the guidelines on SWM in post-disaster situations in the Indian context. We must strengthen the governance systems in line with both the centre and state rules for a resilient and efficacious SWM in disasters.
- We need to develop specific strategies to reduce, reuse and recycle the plastic waste/hazardous waste instead of disposing them into dumping sites of land, sea or river. Use of plastic bags, packaging and bottles should be discouraged and other alternate solutions should be identified for relief distribution.
- A need to develop a waste management plan for post-disaster situations was unanimously identified at the consultation.
- Considering the number of documents and case studies which are available with various stakeholders and international agencies. NIDM can develop a compendium of existing guidelines and case studies to further enhance the resources for solid waste management in post-disaster situations. This document shall be useful for the policy makers and other stakeholders for preparing guidelines/plan on SWM in post-disaster situations in future.

4.6 Conclusion

Overall, the National Consultation highlighted the various challenges of SWM in post-disaster situations. It dwelled on the urgent need of an integrated approach in India, which shall focus on all the phases of disasters. *i.e.* pre-disaster, during disaster as well as post-disaster phase. The guidelines prepared by the Japanese Government provide a comprehensive approach that recommends to develop specific action plans for waste management in the context of different priorities in each phase of the disaster management cycle, be it preparedness, rescue, relief, mitigation, rehabilitation, reconstruction or recovery. Other guidelines by various agencies and case studies also support the need for a holistic plan for waste management which shall complement and supplement the already existing waste management system *i.e.*, during peacetime as well as in disaster situations. The next and last chapter summarize the recommendations of this paper and attempt to provide a suggestive plan for SWM in the context of India.

CHAPTER - 5

CONCLUSION, RECOMMENDATIONS AND WAY-FORWARD

Solid Waste Management (SWM) is usually discussed as a prominent issue of environmental concern but *"Solid Waste Management in Post-disaster Scenarios"* rarely forms part of scientific investigation and curiosity. Thus, this area remains less prioritized and sometimes even overlooked, especially in India. This paper is particularly developed to generate understanding and interpretation of research and guidelines available nationally and internationally which can further provide a guide for handling solid waste management during and post-disaster. This study intends to generate scholarly, institutional and public discourse on the topic through its detailed explanation and examination of the issues and their apt contextualization in disaster settings.

The present study has established that disasters create uncertain, complicated and unpredictable contingencies and challenges around the operations concerning waste management- prioritization of waste management activities vis-a-vis other response operations, planning for waste management process and its appropriate timeline (from collection to disposal and / or recycling), multi-level coordination with local and state machinery, optimization of available resources especially manpower and funds, forecasting and preventing secondary hazards from community contact with waste (disease outbreaks, leakage of hazardous waste), *etc*. Hence, there exists an urgent need for developing a *'Disaster Waste Management Plan'* and its implementation machinery.

This study supports in understanding the prerequisites of a DWM plan, its essential components, key considerations, challenges and risks that might be encountered, on the basis of learnings derived from national and international experiences so far.

Deliberations during the two-day national consultation of NIDM added various significant insights to the topic starting from the overview and challenges, debris and plastic waste issue and its safe disposal, practical solutions for utilization and hazardous waste management in post disaster scenarios. Some of the issues highlighted by the subject experts included capacity development, gender empowerment, community involvement and use of technological solutions and innovative methods for post disaster debris assessment and debris removal such as remote sensing techniques and use of drones, treatment options for hazardous waste using landfilling and energy utilization processes. An important outcome of the discussion was also the consensus that the gap between the policy and its implementation needs to be bridged as much as possible on ground, involving all the stakeholders.

Conclusion

Broadly, the findings from the review of the guidelines, the case studies as well as presentations of Consultation are as follows:

- Post-disaster assessment and estimation of waste quantity generated, its composition, type, *etc.*, form the bedrock of all operations thereafter. But these tasks usually prove to be the most complicated part of operations due to the uncertainty caused by the evolving disaster situations (*e.g.*, aftershocks in an earthquake) and lack of availability of skilled professionals and staff.
- It is observed that the Government of Japan has prepared one of the most comprehensive guidelines in the context of all disasters. It specifically highlights the importance of having a strong pre-existing solid waste management machinery on the foundation of which DWM operations and activities can be designed.
- Japan, US EPA and Thailand have introduced risk reduction planning in waste management which means forecasting, identifying and planning for potential risks and challenges to SWM operations that may arise in specific post-disaster situations, for *e.g.* secondary disasters from fire at the storage or dumping sites and water or air contamination at landfilling sites.
- Importance of stakeholder management is a recurring theme in all guidelines and case studies. Involving affected communities at every step; frequent consultations with communities, domain experts, public and private sector render unique strength to a plan. Pre-negotiating contracts and assigning tasks and activities, beforehand, serve well during the chaos and disruption that a disaster ensues.
- Similarly, many other activities also may get compromised due to non-availability of trained manpower, *e.g.*, technical know-how of operating certain equipment, segregation of waste, its reuse and reutilization. Hence, capacity building and training of local manpower to create a pool of efficient workers that are able to serve during disasters is a pre-requisite for implementation of a DWM plan.
- Monitoring and Evaluation (M&E) is an important stage for implementation of the SWM plan in disasters which continuously reviews and updates the plan.
- Use of technology (barcoding, e-tracking systems, use of drones, IoT devices) and managerial expertise can serve to appraise the activities and keep track of the waste throughout the process. *i.e.*, its location, status, handling and for calculating wages of workers *etc*.

Recommendations and Way Forward

The present paper recommends for development of a holistic coverage of various DWM processes and actions (short, medium and long term-before, during and after disasters) with an attempt to cover different types of wastes that can be generated in a disaster with an exclusive focus on India. It also outlines a unique approach of ***integration of the SWM plan with the DM cycle*** involving planning for disaster waste for each and every phase of disaster i.e., for preparedness, contingency planning, rescue, response, recovery and reconstruction with emphasis on pre-disaster planning as the most integral activity upon which the entire SWM planning and implementation depends. Based on the findings from previous chapters, a suggestive plan for SWM for disaster induced waste is presented below.

Steps for Post-Disaster Solid Waste Management Planning in India

I. Pre - Disaster Solid Waste Contingency Plan

The components of the Contingency Plan (CP) are as given below:

(i) **Stakeholder Engagement:** This component of the CP would involve identification of stakeholders *i.e.*, government, private, technical experts, academia (institutions, researchers), CSOs, NGOs and volunteer organizations; consultations with the stakeholders and designation of roles and responsibilities for both pre and post disaster waste management activities and pre-negotiate contracts for funding, shareholding and obligations *etc*.

(ii) **Communication Strategy:** for clear and unified line of formal command as well as informal communication (horizontal as well as vertical flow of information). It would envisage planning for communication with the community interfaces for dissemination of risks and public messaging at the time of disaster.

(iii) **Strengthening the Institutional Framework:** The waste management activities should be institutionalized in the different phases of disaster management, at local, state and national level. Since, there is already an existing Incident Response System (IRS) in the districts and states, it is proposed to include "waste management" as another Emergency Support Function (ESF) that shall get activated during disasters.

(iv) **Vulnerability, Capacity and Risk Assessment:** A prior assessment of vulnerabilities of the existing waste management system, institutional insufficiency, financial and funding constraints and associated risks should be conducted. The assessment should also provide forecasting of expected risks and challenges associated with waste management such as mixing of waste, leakage of hazardous waste and disease outbreaks. Under this stage, assessment of existing capacities of trained manpower, equipment, machinery and other resources required for waste removal should be done. The findings of the risk assessment would provide basis for preparation of short, medium and long-term plan of waste management.

(v) **Preparation of a Guide for Waste Estimation, Disaster Waste Categorization and Standardized Practices for Waste Management Process** that may include guidelines for on-site and off-site collection, segregation and sorting, storage, transportation, treatment, disposal, recycling and reuse of disaster waste. The waste management process should be based on the *waste hierarchy* approach for reducing and minimizing waste and the 4R principle (Reduce, Reuse, Recycle and Recover) should guide the entire process.

(vi) **Identification of Temporary Storage Sites and Facilities:** Adequate facility for each and every step of the waste management process *i.e.*, collection and sorting centres, temporary storage sites, treatment plants, landfill sites, material recycling and recovery facilities should be designated keeping in view the quantum of waste that could be generated during any unforeseen event or disaster.

(vii) **Logistics Plan for Transportation of Debris and other Wastes:** This section of the plan may delineate the responsibilities of concerned organizations for removal and transportation of the waste from the disaster site, transportation of hazardous waste and identification of alternative routes in case of damage or blockage, sufficient manpower, vehicles, equipment and other resources beforehand.

(viii) **Procedures for Managing Hazardous and Non-biodegradable Waste:** This section of the plan may first and foremost provide sustainable approaches for reducing the generation of hazardous waste. Special consideration for disposal of hazardous waste, such as asbestos, chemical waste, infectious and bio-medical waste and other non-biodegradable waste such as plastic or e-waste shall be given. There must be provisions for an environment friendly treatment and disposal plan based on scientific and sustainable practices.

(ix) **Waste Management at Relief Camp Site:** A separate plan for relief camp site should be developed for collection of municipal waste and medical waste separately and for transfer of the waste from camps to the treatment/disposal sites on regular basis.

(x) **Epidemic/Disease Outbreak Prevention Plan:** This section of the plan would focus on preventing and controlling the risk of outbreak of any vector-borne disease by cleaning the wastes, sanitization of the disaster sites and securing drainage systems (to prevent mixing of waste and water). A Water, Sanitation and Hygiene (WASH) plan may be developed separately.

(xi) **Emergency Employment Plan:** This section would focus on generating livelihoods for the local / affected community by engaging them into temporary employment related to the disaster waste management processes such as waste segregation, transportation, treatment and recycling process. This would also support in boosting of local economy during the rehabilitation process. Remunerative wage rates, work hours, emergency training and so on to be worked out, based on requirement.

(xii) **Capacity Building:** This section of the plan would focus on improvement of skill levels (operation of machinery, equipment, waste categorization, other waste management processes *etc.*) through trainings from certified trainers and experts. Special training and simulation exercises would be planned for identified stakeholders like government officials, local NGOs, volunteers and education for common awareness generation among communities. NDMA, NIDM, NDRF and SDRFs along with ATIs that are already involved in training, mock simulation exercises and other capacity building activities can offer immense support in this area.

(xiii) **Monitoring and Evaluation (M&E) Mechanism Plan:** It is an essential component of the CP. It would envisage setting up of tracking systems for the waste throughout the process cycle like e-passes, barcodes, verification vouchers, output or time-based wage payment systems for managerial monitoring and evaluation. It would also use modern technology like drones, robots, GPS and GIS for debris removal and spatial monitoring of disaster sites- debris sites, storage, landfilling sites and monitoring transportation routes for damaged or blocked routes and traffic.

II. Post Disaster Solid Waste Management Implementation Plan

The Post-Disaster Contingency Plan for SWM would be activated during the post-disaster scenario, under the four broad categories *i.e.*, immediate, short-term, medium term and long-term. The plan should have synergy with the post-disaster DM operations of rescue and relief, damage and need assessment and resettlement and rehabilitation (refer Figures 5.1 and 5.2). The detail of the activities under each of the section are given below:

A. Immediate Plan of Action (within 72 hours of the Disaster):

- The SWM implementation plan would be activated along with the district IRS plan. The concerned agencies would prioritize the debris removal for supporting rescue and relief operations in order to save lives of affected community.

- **Post Disaster Assessments:** This stage would include appropriation of the estimates forecasted in the pre-disaster CP, which will include - estimation of debris/waste generated, waste categorization based on various waste streams, damage to the waste management infrastructure- storage sites, treatment plants and recycling plants, transport routes *etc.*, requirement of external assistance, monitoring and evaluation plan by using technology-based assessment and estimation tools and artificial intelligence.

B. **Short Term Plan (within 15 days of the disaster):** Based on the data and outcomes of assessments and estimations done during the immediate phase, following activities would be initiated under the short-term plan:

- Consult with partners, workers, volunteers and all stakeholders to initiate the waste management process as per the contingency plan, established guidelines, standards and practices for each waste stream.
- Activation of logistics plan which shall include – securing the identified temporary sites for waste and sufficient arrangement for equipment, manpower, vehicles and other resources for transportation, segregation and recycling / reuse/recovery of the waste. This procedure should ensure prevention of harm and safety of workers by providing safety clothing and equipment, immunization if required, *etc*.
- Activation of the communication plan, which shall guide the affected community regarding clean-up of their homes, use of cleaning agents for maintaining hygiene, location of temporary sites for waste collection and extraction of special waste like e-waste, plastic waste at source, *etc*.
- Activation of waste management plan at relief camp sites.
- Initiate the epidemic outbreak prevention operations that include control of vectors, their breeding grounds and securing the water supply and drainage system.

C. **Medium Term Plan**

- Secure treatment, recycling, and final disposal of waste by using environment friendly approaches.
- Extraction and recovery of reusable material for reconstruction by consulting local authorities with technical experts for support
- Regular communication with communities and other stakeholders about segregation of waste and recycling of the waste. Also, communities to be made aware about the work opportunities.
- Arrangements for reconstruction projects- exploring viability of different options for funding, partnerships, contractual obligations, material, equipment, manpower, *etc*.

Figure 5.1: Components of Pre-Disaster Waste Contingency Plan (CP)

Components of Pre-Disaster Contingency Plan

Stakeholder Engagement

- Identification, Consultation, Negotiations, Designation of Roles and Responsibilities of Stakeholders (Public, Private, CSOs, etc.)

Communication Planning

- Formal and Non-Formal Communication
- Horizontal as well as Vertical Flow of Information
- Information Dissemination, Risk Communication and Public Awareness

Institutional Framework

- 3-Tier Framework (Local, State and National)
- Establishment of Waste Management as an ESF in IRS at the District Level

Vulnerability, Capacity and Risk Assessment

- Assessment of Vulnerabilities (Institutional, Financial, Physical etc.)
- Assessment of Capacities (Trained Manpower, Machinery etc.)
- Forecasting Risks and Challenges (Disease Outbreak, Mixing/leakage of Waste etc.)

Logistics Plan

- Waste Transportation, Identification of Vehicles and Drivers, Routes to and from Designated Sites etc.

Designation of Sites and Facilities for all Types of Waste

- Identification of On-site/Off-site Collection, Segregation Centres, Temporary Storage Sites, Landfills, Treatment Plants, Material Recycle and Recovery Facilities

Special Waste Management Plan

- Special Waste: Hazardous, Chemical, Bio-medical and E-Waste
- Sustainable and Scientific Method for Waste Reduction, its Treatment and Disposal

Preparation of a Guide for Waste Management Process/Cycle

- Standard Practices for Waste Estimation, Categorization and Waste Management Processes (Collection to Disposal)
- Waste Hierarchy Approach
- Adherence to 4R Principle

Camp Waste Management Plan

- Municipal and Medical Waste produced at Relief Camps

Epidemic Outbreak Prevention Plan

- Vector Control, WASH, Immunization Plans etc.

Emergency Employment Plan (temporary work)

- Wage Rates, Work Hours, Emergency Training etc.

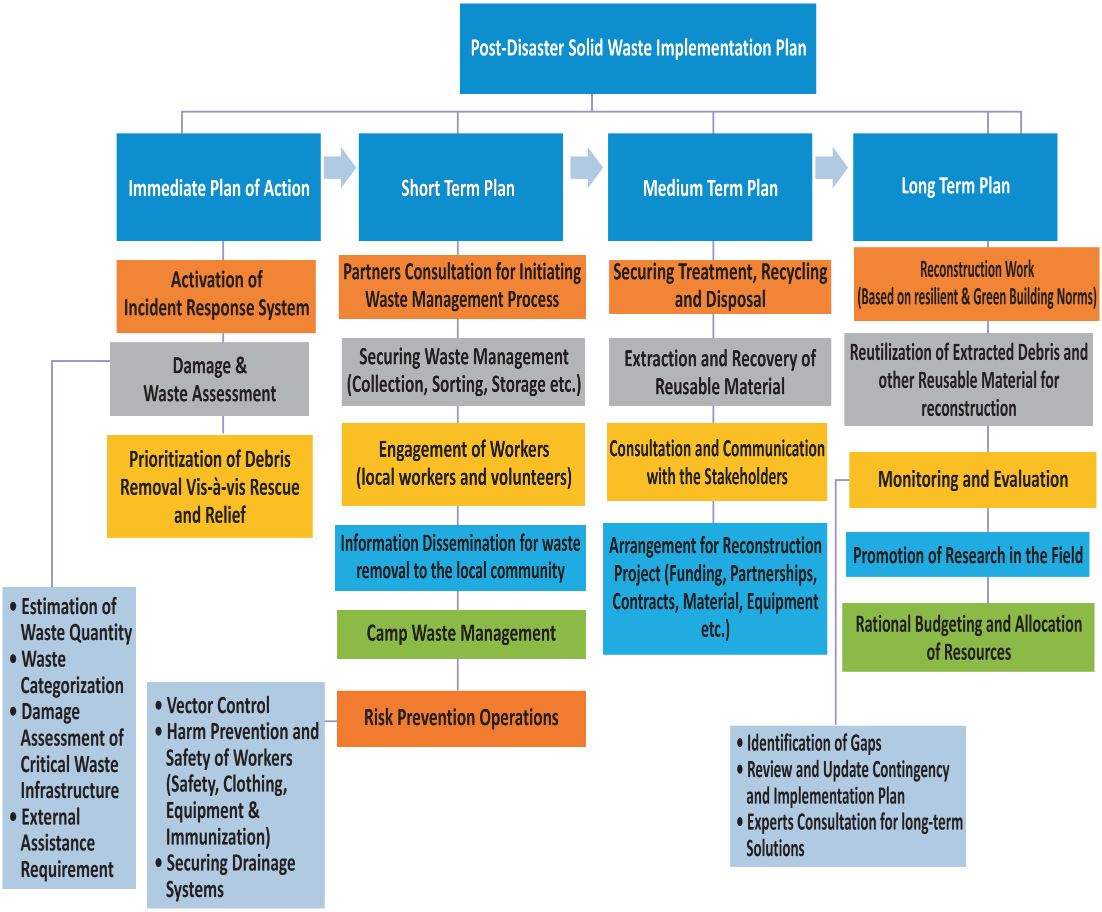
Capacity Building and Development

- Enhancement of Skill Levels of Machinery Operators and other workers
- Training and Simulation Exercises
- Public Awareness Generation
- NDMA, NIDM, NDRF and ATIs to spearhead this

Monitoring and Evaluation (M&E) Mechanism plan

- Managerial and Process Monitoring & Evaluation
- Spatial Monitoring of Disaster Sites through Technologies like Drones, Robots, GPS, GIS etc.
- E-tracking of Waste in Process, Barcoding, E-Passes, Verification Vouchers etc.

Figure 5.2: Post-Disaster Solid Waste Implementation Plan



D. Long Term Plan

- Recycling of Debris and Wastes: Utilization of extracted debris and other reusable waste material for reconstruction and creation of new products from recycled waste like utilization of dust or fly ash for production of construction products. These recycled items can be used in reconstruction plan of the area.
- Promote Sustainable Practices for Waste Management: This section would work upon promoting and institutionalizing sustainable strategies (based on 4Rs) for waste management and building a disaster resilient waste management infrastructure for the region including principles of circular economy and zero waste.
- Monitoring and Evaluation: It would include the activities related to identification of challenges and constraints encountered in the post disaster waste management project; review and update of the contingency and emergency implementation plan on the basis of these learnings and regular consultations with domain experts for their technical expertise for strengthening the future plans from the past lessons.
- Research and Development: Promotion and encouragement of research and studies to assess gaps of the post disaster waste management practices and infrastructure.
- Budgeting and Allocation of Resources: Rational budgeting for the implementation of DWM should be an essential part of the implementation plan. Estimation of costs in various stages of the process, procurement of funds, allocation of resources for future research and capacity-building activities should be critical components of the plan.

This study attempts to provide a framework to chart out an illustrative model for post-disaster solid waste management for India based on our learnings from the array of guidelines, case studies and best practices studied and reviewed in this study. The guiding principles of universally accepted 4Rs and the waste hierarchy approach aim at preventing and minimizing the waste generation and maximizing recovery, reutilisation and recycling of the waste. The prime objective of the suggestive model is to establish a disaster waste management system which is integrated with the 'peace-time' waste management system and forms part of the nation's mainstream development planning. The *'build back better'* approach of long-term recovery lends a broad vision of creating a disaster resilient infrastructure and institutional framework to it. Hence, this model of waste management also supports our international commitments under Sustainable Development Goals 2030, Paris Agreement (COP 21) and the Glasgow Climate Pact (COP 26) along with the Sendai Framework for Disaster Risk Reduction.

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GLOSSARY OF TERMS*

Capacity: The combination of all the strengths, attributes and resources available within a community, society or organization that can reduce the level of risk, or the effects of a disaster.

Chemical Hazards: Hazards involving chemicals or processes which may realize their potential through agents such as fire, explosive, toxic or corrosive effects.

Contingency Plan: A plan developed to assist with managing a gap in capability to ensure services are maintained. This plan describes organized and coordinated courses of action with clearly identified institutional roles and resources, information processes and operational arrangements for specific actions at times of need. Contingency planning can be done as deliberate planning or immediate planning as it seeks to address gaps on needs basis.

Co-processing: It refers to simultaneous recycling of material and recovery of energy within one industrial process. Waste is used as raw material (through material recycling) and/or source of energy (energy recovery) replacing fossil fuel such as coal, petroleum etc.

Debris: According to the UNEP/ OCHA guidelines, it is a mixture of building waste and rubble typically arising from damaged buildings and their demolition. This waste stream can include natural materials such as clay and mud, trees, branches, bushes, *etc*. Disaster debris usually includes soils and sediments, vegetation, construction and demolition waste, municipal solid waste, food waste, vehicles, household hazardous waste (cleaning agents, pesticides, *etc*.), household electrical appliances (refrigerators, air conditioners, *etc*.).

Disaster: The UNDRR defines disaster as a serious disruption in the functioning of a community or a society at any scale due to hazardous events interacting with conditions of exposure, vulnerability and capacity, leading to one or more of the following: human, material, economic and environmental losses and impacts.

Disaster Management Cycle: It illustrates the ongoing process by which governments, civil society and others may plan for and reduce the impact of disasters, react during and immediately following a disaster, and take steps to recover after a disaster has occurred. It includes following stages/ phases: Pre-disaster phase- prevention, mitigation, preparedness; Post disaster phase- response (rescue and relief) and recovery (rehabilitation and reconstruction).

*Sources: UNDRR, 2017 & 2020; UNEP, 2014; UNFCCC 2015 & 2021; United Nations, 2015; MOEFCC (GoI), 2016

Disaster Prevention: Disaster prevention means to take those measures to avoid and prevent the potential risk of hazard in advance.

Disaster Risk Management (DRM): According to UNDRR, 'Disaster Risk Management is the application of disaster risk reduction policies and strategies to prevent new disaster risk, reduce existing disaster risk and manage residual risk, contributing to the strengthening of resilience and reduction of disaster losses.'

Disaster Risk Reduction: It aims at preventing new and reducing existing disaster risk and managing residual risk, all of which contribute to strengthening resilience and therefore, to the achievement of sustainable development.

Disaster Waste: It is the waste that is generated by the impact of a disaster, both as a direct effect of the disaster as well as in the post-disaster phase as a result of poor waste management.

Glasgow Climate Pact: The Glasgow Climate Pact was adopted at the COP 26 held in November 2021 at Glasgow. It is an agreement involving all the nations party to the Paris Agreement (2015) on how to take forward the agenda set in the Paris Agreement.

Hazard: A potentially damaging physical event, phenomenon or human activity that may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation.

Landfill: It is a controlled disposal site for waste, where all emissions of gases, liquids and solid materials are controlled and not allowed to contaminate the surrounding environment.

MAH Units: Major Accident Hazard (MAH) installations have been defined under the Manufacture, Storage and Import of Hazardous Chemicals Rules, 1989. MAH unit means isolated storage and industrial activity at a site handling (including transport through carrier or pipeline) of hazardous chemicals equal to, or in excess of the threshold quantities specified in Column 3 of Schedule 2 and Schedule 3 (of the rules) respectively. MAH installation has the potential to cause extensive damage to life, material and environment within or outside the site boundary.

Mitigation: Measures taken in advance of a disaster aimed at decreasing or eliminating its impact on society and the environment.

NATECH Event: A natural hazard may lead to cascading technological disaster(s). Natural hazards such as earthquakes and floods can initiate events which pose risk to operation and safety at hazardous installations. Accidents triggered by such events are known as 'Natech' -Natural Hazards Triggering Technological Accidents.

Paris Agreement: The Paris Agreement is a legally binding international treaty on climate change that was adopted at COP 21 held in Paris in 2015 and came into force in November 2016. Its objective is to limit the rise in temperature to below 2° Celsius, preferably to 1.5° Celsius over the average temperatures in the pre-industrialization era (1850-1900) levels.

Policy: It provides a deliberate system of principles and statement of intent to guide decisions and achieve rational outcomes.

Preparedness: It is a set of actions that are taken by an entity to strengthen its response and to be able to cope better in the aftermath of a disaster. It means to be prepared and ready to respond immediately and effectively when the emergency occurs.

Reconstruction: It refers to long-term development assistance, which could help people in the affected areas to rebuild their lives and meet their present and future needs. It takes into account reduction of future disaster risks.

Recovery: The appropriate measures taken to recover from an event, including the action taken to support disaster-affected communities in the reconstruction of infrastructure, the restoration of emotional, social, economic and physical wellbeing, and the restoration of the environment.

Rehabilitation: It involves systematic restoration of local services enabling the affected population to resume more or less normal patterns of life. It refers to actions taken in the aftermath of a disaster to enable basic services to resume functioning, repair physical damage, restore community facilities, revive economic activities and provide support for the psychological and social well-being of the survivors.

Relief: Efforts to meet the needs of persons affected by a disaster, to minimize further loss through the provision of immediate shelter and basic human needs.

Resilience: A system or community's ability to rapidly accommodate and recover from the impacts of hazards, restore essential structures and desired functionality, and adapt to new circumstances.

Response: Disaster response refers to the certain activities that are to be taken in the aftermath of the disaster in order to save and protect lives. It involves search and rescue operations, providing first aid, medical relief, distribution of relief items like food, clothing, medicines etc., setting up temporary shelter/ camps for the affected communities.

Rubble: It is waste from damaged and destroyed buildings and infrastructure, and can include wastes from (re)construction works.

Search and Rescue: The process of locating and recovering victims and the application of first aid and basic medical assistance as may be required

Sendai Framework for Disaster Risk Reduction (SFDRR): The SFDRR is an international agreement adopted by the UN member states in 2015 at Sendai (Japan) for disaster risk reduction. SFDRR (2015- 2030) is the successor of the Hyogo Framework for Action (2005-2015). It has set seven targets and outlined four priority areas- understanding disaster risk; strengthening disaster risk governance to manage disaster risk; investing in disaster risk reduction for resilience; and enhancing disaster preparedness for effective response and to building back better in recovery, rehabilitation and reconstruction.

Solid Waste Management (SWM): The Solid Waste Management refers to the complete process of collecting, treating, and disposing of solid waste. It includes the processes and actions required to manage waste from its generation to its final disposal.

Sustainable Development Goals (SDGs): The SDGs are a set of 17 global goals that aim at promoting prosperity while simultaneously protecting the environment. The 2030 Agenda for Sustainable Development was adopted by UN Member States in 2015 that gives the following 17 goals to be achieved between 2015-2030. They are: SDG 1: No poverty, SDG 2: Zero hunger, SDG 3: Good health and wellbeing, SDG 5: Gender equality, SDG 6: Clean water and sanitation, SDG 7: Affordable and clean energy, SDG 8: Decent work and economic growth, SDG 9: Industry, innovation and infrastructure, SDG 10: Reduced inequality, SDG 11: Sustainable cities and communities, SDG 12: Responsible consumption and production, SDG 13: Climate action, SDG 14: Life below water, SDG 15: Life on land, SDG 16: Peace, Justice and strong institutions, and SDG 17: Partnerships for goals.

ANNEXURE

List of Panel Experts and Resource Persons that participated in the National Consultation on Challenges and Solutions for Safe Utilization and Disposal of Solid Waste in Post-disaster Situations

S.No.	Name of Experts	Profile & Affiliation	Topics of Presentations and Discussions
1.	Maj. Gen. M.K. Bindal	Former Executive Director, NIDM	Keynote Address on Challenges & Issues faced in disposal of Solid Waste after disasters & Debris Waste (TS 1 and TS 3)
2.	Shri Mohsen Shahedi	Deputy Inspector General, National Disaster Response Force (NDRF)	Special Address on: Challenges and Issues faced during Response Operation due to Solid Waste / Debris Waste
3.	Prof. Chandan Ghosh	Head, Resilient Infrastructure Division, NIDM	Disaster generated Solid Waste, Types, Issues and Broad Guidelines (TS1 to TS4)
4.	Dr. Garima Aggarwal	Senior Consultant, Resilient Infrastructure Division, NIDM	Convenor & moderator (TS1 to TS4 session)/ Context Setting, Summing Up and Way forward
5.	Dr. Mushtaq Ahmed Memon	Regional Coordinator for Resource Efficiency and SWITCH-Asia RPAC Project Manager, United Nations Environment Programme, Regional Office for Asia and the Pacific	Environmental Concerns and Guidelines on Disaster Waste Management through Global Case Studies
6.	Dr. Neha Vyas	Senior Environment Specialist, World Bank	Environmental Challenges and Solutions through Case Studies
7.	Dr. Ranit Chatterjee	Postdoctoral Fellow Kyoto University, Japan & Co-founder RIKA	Debris Management from NATECH events- Case study of Japan
8.	Dr. Girish Joshi	Senior Consultant, Uttarakhand State Disaster Management Authority	Issues and Solutions for managing post-disaster debris waste - A case study of Uttarakhand (World Bank funded Project)
9.	Ms. Abha Mishra	Odisha State Head, UNDP	Panel expert and moderator TS-2

S.No.	Name of Experts	Profile & Affiliation	Topics of Presentations and Discussions
10.	Mr. Srikrishna Balachandran	Program Manager & OIC, UNDP	Co-Convenor of the TS-2/ Context setting of the session on Plastic Waste Management.
11.	Ms. Kamna Swami	Project Coordinator, GIZ, India	Management of Plastic Waste after disasters – Issues and Solutions [through case studies]
12.	Mr. Amrendra Kumar	Vice President - Recycling, Ramky Reclamation and Recycling Limited	Sustainable Waste Management Practices
13.	Ms. Sangeetha Raghuram	Director - WASH and Circular Economy, Pricewaterhouse Coopers (PwC) Pvt Ltd.	Plastic Waste Management in post disaster scenario
14.	Mr. Abhishek Deshpande	Co-Founder & Chief Customer Office, Recykal	Plastic Waste Management and recycling techniques
15.	Dr. Basanta Raj Adhikari	Department of Civil Engineering, Pulchowk Campus, Institute of Engineering, Tribhuvan University, Nepal	Utilization of Debris in Reconstruction Program - A case study of Nepal Earthquake 2015
16.	Dr. G.N. Qasba	Former Commissioner, Srinagar Municipal Corporation, Jammu & Kashmir	Debris Management during Floods - A Case of Srinagar Floods, 2014
17.	Mr. Lovlesh Sharma	Sector Lead for WASH and Physical Infrastructure, National Institute of Urban Affairs (NIUA)	Issues and Solutions to Reduce - Reuse-Recycle the Solid Waste – A Case Study of Delhi
18.	Prof. Devanshu Pandit	Faculty of Technology, Centre for Environmental Planning & Technology, Ahmedabad, Gujarat	Challenges in Debris Waste Management with reference to Bhuj Earthquake and Solutions
19.	Ms. Madhuri Singh	AVP, IL&FS (Env. Infrastructure and Services)	Management of Construction and Demolition waste in Building Collapse-Planning and governance issues

S.No.	Name of Experts	Profile & Affiliation	Topics of Presentations and Discussions
20.	Dr. Sarat Das	State Project Officer - Disaster Management, Government of Tripura	Conclusions & Way forward
21.	Mr. S.S. Warick	Chief Fire Officer, MIDC & Director, Maharashtra Fire Service	Good Practices for disposal of industrial waste generated due to fire or industrial disasters - A case study of MIDC
22.	Ms. Keerthi D Souza	Managing Director, Life -givers Professionals	International Standards for Industries for Waste Management
23.	Dr. Vijay Aggarwal	President, Consortium of Accredited Healthcare Organizations (CAHO)	Issues and solutions of health - related hazardous solid waste
24.	Dr. Satyajit Patel	Associate Professor, SV NIT, Surat, Gujarat	Technologies for re -using Fly -Ash and dust waste caused due to fire / industrial disasters or building collapse
25.	Mr. Jitu C. Patel	Chairman, Global Society of HSE Professionals CEO, Global Safety Consultants, LLC, USA Director, Global Safety Institute, USA	Conclusions and Way Forward of TS 4 session on wastes generated through industrial disasters, fires and health facilities.
26.	Dr. Shailender Kumar	Faculty, Centre for Disaster Management and Environmental Studies, Miranda House, Univ. of Delhi	Panel Discussions

About the Institute

National Institute of Disaster Management (NIDM) was constituted under an Act of Parliament with a vision to play the role of a premier institute for capacity development in India and the region. The efforts in this direction that began with the formation of the National Centre for Disaster Management (NCDM) in 1995 gained impetus with its redesignation as the National Institute of Disaster Management (NIDM) for training and capacity development. Under the Disaster Management Act 2005, NIDM has been assigned nodal responsibilities for human resource development, capacity building, training, research, documentation and policy advocacy in the field of disaster management.

NIDM is proud to have a multi-disciplinary core team of professionals working in various aspects of disaster management. In its endeavour to facilitate training and capacity development, the Institute has state-of-the-art facilities like class rooms, seminar hall and video-conferencing facilities etc. The Institute has a well-stocked library exclusively on the theme of disaster management and mitigation. The Institute provides training in face-to-face, on-line and self-learning mode as well as satellite based training. In-house and off-campus face-to-face training to the officials of the state governments is provided free of charge including modest boarding and lodging facilities.

NIDM provides Capacity Building support to various National and State level agencies in the field of Disaster Management & Disaster Risk Reduction. The Institute's vision is to create a Disaster Resilient India by building the capacity at all levels for disaster prevention and preparedness.

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