Managing Wastes Produced by Natural Disasters

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EXECUTIVE SUMMARY

There is increasing evidence linking climate change to extreme weather events and natural disasters such as hurricanes, typhoons, tornados, wildfires, floods and ice storms. Other natural disasters include earthquakes, tsunamis and volcanoes. Natural disasters, in a very short time period, can create large quantities of waste materials that that pose unique management challenges. Therefore it is very important to put in place plans, procedures and systems, prior to the disaster event, to manage the waste materials generated. This paper first will describe the types of wastes produced from various types of natural disasters and the characteristics of those wastes. The paper will then describe the important elements of a disaster waste management plan necessary to guide the waste and debris removal and disposal operations. These elements include: definition of responsibilities; identification of waste types and amounts; inventory of current capacity for waste storage and management; inventory of equipment and administrative needs; and the development of necessary plans, strategies, regulations, and agreements. The paper will then review the various technological options for managing disaster wastes including volume reduction, recycling and reuse, waste-to-energy and landfill disposal. The paper will conclude with a review of some lessons learned from communities that have successfully implemented disaster waste management plans.

INTRODUCTION

The U.S. National Oceanic and Atmospheric Administration reported that 2010 was among the warmest years on record (NOAA 2011). The year also was characterized by changes in sea surface temperatures that contributed to many notable weather events including near-record high hurricane activity in the North Atlantic Ocean.

In June 2011, the Pew Center on Global Climate Change issued a report discussing the link between climate change and the frequency of extreme weather events. The report concluded that a combination of factors leads to extreme weather events, but that climate change is making those events more frequent (Pew Center 2011). The report stated: *"[N]o particular short-term event can be conclusively attributed to climate change…What matters is that there is a statistical record of these events occurring with increasing frequency and/or intensity over time, that this trend is consistent with expectations from global warming, and that our understanding of climate physics indicates that this trend should continue into the future as the*

world continues to warm." The Pew Center conclusions were supported by *Scientific American* in a recent article that indicated that the risk of extreme weather events and their intensity are increasing because of climate change (Scientific American 2011). These trends emphasize the importance of planning for and putting in place procedures and systems to manage the waste materials generated by natural disasters.

Extreme weather events and other natural disasters include hurricanes, typhoons, earthquakes, tornados, tsunamis, wildfires, floods, volcanoes and ice storms. Such events can create, in a very sort time period, large quantities of waste materials that that pose unique management challenges. Many of these wastes contain hazardous and toxic substances and can pose significant threats to human health and safety and the environment. A coordinated effort by local, regional and national agencies is important to assure safe and efficient removal, transport and disposal or recovery of such disaster debris. A well managed and timely response is necessary to restore community infrastructure and services and prevent further contamination and spread of disease.

In addition to natural disasters, there are other catastrophic events that are caused accidently or deliberately by human activity including oil and industrial chemical spills, transportation accidents and the release of chemical, biological or radiological materials from terrorist and homeland security incidents. Response to these events is even more difficult and complex due to the nature of the materials and the national defense and law enforcement issues often involved. Due to these complexities, response to these types of human-caused events cannot be adequately discussed in this paper but some additional information is provided in the references (Thorneloe et al. 2007).

The following sections will discuss the types and characteristics of wastes that are produced from natural disasters, and the planning, organization and technological systems that are necessary for their safe and environmentally sound management.

WASTES AND DEBRIS FROM NATURAL DISASTERS

An important first step in planning for disaster waste management is to understand the types of waste materials that result from different natural disasters. The U.S. Environmental Protection Agency has developed a very useful planning guide that identifies such wastes (EPA 2008). Excerpts from that guide follow:

Hurricanes and Typhoons

Hurricanes and typhoons involve powerful winds, storm surge, and rain. Flooding along coast lines produces construction and demolition (C&D) debris, damaged automobiles, boats and furnishings. Winds produce fallen trees and flying debris. Vegetative debris is usually generated in very large quantities in most hurricanes and typhoons. Major hurricanes can also leave behind large amounts of displaced sediments.

Earthquakes and Tsunamis

Earthquakes are caused by a sudden movement of the earth's crust along fault lines. Resulting debris can include C&D materials, automobiles, furniture, and other debris. Earthquakes at sea can produce tsunamis that can cause significant damage to roads, bridges and buildings along coastlines and generate significant debris.

Tornados

Tornados involve high velocity winds that can damage structures and infrastructure along a narrow path hundreds of kilometers miles long. Winds entrain projectile materials that put C&D materials, automobiles, vegetative debris, furniture, and other materials into the waste stream.

Floods

Floods destroy structures and personal property; uproot trees; and displace soil and sediment. Floods also destroy roads and bridges. In the aftermath of a flood, citizens dispose of flood-damaged household items. Mud, sediment, sandbags, and other reinforcing materials also add to the volume of debris needing management, as do C&D materials and mixed materials from demolished houses and automobiles.

Wildfires

Wildfires can generate large amounts of mixed debris, ash and charred wood waste, mixed metals, C&D materials and fire damaged automobiles, furniture and other home contents. In addition, large-scale loss of plants serving as ground cover can lead to mud slides, increasing the debris stream.

Volcanoes

Volcanoes can create ash and molten rock debris and damaged structures, charred wood waste, fallen trees, mixed metals and C&D materials.

Winter Storms

Winter ice storms create large amounts of vegetative debris. Heavy snow and ice accumulations break tree branches and can also collapse roof structures.

Estimating Waste Quantities

It is important to be able to forecast the amount and types of debris generated during different types and sizes of natural disasters. Estimates can be developed from previous experience or experience in other communities. Estimates also can be made using forecast tools. The EPA guide describes two forecasting tools. The Hazards U.S. Multi-Hazard Program, developed by the Federal Emergency Management Agency, is a nationally applicable standardized methodology and software program that estimates potential losses from earthquakes, hurricane winds, and floods (FEMA 2009). The U.S. Army Corps of Engineers has developed a Hurricane Debris Prediction Model to provide estimates of possible debris volumes for areas impacted by hurricane force winds based on primary five factors: the number of households, vegetation density factor, commercial density, storm wind intensity, and rainfall intensity (USACE). Estimating waste quantities is an important first step in developing disaster waste management plans.

DISASTER WASTE MANAGEMENT PLANNING

Since major natural disasters can generate enormous volumes of debris in short periods of time, removal and disposal operations must be implemented quickly to expedite recovery operations and to protect public health and safety of the local population. Therefore prior to the occurrence of a disaster it is important to have in place an in-depth plan to guide the waste and debris removal and disposal operations. The quantities of wastes generated may overwhelm the capacity of existing recycling, composting, combustion, and disposal facilities. There may be a need to develop additional staging and storage areas to store, separate, or process the waste material before it is sent to a final disposal site. A disaster debris management plan should aid communities in determining the appropriate management options in advance and help avoid rushed or, ultimately, poor decisions. Careful planning can speed recovery, protect human health and the environment, and prevent the generation of additional waste.

In the U.S. both FEMA and EPA have developed guides for developing disaster waste management plans (FEMA 2007, EPA 2008). The goal of such plans is to identify how waste and debris management activities will be facilitated and coordinated based on the local conditions and situations. Important elements of a disaster waste management plan from those guides include the following.

Define Responsibilities for Waste and Debris Management

Prior to a natural disaster the organization and staff responsibilities for management of waste and debris should be established. This should cover the responsibilities of national, regional and local governments and the agencies and the departments within those governments. The staff should be comprised of personnel to perform functions including engineering, administration, legal, operations, contracting and procurement, and public information. Also it is very important to have in place prior to the event, contracts with companies skilled and capable of handling and processing disaster debris, so that they can be deployed immediately after the event.

Identify Waste Types and Forecast Amounts

As discussed previously it is important to estimate the amounts and types of wastes that might be generated and their characteristics. Certain natural disasters are more prevalent in different parts of the country and produce different waste types. For example hurricanes occur along coastal areas and floods along river bodies. Therefore waste estimation and characterization needs to be carried out on a location specific basis.

Inventory Current Capacity for Waste Management

Existing solid waste management facilities, including recycling, composting, combustion and disposal facilities need to be inventoried, along with their daily and permitted capacity to receive different types of wastes. Each facility's ability to manage additional debris beyond their normal or permitted daily load should be evaluated. If there is not sufficient capacity to manage the predicted amount of waste locally, facilities outside of the immediate area should also be identified as well as the options for transportation of debris to such facilities. Mutual aid agreements for use of such facilities should be established with neighboring communities in advance of a natural disaster.

Identify Temporary Waste Storage and Reduction Sites

Some natural disasters can generate much more debris than a community typically manages annually. Therefore it is important to pre-select temporary sites that can be used for the storing, sorting, and processing of debris. Sites selected in the past have included disposal facilities, local parks, and closed industrial or military facilities. Conveniently located sites can reduce travel time when transferring debris to processing or management facilities and result in expedited debris clean-up.

Inventory Equipment and Administrative Needs

A disaster management plan should identify in advance the types of equipment and supplies needed to implement the plan. This includes equipment for administrative purposes as well as debris collection and processing. The EPA guide provides a list of possible equipment needs for both the initial response and debris processing. Fuel needs and fueling facilities for equipment and vehicles should also be identified. Administrative needs include office, lodging and sustenance for waste collection and processing personnel as well as communication and monitoring equipment.

Create a Debris Removal Strategy

The debris management plan needs to include a debris removal strategy that identifies the priorities for removing and clearing debris from various locations and situations. A high priority should be the clearing of debris that hinders immediate life saving actions and that poses an immediate threat to public health and safety. This includes the clearing of major arterial roads and roads leading to health care facilities. It is important to provide clear access routes to allow for movement of emergency vehicles, law enforcement, resumption of critical services and access to critical public facilities and utilities. The next priority is to open access to important community facilities, such as schools, municipal buildings, airports, seaports and removing and disposing the debris that hinders the orderly recovery of the community. This strategy needs to be in place so that it can be implemented immediately after the event passes.

Create a Waste Prevention Strategy

A disaster debris management plan should include a waste prevention strategy that identifies preventative measures aimed at reducing the generation of disaster debris. Such plans, sometimes called hazard mitigation plans, should be part of a community's long-term strategy to reduce disaster losses and damages to lives, property, and the economy. These strategies can include a program to educate the public on how they may decrease the amount of damage that their property might suffer in a natural disaster. They can also include a building code evaluation to help determine whether current codes will allow the community to withstand disasters, and constructing public works projects such as levees that limit the extent of flooding. More information about hazard mitigation plans can be found at FEMA’s website (FEMA 2010).

Develop a Communication Plan

A communication plan is an important part of the disaster debris management plan. The debris management team will be required to communicate with other governmental agencies, local commercial and industrial enterprises, waste collectors and processors and the general public regarding the debris removal process. The communication plan should describe what information will need to be provided and how such communication should take place. How decisions will be communicated through the chain-of-command should be clearly articulated.

Communication with the general public should be timely, consistent, updated, and clear and in some communities might need to be in several languages.

Identify Harmful Materials

The wastes generated from a natural disaster often contain significant quantities of hazardous materials that will require special handling and disposal in order to prevent harm to human health or the environment. Examples include asbestos containing wastes, PCBs, explosives and flammable substances. These materials can be found in automotive batteries, pesticide containers, automotive fluids, solvents, paint thinners and strippers, and compressed gas containers. Plans need to be developed to identify these materials, separate them from the mixed waste stream, collect and transport them in a safe manner and dispose of them in conformance with environmental rules and regulations.

Establish Regulatory Requirements, Mutual Aid Agreements and Contractual Documents.

An effective disaster debris management plan should include a listing of all national, regional, and local regulations that govern how each debris type must be managed. The plan should also include an updated contact list of pertinent national, regional, and local regulatory officials who may need to be contacted during clean-up. Opportunities for financial aid from regional and national governments need to be identified and eligibility requirements and application procedures need to be understood. Mutual aid agreements with neighboring regional and local governments should be established. These agreements should provide for mutual commitments to support one another in the event of a natural disaster. These agreements can provide for the loan of equipment and personnel. For some natural disasters it will be necessary to engage the services of private sector companies to carry our debris clearance, removal and disposal services. Contracts for these services should be established prior to the event and should specify the debris removal and management tasks to be undertaken and the terms, conditions and payments for those activities.

WASTE AND DEBRIS MANANGEMENT TECHNOLOGIES

There are a number of existing technologies that can be used to manage the debris and wastes produced from a natural disaster. These include conventional grinding, shredding and incineration technologies to reduce the volume of debris prior to disposal; technologies to recover useful materials and products through reuse, recycling, composting and energy recovery; and ultimate disposal in municipal landfills, hazardous waste landfills and incinerators and C&D landfills. Brief summaries of these technologies follow.

Volume Reduction

Natural disasters that produce significant quantities of woody debris may present the opportunity to employ grinders and shredders to reduce the volume of the waste and produce mulch that can be used to replenish topsoil and retain soil moisture. Shredding and grinding can reduce the volume of the debris by as much as 75 percent. The economic feasibility of shredding and grinding woody debris should be evaluated relative to other volume reduction processes such as incineration. The opportunity to use recycled wood chips as mulch for agricultural purposes or as fuel for industrial purposes can affect the economics positively.

There are several incineration methods available for volume reduction. The least desirable is open-air incineration because it lacks any type of environmental control. However controlled

open-air incineration can be effective in reducing clean, woody debris in rural areas. Air curtain pit incinerators can be a more effective means to reduce debris volume and reduce some of the environmental concerns of open-air incineration. Air curtain incineration can reduce volume up to 95 percent. However the incineration unit must be designed as an engineered system. The air curtain and pit must be precisely configured to function properly so that the high velocity air curtain traps and re-circulates combustion products.

The use of open burning or air curtain incineration is often very controversial. Planners will find that there will be a significant demand from the public and local officials about the environmental standards and safeguards and the health issues and risks associated with these types of incineration processes.

Reuse and Recycling

Recycling and reuse of disaster wastes can reduce the burden on disposal facilities, conserve resources and possibly provide a source of revenue. Options and priorities for reusing and recycling disaster debris materials should be identified in advance and included in disaster debris management plans. These plans should identify available recycling markets and should inventory existing local recyclers of scrap metal, mixed C&D materials, land clearing debris, concrete, asphalt pavement, hazardous waste, and electronics.

C&D debris from demolished buildings and collapsed road and bridges offer several opportunities for recycling and reuse. Bulky, heavy materials such as masonry, bricks, blocks, and concrete can be crushed into aggregate and reused in road reconstruction or as fill. Lumber, vegetative debris and other wood products can be directly reused or ground and used for boiler fuel, mulch, and engineered lumber. Treated wood and wood painted with lead-based paint should be removed from wood meant to be recycled as mulch or composted. Asphalt shingles can be recycled into new asphalt pavement mixes or used in cement production. Gypsum drywall can be recycled into new drywall, cement, and agricultural uses. Metal can be recycled back into metal products.

Metals, damaged automobiles and boats and household appliances can be recycled under many circumstances. Fluids should be drained and batteries, tires, gas tanks, airbags, and mercury switches should be removed and managed appropriately. Metal household appliances can be separated and recycled but refrigerants and capacitors containing PCBs should be removed by certified technicians to prevent releases.

Other waste materials may also provide opportunities for recycling. Food wastes can be composted and animal carcasses and meat can be rendered. Sediments should be tested for contaminants and screened to remove other debris. If not contaminated, they can be used as fill in reconstruction projects, or used as cover material in landfills. Electronics waste can be repaired and reused or sent to electronics recyclers.

Waste-to-Energy

Natural disaster debris may be sent to a waste-to-energy facility where the combustible material can be used to produce energy and the volume of material to be landfilled can be reduced by 85 to 90 percent. Typical waste-to-energy facilities can handle many types of debris, including vegetative debris, C&D materials, furniture and other home contents, and putrescible wastes.

Additional storage capacity may be necessary if the volume of debris is considerably larger than the design capacity of the units. These facilities are subject to stringent environmental standards and are equipped with extensive air and water pollution control systems.

Using combustible debris to create energy in the form of heat, fuel or electricity can have both environmental and economic benefits as compared to disposing of it by open burning or landfill. In addition to waste-to-energy facilities, industrial boilers and furnaces may be able to accept combustible material generated from a natural disaster and power plants that can use this material may also exist in the vicinity of communities affected by disasters, thereby reducing transportation costs.

Landfill Disposal

Following reuse, recycling, and energy recovery, the remaining disaster waste will need to be disposed of properly and safely. Hazardous wastes should be removed and disposed of in a hazardous waste landfill or incinerator. Most of the remaining wasted can be disposed, as appropriate, in either a municipal solid waste landfill or C&D landfill. Municipal solid waste landfills must be designed and operated to protect human health and the environment. This often includes waste screening, location criteria, operational requirements, design standards, regulation of discharges to groundwater, surface water and air, and closure/post-closure standards. These requirements should be specified in an operating permit issued by a regional or local agency. C&D landfills also have operational requirements and design standards, but C&D landfill requirements tend to be less stringent than municipal solid waste landfill standards. It is important to check with national, regional and local environmental agencies to determine appropriate requirements for C&D landfills.

One main component of C&D materials is gypsum wallboard, which consists of a gypsum core between two layers of paper. Under the anaerobic conditions that exist in a landfill, gypsum wallboard that comes in contact with moisture and organic material may lead to the production of hydrogen sulfide gas. Hydrogen sulfide may pose an odor problem and, in high concentrations, may pose a health risk to landfill workers and nearby residents. Gypsum wallboard can be separated out and recycled. Also if the landfill has a gas collection system the hydrogen sulfide can be collected and destroyed through combustion.

Advance planning will help a community utilize environmentally acceptable practices for management of disaster waste. The disaster waste management plan should help ensure that: reuse, recycling and energy recovery opportunities are used to the fullest extent possible; necessary storage or staging locations are identified; hazardous wastes are properly managed; and available landfill capacity is used appropriately.

CONCLUSIONS

A summary of important lessons learned regarding disaster waste management planning is presented in the EPA guide (EPA 2008) along with compilation of successful individual case studies from the U.S. These case studies are presented as examples of how others overcame obstacles during clean-up and recovery. The paragraphs below rephrase some of the most important lessons as stated in the EPA document.

Experience has shown that having a disaster waste management plan and thinking though the elements of such the plan will significantly improve the quality and speed of response and will increase the confidence of the community in the local government's ability to respond effectively

to a disaster. Many community leaders from communities that have experienced natural disasters believe that a disaster management plan gave them an important place to start and made them more prepared for the disaster. All components of the plan need to be addressed and updated regularly and communities need to be fully prepared to implement the plan when a natural disaster strikes.

Planners need to anticipate the types of natural disasters that are likely to impact their community and the amount of waste and debris that may be generated. Having an inventory of existing waste management facilities, their capacities, and capabilities is important. This inventory should include potential temporary storage, staging and disposal sites.

Having pre-negotiated contracts or a list of pre-qualified contractors for managing waste and debris will help ensure that clean-up efforts start quickly. Identifying equipment and administrative needs in advance will help to ensure that the necessary equipment, supplies and people will be in place. A good plan for communicating with the waste management team, governmental agencies, industries and the public will help ensure that that the disaster waste management process will be understood. Making sure that debris management is accomplished in an environmentally sound manner will protect the community during and immediately after the natural disaster occurs, as well as, into the future.

As summed up in the FEMA guidance (FEMA 2007): *"The speed of initial debris clearance, removal and disposal operations depends upon the depth of pre-disaster planning…debris clearance, removal and disposal activities are a visible sign of action that helps restore a sense of normalcy to a stunned community."*

REFERENCES

EPA 2008, *Planning for Natural Disasters*, U.S. Environmental Protection Agency, EPA A530-K-08-001, March 2008.

FEMA 2007, Debris Management Guide 325, the Federal Emergency Management Agency, June 2007 **http://www.fema.gov/pdf/government/grant/pa/demagde.pdf**.

FEMA 2009, Hazards U.S. Multi-Hazard Program, the Federal Emergency Management Agency, June 2009, **http://www.fema.gov/plan/prevent/hazus/index.hstm.**

FEMA 2010, Multi-Hazard Planning, the Federal Emergency Management Agency, August 2010, **http://www.fema.gov/plan/mitplanning.**

NOAA 2011, *State of Climate in 2010,* The National Oceanic and Atmospheric Administration, June 28, 2011, **http://www.ncdc.noaa.gov/bams-state-of-the-climate/2010.php**.

Pew Center 2011, *Extreme Weather and Climate Change: Understanding the Link, Managing the Risk,* The Pew Center on Global Climate Change, June 28, 2011, **http://www.pewclimate.org/docUploads/white-paper-extreme-weather-climate-change-understanding-link-managing-risk.pdf**.

Scientific American 2011, *Extreme Weather Caused by Climate Change*, June 28, 2011, **http://www.scientificamerican.com/article.cfm?id=extreme-weather-caused-by-climate-change**.

Thorneloe S, Lemieux P, Rodgers M, Christman R, and Nickel K. *Decision Support Tool for the Management of Debris from Homeland Security Incidents,* Eleventh International Waste Management and Landfill Symposium, Sardinia Italy 2007.

USACE, Hurricane Debris Prediction Model, U.S. Army Corps of Engineers, **https://eportal.usace.army.mil/sites/ENGLink/default.aspx**