Disaster Waste Management and the Christchurch Experience

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EXECUTIVE SUMMARY

Disasters can create the equivalent of 20 years of waste in only a few days. Disaster waste can have direct impacts on public health and safety, and on the environment. The management of such waste has a great direct cost to society in terms of labor, equipment, processing, transport and disposal. Disaster waste management also has indirect costs, in the sense that slow management can slow down a recovery, greatly affecting the ability of commerce and industry to re-start. In addition, a disaster can lead to the disruption of normal solid waste management systems, or result in inappropriate management that leads to expensive environmental remediation. Finally, there are social impacts implicit in disaster waste management decisions because of psychological impact we expect when waste is not cleared quickly or is cleared too quickly. The paper gives an overview of the challenge of disaster waste management, examining issues of waste quantity and composition; waste treatment; environmental, economic, and social impacts; health and safety matters; and planning.

Christchurch, New Zealand, and the broader region of Canterbury were impacted during this research by a series of shallow earthquakes. This has led to the largest natural disaster emergency in New Zealand's history, and the management of approximately 8 million tons of building and infrastructure debris has become a major issue. The paper provides an overview of the status of disaster waste management in Christchurch as a case study.

A key conclusion is the vital role of planning in effective disaster waste management. In spite of the frequency of disasters, in most countries the ratio of time spent on planning for disaster waste management to the time spent on normal waste management is extremely low. Disaster waste management also requires improved education or training of those involved in response efforts. All solid waste professionals have a role to play to respond to the challenges of disaster waste management.

INTRODUCTION

The planning, design, and operation of solid waste management systems are complex tasks requiring substantial effort and attention by communities. After a disaster, solid waste management takes on greater importance and is also more difficult to accomplish. Solid waste management is connected to every part of the response and recovery of a community after a disaster. Failure of solid waste management systems after disasters can lead to major social problems, far outweighing the problems caused by inadequate solid waste management before the disaster. Awareness, planning, and training all have important roles to play for those solid waste professionals who will be called upon to manage after a disaster.

Disasters come in many forms, both man-made and natural—fire, flood, earthquake, tsunami, hurricane/cyclone, tornado, volcanic eruption, severe drought, civil conflict, war. Each has its particular characteristics, which means that planning and training for each is distinct. A number of general features of all disaster types can be highlighted, and these will be the focus of this paper.

This paper draws heavily on a recent literature review on disaster waste management published in *Waste Management* (Brown, Milke, and Seville, 2011a). That article has 120 references from a wide variety of sources, and is the first journal-standard review of the topic. Other key overview reports related to disaster waste management exist, the most notable of which are the 2008 USEPA report "Planning for Natural Disaster Debris" (USEPA, 2008) and the 2011 UNEP/OCHA report "Disaster Waste Management Guidelines" (UNEP, 2011).

Christchurch, New Zealand, and the larger region of Canterbury (total impacted population of roughly 400,000) have experienced, since 3 September 2010, a series of strong, shallow earthquakes on faults that had not previously been identified. The nearness of the earthquakes to the urban area has led to severe impacts, with 181 deaths, an estimated 10,000 to 15,000 houses that will need to be demolished, in excess of 1000 (mostly multi-storied) commercial buildings to be demolished, upwards of 200,000 tons of contaminated silt/sand from liquefaction, and major damage to infrastructure for water supply, sewage, stormwater, electricity, and roads. The most serious event was a 6.3 magnitude earthquake on 22 February 2011, centered only 5 to 10 km from the city center. This earthquake generated some of the highest accelerations ever recorded in an urban area (see Figure 1), and the largest natural disaster emergency in New Zealand's history. Major issues of solid waste management resulted; overall, an estimated 8 million tons of building and infrastructure debris were created. The cost to insurers for rebuilding is estimated at NZ$15 billion, making it the third costliest earthquake ever, worldwide. The relative cost of 6 to 8% of GDP is very high for any natural disaster faced by a country of New Zealand's size (a little over 4 million in population).

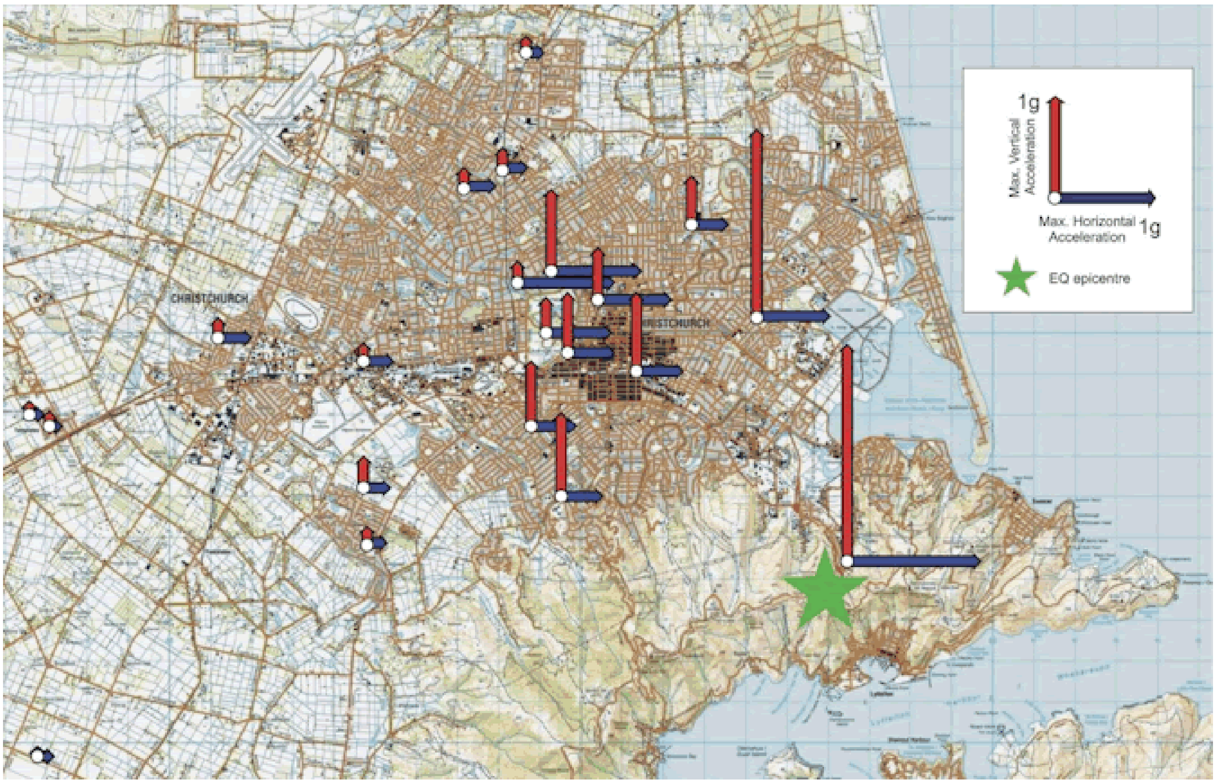

Figure 1: Maximum accelerations experienced in Christchurch, New Zealand, during the magnitude 6.3 earthquake on 22 February 2011 (Royal Society of New Zealand, et al., 2011).

WASTE QUANTITIES AND COMPOSITION

The quantities and composition of waste can vary dramatically between disasters as a function of the type of disaster, the size of the disaster, and the development status of the country. Some reported quantities are provided in Table 1.

Table 1: Reported Waste Quantities from Previous Disasters (Brown, Milke, and Seville, 2011a)

Year	Event	Estimated Waste Quantities
2011	Christchurch earthquake	8 million tons
2010	Haiti earthquake	23 to 60 million tons
2009	L'Aquila earthquake, Italy	1.5 to 3 million tons
2008	Sichuan earthquake , China	20 million tons
2005	Hurricane Katrina, USA	76 million cubic metres
2004	Hurricanes Frances and Jeanne, Florida, USA	3 million cubic metres
2004	Indian Ocean Tsunami (Indonesia alone)	10 million cubic metres
1999	Marmara Earthquake, Turkey	13 million tons
1995	Hanshin-Awaji Earthquake, Kobe, Japan	15 million tons

The largest component of the waste can be classified as similar to construction and demolition waste, although the waste can have fractions such as vehicles and vessels, industrial chemicals, and human and animal corpses. There can also be uniquely post-disaster waste fractions such as unwanted donations, rotten food because of power outages, and packaging for relief food.

Waste from hurricanes and cyclones tends to be higher in vegetative debris than that from other disaster types, waste from floods is higher in building contents (e.g., carpets), and waste from earthquakes is higher in building materials (concrete, timber) and infrastructure materials (e.g., paving, piping).

Appropriate planning post-disaster requires a sensible estimate of both the quantity of waste and its composition. Because recycling/recovery options can require large infusion of new capital plant, we need to estimate the economic viability of particular recycling/recovery options, and so we require estimates of quantities and composition. Estimation of these can be difficult immediately after a disaster when there are high demands on key people. If the estimation is left until the community is ready to clean up and good data are available, it can mean long delays between the disaster and the time when clean-up begins. After estimates of quantities, composition, and cost are completed, time is needed to obtain equipment, assess effects, write contracts, set prices, and obtain approval. To avoid long delays, post-disaster estimation of waste quantity and composition needs to be closely tied to pre-disaster planning.

Christchurch has an estimated 8 million tons of waste generated by the earthquakes. An unuusally large fraction (20-50%) will likely be infrastructure waste. Liquefaction has caused the need to demolish whole residential areas. Not only homes will need to be removed, but also their associated streets, curbs, drinking water pipes, sewer pipes, and electrical systems. For example, 300 km of sewer pipes were damaged. Although much of these materials can be reused, a large fraction has been badly damaged or is contaminated to the point where reuse is impractical. The Christchurch region typically generates roughly 400,000 tons of waste per year, and so the earthquakes have created about 20 years of waste in less than one year. New waste management systems are required.

WASTE TREATMENT

The choices for waste treatment do not change after a disaster. What does change is the large quantities of specific materials (e.g., gypsum wallboard, treated timber). On the one hand, these large quantities can make certain treatment options more economically favorable; on the other hand, they also worsen issues of waste storage and market saturation. The amount of separation of waste materials is still a critical decision for waste managers. The large quantities allow for bigger operations and also greater assurance that any processing facility will operate at capacity for a fixed duration, both of which will improve the economics. Although reconstruction creates demand for certain materials, such as roading aggregate, the timing of recovery can often mean that a large stockpile of materials must be kept (and properly managed) over a lengthy recovery phase. The combination of a need to process materials and the need to stockpile has led to many authors noting the importance of temporary staging areas for disaster waste (FEMA, 2007; USEPA, 2008).

After a disaster, waste treatment decisions are frequently not enacted quickly because of pre-disaster environmental and waste regulations. If the ability to enact waste management decisions is slow before a disaster, the many social demands afterwards are likely to slow matters further unless emergency powers, through some form of waivers, are granted. A key factor in allowing rapid implementation of new waste services is effective public consultation. Again, public consultation can be slow and disputatious before a disaster, and only becomes more difficult afterwards; however, some manner of public consultation can help communities find reasonable emergency measures to handle a waste management crisis. Without any consultation, the likelihood of disagreement is high, and the potential increases for public protests and court cases that would stop implementation.

Brown, Milke, and Seville (2011b) describes the response of Australian authorities after the 2009 Australian bushfires to the demand for new landfill space. After quick consultation with various parties, a new landfill cell alongside an existing landfill was agreed as the best way forward. Design, regulatory approval, and construction all occurred within 10 days of the joint decision.

In Christchurch, the community has opted for a common waste processing site in order to improve the economics of waste processing, and to also allow for rapid movement of wastes away from urban areas. Although the community had not previously agreed on a suitable site, there was fortunately land nearby that proved appropriate. Much of the waste would seem to be economically recoverable, although a need for storage of waste-derived products will be necessary. There is still discussion about what level of landfill protection is appropriate for the non-recoverable residue. Six months after the February event, the demolition of buildings and infrastructure is picking up in pace, and the waste processing capacity is struggling to keep up, leading to storage of unprocessed waste. One significant challenge that remains is to agree on an appropriate treatment for treated timber removed from buildings during demolition.

HEALTH AND SAFETY

Health and safety issues are complicated enough for waste managers before a disaster; after a disaster they can only become worse. There is an inevitable human desire to take emergency action in a crisis, even if that leads to riskier waste management practices. And there is a societal need to clean up the waste quickly, along with a desire to relax certain pre-existing regulations for short periods of time. When is it reasonable to relax rules, and when is it not?

Health and safety can be a concern because of (1) the disaster waste itself (e.g., spoiled food leading to proliferation of disease vectors), (2) the public impact of improper waste management (open burning of waste), or (3) the impacts on waste management workers (fine particulates from grinding of waste concrete). Decisions made in haste can lead to long-term regrets, such as the health impacts increasingly noted in emergency responders and clean-up workers in the aftermath of the 2001 World Trade Center collapses (Landrigan, et al., 2004).

The most likely pressure point for health and safety concerns in disaster waste management are the issues of fine particulates and, in particular, asbestos exposure. In many developed countries, asbestos removal from buildings during demolition requires trained personnel and can take days for relatively small buildings. When one extrapolates normal conditions to thousands of buildings after a disaster, the cost and delays can seem enormous. Significant research is needed on appropriate responses to asbestos hazards after disasters, and how to plan for those responses now.

The greatest tension in the Christchurch situation has been related to the potential health and safety impacts on demolition and waste workers. This becomes a factor in the choice of a centralized or decentralized approach to disaster clean-up. In a decentralized approach, property owners (or more likely, their insurers) negotiate demolition and clean-up contracts with individual companies; while in a centralized approach, all work must be done through one contractor. Some companies that might be excluded from a centralized contract could push for a decentralized approach by stating that they can provide the service at a lower cost. If a decentralized approach proceeds under these terms, the risk of health and safety violations by one of the many small companies, each under intense cost pressure, could be unacceptably high. The Christchurch decision has been to provide a choice of either a centralized contractor or for independent work, and this will require diligent monitoring of health and safety issues for the many workers involved.

INDIRECT IMPACTS

The large impact that disaster waste management has on the overall disaster recovery process has been appreciated only in recent years. Previously, emergency response and recovery managers had identified the critical infrastructure or 'lifelines' and their inter-relationships (Centre for Advanced Engineering, 1991). This earlier work focused on roads, bridges, sewage pump stations, etc., as key chokepoints in an infrastructure system that, through various interrelations with other infrastructure subsystems, can constrain recovery speeds. In a more subtle way, waste management after a disaster can also seriously impede the speed of recovery, and so should be seen as a 'lifeline service'.

We analyzed the likely relative importance of various lifeline services after a large earthquake in the New Zealand capital city of Wellington (Brown, Milke, and Seville, 2010b). Some key conclusions were:

- Although of low importance during the immediate response, waste management is likely to increase in importance during the recovery phase and reach a higher level of importance than some services such as communications and airports.
- Not only disaster debris but also day-to-day municipal waste management needs to be considered in pre-disaster planning.
- Waste management after a disaster is closely tied to a number of other infrastructure services, in particular roads and stormwater management, and therefore good waste management is important to avoid poor functioning of key sub-systems.

The indirect impacts of disaster waste extend beyond the impact on lifeline services. There is a recognized economic impact of slow recovery, and poor disaster waste management has been cited as a key obstacle to post-disaster economic recovery. Unfortunately, there are no good methods to estimate the avoidable economic impact of inefficient waste management, and so there is no economic justification available for a higher priority to disaster waste management.

The indirect impacts extend beyond economics to a wide variety of social impacts. Clean-up after a disaster can provide jobs for people displaced from their typical employment. This can be especially important in developing countries where government support systems are weak or non-existent. Slow management of disaster waste can lead to serious issues of public protest, which can encourage poor practices such as open burning of waste. Public participation in disaster waste management can have a psychological benefit on a community allowing it to feel that progress is being made to recovery and that people have made individual contributions at a time of great personal frustration. The challenge facing those who want more public participation is how to allow that without unduly increasing health and safety risks.

Solid waste managers also need to be aware of the attachment of owners to personal property and must facilitate recovery of personal goods. This might imply a need to provide an opportunity for property owners to be aware of (or perhaps participate in) necessary demolition and clean-up. Finally, the difficult issue of public communication and consultation becomes even more difficult and important after a disaster. Much more investigation is needed into the social impacts of disaster waste management.

In Christchurch, there has been relatively quick and strong recognition of the potential impact of disaster waste on long-term recovery. There has also been strong recognition by central government of an economic and social need for quick recovery, and this has led to support for rules and processes that allow for quicker demolition and clean-up, even if at slightly higher direct costs. The greatest difficulties so far in this regard, in my opinion, have been weak public consultation and weak empathy for local residents wishing to have more involvement in clean-up. Consultation proved difficult during the early period after the large February earthquake because of poor electricity service, and no postal service. Traditional methods of communication and consultation proved ineffective, and no pre-existing alternatives (eg, neighborhood action groups) were able to fill the gap. The weak empathy noted by some residents and business owners seems to be a result of a strong emphasis by authorities on enforcing rigorous safety rules, perhaps even more rigorous than existed before the disaster. A tendency to hypersensitivity to risk after a disaster is one worthy of further investigation.

PLANNING

There is a strong recognition of the need for pre-disaster planning of disaster waste management. The United States Environmental Protection Agency (USEPA) and the Federal Emergency Management Agency (FEMA) have had planning systems in place; however, the massive scale of waste problems after Hurricane Katrina highlighted a number of deficiencies that have since been improved. One strong component to US planning has been the negotiation of pre-arranged contracts and costs with contractors. One weakness in these plans is that they give little guidance on decision-making processes. They also do not consider the effectiveness of different organizational, financial, and legal arrangements in various disaster recovery situations.

The use of single contractors for managing all, or significant sub-fractions, of disaster waste is an increasingly common organizational response. The use of single contractors ensures co-ordination and government oversight without direct day-to-day management by an often overwhelmed local or regional governmental entity.

Solid waste management is governed by a multitude of laws and regulations, with great variability between locations. This complexity makes it difficult to discuss common issues. Still, it is important to recognize that the local legal environment can have a strong control over local management of disaster waste. Careful study of existing laws and regulations is needed during the planning phase to identify legal means to facilitate good decisions related to disaster waste management. This is likely to mean a need in legislation for emergency powers that can override certain regulations under well defined conditions.

In our study of the relevant New Zealand legislation, 17 pieces of relevant legislation were identified (Brown, Milke, and Seville, 2010a). Many, but not all, had emergency provisions that could allow for facilitated disaster waste management. The largest deficiency noted was any system for managing long-term liability for adverse effects resulting from acting under emergency powers. When faced with a decision on waste treatment or disposal under difficult and urgent post-disaster conditions, there could be little use of emergency powers without some form of at least partial protection for negative effects.

In the Christchurch situation, even with relatively strong legislation in place, the New Zealand Parliament saw a need for new urgent legislation. The Canterbury Earthquake Response and Recovery Act (CERRA) established the Canterbury Earthquake Recovery Authority (CERA) (New Zealand Government, 2011). The legislation gives CERA strong powers to override a large number of regulations. This has been the subject of substantial legal debate (New Zealand Law Society, 2011), with some commenting that it provides too much power and too little opportunity for consultation or public comment. To date, there has been no great uproar over excessive use of these exceptional powers, though the concern still exists.

Negotiation with insurers and reinsurers has become an important planning task in the aftermath of the Christchurch earthquakes. The policies that insurers have with property owners will pay for only the lowest cost required, even though this might cause long delays in recovery, or interfere with joint rebuilding with other property owners and their various insurers. Because of this, the government and CERA have advanced negotiations to find ways to speed up removal of debris and also allow quicker rebuilding. The negotiation with insurers became an aspect of recovery where, in hindsight, more planning had been needed.

The large impact on infrastructure over a wide area has implied major challenges in restoring roads, sewers, electricity, and so on. Before the disaster, various organizations would specialize in each of these services and look at their interrelationships as needed. After the disaster, that piecemeal approach would not work and instead the city has agreed on an Alliance contract involving five construction companies, the City Council and CERA (CERA, 2011). This should bring the expertise of each organization to the project, reduce miscommunication between specialist organizations, and so make for a more rapid and less costly rebuild.

CONCLUSION

A key conclusion is the vital role of planning in effective disaster waste management. In spite of the frequency of disasters, the ratio of time spent on planning for disaster waste management to the time spent on normal waste management is extremely low in most countries. Planning requires governments to face difficult decisions that might not become relevant for many years, if at all. It can be difficult enough for society to accept a waste disposal siting decision when waste piles up on the street; one can imagine how difficult it can be to agree on a waste processing or disposal site in advance of a disaster that might not occur in people's lifetimes. Similarly, the tough thinking, consultation, and negotiating that goes with disaster planning can be too easily put off for another day. However, when the day comes that recovery plans are needed, society will turn to waste managers and expect quick and appropriate solutions. As waste professionals, we have a strong duty to engage now in thorough planning.

Effective planning is a necessary condition, but not a sufficient condition, for achieving good disaster waste management. Another key condition is the employment of well educated and well trained individuals who can participate in the decision-making. The disaster response team needs to have knowledgeable waste management professionals and an ability to call on foreign expertise. We cannot wait and educate the people needed after a disaster strikes-- the lack of well educated solid waste professionals in a region can be sadly exposed by a disaster. In addition, civil defense drills and exercises need to include solid waste aspects. These will highlight the need for the presence of solid waste professionals in civil defense teams, and also the need for short-courses to increase awareness of solid waste issues by civil defense staff.

Compared with excellent day-to-day solid waste management in many places around the world, disaster waste management is an unmet challenge for solid waste professionals. Much research into the topic is needed, and every year its urgency increases. The increased urbanization in developing countries has greatly increased the world's risk of massive disasters, and concomitant massive solid waste management crises. Even in developed countries, the increased investment in infrastructure and the complex interrelationships of infrastructure services have made solid waste management a key dimension to recovery and rebuild after disasters. We all have a role to play and a responsibility to meet the challenge.

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