International Journal of Waste Management and Technology
Vol. 6, No. 1, January 2023, p. 1-9, ISSN: 2327-8757 (Online)
Available online at http://www.ijwmt.com/

Research article

Planning and implementing effective debris management is a crucial part of ensuring resilience

J.A. Atchue, III and Allen Morse

Ceres Environmental Services, Inc. 6968 Professional Parkway East Sarasota, FL 34240

Phone and fax: 1 (800) 218-4424 and 1 (866) 228-5636

Joe.Atchue@ceresenv.com Allen.Morse@ceresenv.com,

Abstract

Abstract: This paper discusses the potential positive and negative impacts on resilience resulting from effectively (or ineffectively) managing disaster debris. A brief discussion focuses on how resilience has gained importance as part of the disaster response and recovery paradigm. Several cases of positive and negative disaster debris management scenarios are provided with discussion on how these various cases could have either positive or negative impacts to resiliency. In the cases of negative impacts, which sadly are far more common, we discuss how poor management of disaster debris waste can impact economic, environmental, and social dimensions of recovery. The positive impacts associated with proper debris waste management also are discussed. Poor debris management is a continuing issue in the response to and recovery from disasters, particularly in less-developed countries. We argue a greater focus on properly managing disaster wastes will lead to economic, environmental, and health benefits that also will increase local populations' resilience.

Keywords: Disaster Debris; Planning; Landfilling; Transportation; Recycling; Resilience

Introduction

Being resilient in the face of adversity is a trait much admired by virtually every-one. In 2005, the Hyogo Framework for Action (UNISDR, 2005) defined disaster resilience as… *the capacity of a system, community or society potentially exposed to hazards to adapt, by resisting or changing in order to reach and maintain an acceptable level of functioning and structure*. USAID (2012) defined it as… *the ability of people, households,* *communities, countries, and systems to mitigate, adapt to, and recover from shocks and stresses in a manner that reduces chronic vulnerability and facilitates inclusive growth*. In both cases, the focus in on recovering from a disaster, which may be a significant disturbance in, or some other shock to, the environment, whether a drought, earthquake, flood, hurricane, or some other natural (or even human-induced phenomena).

Boonmee *et.al.*, 2018 point out… *post-disaster waste management is one of the most important operational management systems that have been developed to help affected communities recover and restore conditions back to a stable situation after a disaster*. They continue, that effective post-disaster strategies for optimizing waste management (often) are lacking. Lack of such strategies impacts efficiency increasing cost and time to complete the removal of the debris. Time pressure can force poor decision-making in many different areas including decisions about recycling, waste removal and segregation, land-fill design and construction to name a few. All of these decisions have the potential for economic, environmental, health, and psychological impacts that if poorly made can impact resilience.

Recently though, much excellent work has been done discussing post-disaster resilience including Mabon (2019), who focused on how "building back greener" had positive eco-social impacts in Futaba County, Fukushima Prefecture, Japan after the 2011 earthquake and tsunami. Marchesini *et al*. (2021) and Khanal *et al.* (2021) have discussed how waste quantification is key to enabling a more efficient waste management process that can decrease negative environmental and health impacts such including improper handling (and classification) of wastes, both hazardous and infectious. More rapid cleanup allows for more rapid recovery that can lead to a quicker "return to normal" thus enhancing resilience.

Perhaps surprisingly, the civil engineering field has focused on resilience both for physical, social, and economic systems (Lu *et al., 2020*). Kima *et al.* (2018) and Saja *et al.* (2021) state delays in debris removal can delay initial disaster response (in part because first responders do not have clear access-ways) and impact recovery processes overall, which can lead to longer timeframes for the recovery and decrease community engagement and hence resilience. Chang *et al*. (2010) point out a lack of building materials including aggregate, sand, stone, cement, and wood has impacted reconstruction in both post-tsunami Aceh and Christchurch. This clearly impacts the pace of reconstruction. Slower reconstruction means a slower "return to normalcy" which will have definite economic and likely knock-on social impacts.

Finally, Lindanger (2012), has pointed out that in working towards resilience, it is important to ensure that the focus of recovery is not merely technical but also includes the people who have been impacted. This is an important consideration in response and recovery operations that is better accounted for now than (for example) in the response to the Boxing Day Tsunami of 2004 at certain locations. It is however crucial, to understand that all technical activities, whether debris-related, rebuilding, or even initial response

This paper focuses on an area that has not been deeply reviewed; identifying how proper debris management in disaster responses, in both the humanitarian response and subsequent cleanup phases is a crucial contributor to resilience. Writing elsewhere (Morse and Atchue, 2022) we have indicated that the donor response to debris management is uncoordinated and often leaves large volumes of debris in place after the work has been "completed." Our argument here is that this poor debris management impacts the ability of those impacted by a disaster to respond as resiliently as they might. Below we discuss both "less-than-optimal" and "optimal" debris management scenarios and our assessment on their potential to impact resiliency.

Results and Discussion

Below we provide eight example debris management scenarios and discussing their potential to impact resilience. The scenarios (five negative and three positive) we discuss below are by no means exhaustive, and the donor community continues to make efforts to better manage dis-aster debris. But the fact that these scenarios are common, means there is a long way to go to effectively manage disaster debris. In the first five scenarios, we identify a specific aspect of disaster debris waste management. In the latter three scenarios, we pro-vide some appropriate waste management scenarios. As with all of these scenarios, the impacts can include economic, environmental, health, and psychological. Note, that because debris management is of lower priority (in general), we have been unable to find any studies that focus directly on its impact on resilience. In the Conclusions section, we discuss our perceptions of how these various scenarios can impact resiliency.

Organic material including vegetation not disposed properly

In many cases, vegetation is brought to a "staging area" preparatory to ultimate relocation, often with that relocation never happening. This can leave piles of organic material rotting on the ground. While some would argue that this is "natural", too of-ten this staging area becomes an unofficial dumping site for all waste. The organic de-bris can serve as both home and food to many pests and act as a magnet for rats and other vermin. Over time, as it decomposes, it can even become an ignition source and catch on fire. Protection from direct sunlight can provide areas for water to pool and act as mosquito breeding grounds. Our observations (including in Haiti, the Philippines, and Puerto Rico) are that other trash and garbage often are added to these piles, leading to a cycle where they become the local rubbish drop.

Wrecked vehicles, white goods and electronics discarded without proper pre-treatment

Vehicles contain a number of hazardous materials that become waste when they are wrecked. These include windshield washer and brake fluid, and of course gasoline or diesel fuel. Lead acid batteries also are hazardous and in cases where a car is all-electric, then the lithium-ion batteries are extremely hazardous. All of the fluids, including battery acid, can impact drinking water quality. In addition, battery acid can cause burns and most of the other fluids are flammable in addition to being toxic. Lithium-ion (Li-ion) batteries present an extreme hazard for fires.

White goods such as air conditioners, washing machines, microwaves, and electronics such as cell phones, tablets, computers, and televisions also can harbor hazardous waste. The gasses in air conditioners, whether in vehicles or homes are charged with compounds that have significantly negative impacts on climate. If they are simply released into the atmosphere, they will add to the burden of Greenhouse Gasses al-ready present. Hazards from electronic devices include the metals Beryllium, brominated flame retardants, Cadmium, Chromium, Lead, and Mercury. Some devices, whether white goods or electronics, may have capacitors containing Polychlorinated Biphenyls (PCB). Such types of capacitors can be found in air conditioners, fluorescent light ballasts, dehumidifiers, microwaves, submersible pumps, mercury vapor lamps, copy machines and electrical control panels and also may be found in refrigerators, washing machines, dryers, and fans. Virtually all portable electronic devices will have a lithium-ion battery, that presents the same danger as from electric vehicles.

Not segregating (or even identifying) hazardous wastes

Even the poorest country makes use of a number of hazardous chemicals. These include things such as organic solvents including benzene, toluene, and xylene, acids and bases such as ammonia, chlorine bleach, and sulfuric acid, agricultural chemicals such as pesticides, and fertilizers, and high strength BOD and COD wastes from agri-processing and other industrial activities. In addition, Cadmium, Chromium, Lead, and Mercury, and even organic

International Journal of Waste Management and Technology
Vol. 6, No. 1, January 2023, p. 1-9, ISSN: 2327-8757 (Online)
Available online at http://www.ijwmt.com/

monomers can be found in disaster debris waste. These may be located at industrial facilities, small shops, and even in households and farms. Some of these wastes are carcinogens, others may spontaneously ignite, cause chemical burns or asphyxiation, or other problems. For example, battery acid, not only can cause significant chemical burns but the Cadmium, Chromium, and Lead it contains can contaminate drinking water causing a variety of ailments.

Poor solid waste landfill management

While efforts often are made to identify appropriate landfill locations and to engineer them properly, lack of experience with proper operation, can lead to problems many years later. If organic waste such as garbage is placed in the landfill, it may putrify, generating methane and leaching noxious wastes into surface or groundwater. In cases where there has been inappropriate segregation of hazardous wastes, these wastes may leak from whatever containers in which they are placed and either leach into drinking water, or potentially combine and ignite. One of us (Morse personal observation) had an opportunity to revisit the Port au Prince debris landfill he helped to oversee during the 2010 Haiti earthquake response. He reported that it was smoldering, filthy, and accepting all manner of trash. This was in large part because the Hai-tian Government did not provide operational funding for it after the response ceased. Landfills that do not properly manage waste either on acceptance, or in the long term are essentially ticking timebombs, as the American experience with the Love Canal landfill shows.

Not recycling, or only recycling a limited suite of materials

Recycling often is viewed as a “nice-to-have” recovery activity rather than one essential to sustainable and resilient recovery. In fact, the United States’ (US) Federal Emergency Management Agency (FEMA) did not even acknowledge recycling as an option until 2007. In disaster response and recovery operations in less-developed countries, recycling may, or may not, occur. The rationale often is that there is insufficient labor or specialized equipment available to properly do the work. While the specialized equipment argument is one that has some truth, there often are more than enough people interested in work for pay to support some level of recycling. In the US, Fetter and Rakes (2012) point out that with little added effort in terms of disaster debris management (<1 percent of cost), the value of the activity can be increased by >30 percent, although they also indicate that too much focus on recycling can increase costs with only limited impact on value.

Working with coconut farmers to harvest downed trees after Typhoon Haiyan

In Leyte Province after Typhoon Haiyan (Yolanda in the Philippines) coconut farmers were able to make use of the tens of millions of downed trees. Some used fronds and wood as feed stock for fuel pellets, which while high in ash, had acceptable heating values (Acda, 2015). Durst (2015) indicated that the Food and Agri-culture Organization and other actors were able to put local people to work clearing the trees and rendering them into construction materials. Taganas (2019) con-firmed that coconut farmers did benefit from this activity but indicated that as many as 30 percent were unaware that the government was implementing it.

Incorporating green solutions in recovery after the Great Eastern Japan Earthquake

Mabon (2019) observed that ecosystem approaches brought some resilience benefits in Futaba County, Fukushima Prefecture, after the 2011 earthquake with its subsequent disasters. He points out that cultural ecosystem services identified at the municipality level were strong components of recovery plans. Further he observed these cultural services appeared critical to residents recovering a sense of identity and pride. Recovery planning was the responsibility of the local municipalities, with substantial input and assistance from the prefectural and national government. In addition, municipalities were able to access academic and other resources for both planning and implementation (Mabon, 2019). There is a strong emphasis on community participation in these processes. In fact, Lindanger (2012) argues that the municipalities used the recovery planning process to systematically evaluate existing landscape features as a part of green infrastructure, and to explicitly consider the ecosystem services provided, in ways not done previously.

The USAID Hariyo Ban project's support after the 2015 Nepal earthquake

USAID's Hariyo Ban Project in Nepal (WWF Nepal, 2017) assisted in the response to Nepal's 2015 "Gorka" Earthquake. Their work included livelihoods recovery, rehabilitating water supply system, foot trails, and disaster risk reduction (DRR), which included soil bioengineering for landslide stabilization. The work supported more than 100,000 earthquake-affected people of which almost 50,000 were women and girls. As part of its response, Hariyo Ban worked with other sectors and the Nepalese government, assisting them in adopting environmentally sound practices to re-duce impacts from recovery and reconstruction activities, by "building back safer and greener."

Resilience is a widely used term in science and engineering. In general, it refers to the ability of a "system" (this can include businesses, electronic circuits, economies, ecosystems, and governments) to return to some approximation of a former state after it is perturbed by some force. In disaster response and recovery, a human dimension is added to resilience encompassing individuals, families, societies, governments, and economies. While an individual's status will not influence resilience, the aggregate status of impacted individuals can support or inhibit resilience. For example:

- Individuals injured, or becoming ill, as a result of a disaster are less able to contribute to subsequent recovery activities until they are better;

- Similarly, individuals with limited access to food, water, shelter, or sanitation are less able to contribute, simply because they have insufficient energy to do so;

- In the medium term, individuals becoming aware that their environment has been polluted as a result of poor debris management also will likely experience negative feelings.

While physical capability is an important aspect of resilience, there also is a mental dimension that is potentially even more important. On top of struggling with the fact of the disaster being visited upon them, the three points above can lead to anxiety, depression, panic attacks, and post-traumatic stress disorder (PTSD) (Mao and Agyapong, 2021). All of these can lead to a decreased ability to respond to situations and decrease overall resiliency of responses. Mao and Agyapong also indicate that government support, whether from local, regional, or national (and we would add international) organizations can provide significant assistance from resources outside the disaster area that can enhance resilience as local populations recover from the insult.

Below we identify some of the anticipated impacts to resilience from negative and positive debris management scenarios.

Negative scenarios

The first five previous scenarios all represent aspects of improper waste management. The impacts associated with each of these scenarios can be at the level of the individual, community, or higher.

The impacts of improper staging or disposal of organic waste on resilience can be associated with poorer health outcomes for local communities near the areas. There can be increased mosquito-borne diseases, including Chikungunya virus, Dengue fever, Malaria, West Nile virus, and Zika virus. Increased rat (and other small mammal populations) can potentially spread Hantavirus, Leptospirosis, Plague, Rabies, Salmonella, and Tularemia. Children (being children) also are likely to play on the piles left behind and as a result injure themselves or even be bitten.

People living in environments where exposure to the various diseases listed above are well-aware of the potential for contracting them. However, knowledge that this potential has increased resulting from the poor management of wastes by the government of donor community will certainly leave a bitter taste. Should people become ill, or children injured, that can impact personal attitudes, increasing negativity and result in lowered resilience.

Most of the hazards discussed above may cause burns, chemical and otherwise, detonate, or cause asphyxiation, leading to immediate harm to people nearby and potential damage to structures. While Greenhouse gases are a long-term concern, we do not discuss them here, simply because, the timeframe of impact is so long. Wastes associated with vehicles and white goods, in the longer term, also have the potential to negatively impact ecosystem functions, and contaminate soil, and water. Diminished ecosystem functionality can decrease ecosystems services. For example, contaminated soil may inhibit plant growth or deter it altogether. This could lead to failed recovery of a flood management system replanted in local grass and shrubs. Contaminated water can cause a variety of diseases, including of the kidney and liver, and of course cancers of various types. Knowledge that this contamination has taken place, can impact, already fragile people increasing the potential for depression. People who suffer actual injury or illness as a result of this improper management, whether as a result of fighting a Li-ion battery fire, or inhalation of gasoline fumes present real-life examples of the continued danger the local population faces.

Improper management of hazardous wastes is an acknowledged worldwide problem that only serves to magnify already awful situations. Common hazardous wastes in developing country contexts include asbestos, various metals, organic solvents, and PCB to name a few. While exposure to some of these, such as mercury in the form of methyl mercury, can cause immediate death, others such as asbestos and organic solvents act on longer timeframes that result in debilitating illness and often death. Similar to the failures discussed above, knowledge of the exposure or potential for exposure likely will have negative impacts on resilience, at least in the medium term.

Poor landfill management may be a misnomer as many of the “landfills” in less developed countries are no more than open dumps with no liner or other engineering controls. As such, any of the hazardous contaminants previously discussed that are placed in open dumps or poorly managed landfills are likely to contribute to poor human and environmental health. Such impacts remove people from the workforce, or education, decrease economic growth, and increase morbidity and mortality rates. All of these impacts in turn can decrease resilience.

Recycling in disaster recovery situations often is considered a “nice-to-have”. The arguments against it include the expense required to stage and pre-sort waste prior to actually recycling, and a lack of appropriate labor and equipment. Our argument is that recycling can contribute to resilience on a number of levels. People who are able to work in jobs that have demonstrable impacts and provide a decent wage typically are more fulfilled than those who are relegated to camps with little or no work to perform. This positive attitude is likely to be reflected in their approach to the disaster and aid in increased resiliency. It also can serve as an exemplar for those unable to work. Economically, not only does the work remove people from the need for government support (at least to some extent), but it also generates tax revenues, from the salaries and eventually from the purchase of the recycled materials. Finally, using locally sourced recycled materials rather than importing can help to decrease expenses associated with importing the new materials.

Short-term impacts to people include potential injury or death associated with exposure to chemicals. Medium and long-term impacts would be associated with the chemical discharging into the environment and polluting, drinking water, farmland, or damaging ecosystem functions. Most short-term impacts will decrease the physical potential of individuals to work. These impacts also can cause friends and family members psychological hurt and lead to depression, PTSD or other ailments. Individuals' knowledge of potential exposure to potentially life-threatening wastes as a result of government or donor mismanagement of those wastes can lead to increased depression and anxiety and therefor decrease resiliency.

Populations impacted by disaster already are stressed by lack of access to food, sanitation, shelter, and water which decreases immunity and increases psychological distress. This heightened exposure and susceptibility to disease can increase depression and also lead to lower job attendance, creating a hysteresis loop that must necessarily impact the ability to "bounce back."

Positive scenarios

Of the three positive scenarios, one came about as the result of a decision to take advantage of the millions of downed coconut trees as a resource, whether for heat or construction (Acda, 2015; Taganas, 2019; WWF Nepal, 2017). The second and third scenarios both focused on the importance of incorporating green approaches in responding their disasters (Mabon, 2019; WWF Nepal, 2017). Each brings various impacts of note.

In Leyte, after Typhoon Haiyan, not only did tens of thousands of coconut farmers benefit from the money they made removing their destroyed trees; the recycled materials had direct benefits, either by providing energy sources for cooking or interim building materials to enable quick reconstruction of housing. This decreased humanitarian burdens on the government and donors, enabled people to return to their homes more quickly, and in general minimized disruption. All of these positive impacts and the lessons learned from implementing them contribute to enhanced resiliency.

In response to the Great Eastern Japan Earthquake of 2011, both county and municipal governments worked closely with inhabitants to understand the importance of cultural ecosystem services and to incorporate them as strong components of recovery plans (Mabon, 2019). This resulted in more extensive use of green infrastructure as part of planning for the next disaster. Finally, in response to the large 2015 Gorka Earthquake in Nepal, a US Agency for International Development project, worked with the national government to include soil bioengineering for landslide stabilization (WWF Nepal, 2017). In both cases government reached out to and included impacted populations in their planning, which resulted in plans that considered green infrastructure as part of future disaster preparedness.

Conclusion

The manner in which disaster debris is managed can have either positive or negative impacts to the subsequent resilience of the disaster response. We argue the low priority given to disaster debris management in the international development com-munity's disaster response and recovery operations contributes to lower resilience as a result of real and perceived increases in risk associated with improper waste management. We provide examples of positive and negative waste management scenarios and discuss their various impacts on human mental and physical health and subsequent potential to impact the resilience of responses to disasters. As yet we are aware of no studies examining this linkage but see such studies as validating our thesis and also serving as an impetus to raise the importance of disaster debris management.

Acknowledgement

Funding: This research was funded by our employer, Ceres Environmental Services, Inc.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Acknowledgments: The author's wish to acknowledge the financial support of Ceres Environmental Services, Inc. for providing us the time to prepare this paper.

Conflicts of Interest: The authors declare no conflict of interest.

References

Acda, Menandro N. 2015. Fuel pellets from downed coconut (Cocos nucifera) in super typhoon Haiyan. Biomass and Bioenergy. Volume 83, December 2015, Pages 539-542. https://doi.org/10.1016/j.biombioe.2015.11.005

Boonmee, Chawis, Mikiharu Arimura, Takumi Asada. 2018. Location and allocation optimization for integrated decisions on post-disaster waste supply chain management: On-site and off-site separation for recyclable materials. International Journal of Disaster Risk Reduction 31 (2018) 902–917. https://doi.org/10.1016/j.ijdrr.2018.07.003

Chang, Yan, Suzanne Wilkinson, Erica Seville, Regan Potangoroa. 2010. Resourcing for a resilient post-disaster reconstruction environment. International Journal of Disaster Resilience in the Built Environment · February 2010. 10.1108/17595901011026481

Fetter, Gary and Terry Rakes. Incorporating recycling into post-disaster debris disposal. Socio-Economic Planning Sciences 46 (2012) 14-22. https://doi.org/10.1016/j.seps.2011.10.001

Khanal, Rajib, Prem Upadhaya Subedi, Rupesh Kumar Yadawa, Bikram Pandey. Post-earthquake reconstruction: Managing debris and construction waste in Gorkha and Sindhupalchok Districts, Nepal Progress in Disaster Science 9 (2021).

Kima, Jooho, Abhijeet Deshmukha, and Makarand Hastak. A framework for assessing the resilience of a disaster debris management system. International Journal of Disaster Risk Reduction. Volume 28, June 2018, Pages 674-687. https://doi.org/10.1016/j.ijdrr.2018.01.028

Lindanger, Håvard Benum. 2012. Resilience in a Global Disaster: The Local in Disaster-Induced Compressed Globalization. Forum for Development Studies. Volume 39, 2012 - Issue 3. Pages 387-406. https://doi.org/10.1080/08039410.2012.691896

Lu, Xinzheng, Wenjie Liao, Dongping Fang, Kaiqi Lin, Yuan Tian, Chi Zhang, Zhe Zheng, and Pengju Zhao. Quantification of disaster resilience in civil engineering: A review. Journal of Safety Science and Resilience 1 (2020) 19–30.

Mabon, Leslie. Enhancing post-disaster resilience by 'building back greener': Evaluating the contribution of nature-based solutions to recovery planning in Futaba County, Fukushima Prefecture, Japan. Landscape and Urban Planning. Volume 187, July 2019, Pages 105-118. https://doi.org/10.1016/j.landurbplan.2019.03.013.

Mao W, and Agyapong VIO (2021) The Role of Social Determinants in Mental Health and Resilience After Disasters: Implications for Public Health Policy and Practice. Front. Public Health 9:658528. https//doi.org/10.3389/fpubh.2021.658528.

Marchesini Gaïa, Helene Beraud, Bruno Barroca. Quantification of disaster waste: Review of the available methods. International Journal of Disaster Risk Reduction (53) 2021. https://doi.org/10.1016/j.ijdrr.2020.101996

Morse, Allen and J.A. Atchue, III. 2022. Are donors adequately managing debris waste from natural (and other) disasters? International Journal of Materials, Methods and Technologies. Vol. 6, No. 1, May 2022, pp. 1-10, ISSN: 2327 - 0322 (Online) Available online at http://ijmmt.comAuthor

Saja, A. M. Aslam, Melissa Teo, Ashantha Goonetilleke, Abdul M. Ziyath. A Critical Review of Social Resilience Properties and Pathways in Disaster Management. Int J Disaster Risk Sci (2021) 12:790–804

Taganas, Analou 2019. Assessing the impact of super Typhoon Yolanda (Haiyan) on the livelihood of coconut dependent farmers in Kananga, Leyte and Sogod, Southern Leyte, Philippines. Review of Socio-Economic Research and Development Studies. 2019. Volume 3 No. 1, 58-77. https://papers.ssrn.com/sol3/papers.cfm?abstract_id=3804173.

UNISDR. Hyogo Framework for Action 2005 - 2015: Building the Resilience of Nations and Communities to Disasters.; UNISDR, Switzerland. 2005. https://www.unisdr.org/files/1217_HFAbrochureEnglish.pdf#:~:text=The%20Hyogo%20Framework%20for%20Action%20%28HFA%29%20is%20the,for%20vulnerable%20communities%20in%20thecontext%20of%20sustainable%20development. 6pp.

USAID. Building Resilience to Recurrent Crises: USAID Policy and Program Guidance.; USAID, USA, 2012. 32 pp.

WWF Nepal. 2017. Biodiversity, People and Climate Change: Final Technical Report of the Hariyo Ban Program, First Phase. WWF Nepal, Hariyo Ban Program, Kathmandu, Nepal.