IMPACTS OF SEVERE WEATHER EVENTS ON IMPLEMENTING THE WASTE HIERARCHY - THE CASE OF ETHEKWINI METROPOLITAN MUNICIPALITY

MUSWEMA*AP, CHETTY** P, OKEM[β] A, OELOFSE* S

***** amuswema@csir.co.za, Council for Scientific and Industrial Research (CSIR), Waste for Development Research Group
****** eThekwini Municipality, Cleansing and Solid Waste (CSW).
[β] School of Life Sciences, University of KwaZulu-Natal (UKZN).

ABSTRACT

This case study is an overview investigating the interaction between severe weather incidents and solid waste management. The study seeks to understand how extreme weather events affect the implementation of the waste hierarchy (an approach that emphasises that waste must firstly be avoided and if not avoided, minimised and diverted from landfill for beneficiation purposes). There is robust scientific evidence linking the frequency of extreme weather events to climate change. Climate change models demonstrate the likelihood that extreme weather events are likely to become more frequent in the current, near- and long-term. Similarly, the socio-economic impacts of these extreme weather events are projected to become increasingly severe.

The study is located in the broader context of climate change and its implications for solid waste management in eThekwini metro. Using a case study desktop review approach, the study examines how extreme weather events affect the implementation of the waste hierarchy in eThekwini Municipality. Additional consequences to extreme weather events for the vulnerable (especially those located in informal settlements) including the negative impact on informal housing, mortality and the loss of assets and livelihood is discussed. This paper argues that there are a number of options to manage waste from severe weather events, including the application of the waste hierarchy (as well as options to stimulate job creation) as a tool to manage wastes. Additionally there is a need for the individual sector plans from each of the line departments to be finalised, completed and made available (to public and officials).

Key words: Solid Waste Management, waste hierarchy, Disaster, Risk, Vulnerability

1 INTRODUCTION

The waste management sector is vulnerable to climate change as a result of the logistical complexity of solid waste removal and disposal systems (Zimmerman & Faris, 2010). Koop & van Leeuwen (2017) add that climate change-related extreme weather events could potentially damage municipal assets such as waste collection vehicles, landfills and other related infrastructure (road, water and sanitation). In addition, the waste sector has to deal with the debris and waste that remains following extreme weather events. Extreme weather events could also exacerbate public health concerns with stagnant water and organic waste which is a focal point for vector proliferation (Brown, Milke & Seville, 2011). Furthermore, climate change-related weather events could undermine the ability of local governments in meeting regulatory requirements such as implementing the waste hierarchy (i.e. to minimise, reuse recycle, and treat waste, with disposal as last option) and reducing the volumes of waste going to landfill. Gabrielli *et al* (2018: 8) also argue that the presence of debris in the street from an inadequate disaster waste management program will often “extend… the needed time for the waste and debris removal from the street” and therefore add to the stress in the communities affected.

Potential climate change impacts on waste collection and recycling, are summarised by Newton *et. al.* (2011) as:

- increased risks of flooding leading to localised disruption of waste collection rounds, and potential difficulties reaching waste treatment and disposal facilities;
- capacity to cope with large volumes of waste generated by extreme weather events including floods and fires;
- potential loss of value and degradation of paper and cardboard for recycling due to increased moisture content and contamination;
- health and safety issues for communities and staff;
- increased rates of decay of putrescible waste in warmer climates, necessitating more frequent collections of food waste to avoid nuisances from odour and potential health risks;
- possible increase in nuisance due to waste being dispersed by high winds;
- increased risk of fires at waste disposal sites due to high fire-danger days, increase in lightning frequencies associated with extreme rainfall events on very hot days; and,
- the possible risk of flooding or overflowing leachate control systems at landfill sites due to extreme rainfall events.

While climate change affects all countries, developing countries especially those classified as low- and middle-income are more at risk. An additional challenge facing developing countries is the lack of data relating to solid waste management and how this impacts on climate change (Koop & van Leeuwen, 2017). Mitigation and adaptation are two approaches that cities can employ to deal with climate change. At the core of mitigation strategies is the reduction of green house gassess (GHG) responsible for climate change impacts, while adaptation strategies are essentially reactive or based on risks and vulnerability. Examples of adaptation in waste management is planning for increased or localisded flooding, which may disrupt collection services. Managing flood related waste i.e. diverting what can be recycled to these facilities, and what can not be recycled to other treatment options, especially if these are likely to result in a nuisance or health and safety issues followed by disposal (Newton *et al.*, 2011). Mitigation measures might include reducing the green house gasses associated with diverssion of the organic fractions of solid waste including garden waste and food waste from landfill to other treatment options like biofuels and anaerobic digestion (Duku, Gu & Hagan, 2011; Kemausuor, Kamp, Thomsen, Bensah & Stergård, 2014).

According to Koop & van Leeuwen (2017), developing countries account for 93% of urbanization globally, of which 40% is reportedly characterised by the expansion of informal settlements. This is also true considering, poverty levels, the limited tax base (for instance also due to high unemployment rates), relatively small economies, a lack of baseline data (for both waste and climate-related impacts) and increasing service delivery challenges (i.e. backlogs) (Dulal, 2016; Ezeah & Roberts, 2012). All these contribute to making these countries vulnerable to the impacts of severe climate events.

The purpose of this paper is to highlight the importance of and roles of good solid waste management following severe weather induced disasters. This paper is based on a review of literature which discusses similar occurences of severe weather from relevant international literature and provides some guidance on this topic.

2 THE POLICY CONTEXT OF DISASTER MANAGEMENT IN ETHEKWINI METRO

A disaster is defined (in South African legislation) as being either progressive or sudden, widespread or localised, natural or human-induced, which results in death or injury, damage to property, disruption to community infrastructure or the environment (RSA, 2002). The term, therefore, alludes to a very broad set of circumstances, any of which could result in a disaster being declared, and managing the waste from one is equally as complex.

One of the consequences of climate change is likely to be the increased frequency and severity of natural disasters (Agamuthu et. al., 2015; EEA, 2010). The national legislation concerning a disaster is contained in the amended Disaster Management Amendment Act, No. 16 of 2015 (RSA, 2015). The Act provides for an integrated and coordinated approach (between national government and local municipalities) to disaster management, reducing risk and severity, facilitating emergency preparedness, recovery, national, provincial and municipal disaster management centres, and disaster management volunteers. The eThekwini metro's response to a declared disaster is outlined in the metros disaster management plan (eThekwini Municipality, 2016a), and coordinated by the Municipal Disaster Management Centre. The municipal disaster management plan also recognises a number of natural disasters including severe storm events. A Disaster Management Advisory Forum is established and chaired by the Municipal Manager, whose office coordinates roles and responses of the various line function and departments included in the response to an emergency. These include (but is not limited to): Metro Police, Health, Fire and Emergency Services, Housing, Parks Recreation and Culture and Durban Solid Waste (DSW).

The eThekwini Disaster Management Plan (eThekwini Municipality, 2016a) is a framework document which should be supported by detailed departmental plans compiled by the different line departments. Under solid waste management, the following required tasks are stipulated:

1. Compile a departmental risk management programmes.
2. Compile plans to ensure continuation of solid waste services during emergencies / disaster situations.
3. Submit and ensure regular review of plans.
4. Provide a representative at the disaster operations centre when this is activated.
5. Advising of facilities for the disposal of hazardous waste.
6. Advising of facilities for incineration.
7. Provide refuse bags and/or skips for the collection of debris and waste from affected area.
8. Maintain a schedule for waste removal from Assembly/Reception Area.

9. Maintain a database of staff resources (positions, posts, areas of responsibility and contact details).
10. Provision of any other interventions in accordance with statutory obligations and / or the dictates of the circumstances.

The detailed departmental plans (i.e. including from DSW) should be recorded within the framework document (or alternatively included as appendices). It is recommended that a copy of the detailed plans from each department (especially regarding solid waste management planning) be included in the overall disaster management plan. Following, taken from the latest IWMP, is an indication of how waste is managed within the metro.

3 WASTE MANAGEMENT IN ETHEKWINI METRO

The eThekwini metro is located on the eastern seaboard of South Africa. It has a landmass of 2 297km² and is home to approximately 3 555 868 people divided into 103 wards (based on the 2015 IDP) (eThekwini Municipality, 2016b). The metro currently manages four landfill sites including; Bisasar Road (with a limited capacity for receiving additional municipal solid waste), Buffelsdraai, Mariannhill and Lovu (commissioned in July 2014). Waste is brought in for landfilling from the surrounding landfill catchment areas. The municipal integrated waste management plan (IWMP), provides a breakdown of the different waste streams generated by the inhabitants of the metro, which are then disposed to landfill (based on data from 2013 to 2015).

There appears to be a decreasing overall trend of landfilled material for the period reported between 2013 – 2015 in the Integrated Waste Management Plan, despite the growth in population and influx of people into the metro. This implies that there is a better diversion of waste from landfill. It should, however, be noted that domestic solid waste (collected by the municipality and also by private contractors and informal waste pickers) constituted between 53% and 57% (the majority of waste disposed of) during this 3 year period. The amount of domestic solid waste collected by private contractors appears to have decreased during this same period (i.e. 168 357 tons in 2014 down to 143 124 in 2015). Also, the total cover material (both brought on to landfill sites and purchased for landfilling) appears to have decreased (i.e. 490 930 tons in 2013, 484 653 tons in 2014 and 366 368 tons in 2015).

Business waste also appears to have been reduced, even though this is only a small component (i.e. 1% by mass for the period 2013 - 2015) of the waste landfilled year on year. It should also be pointed out that garden waste and mixed loads (consisting of general solid waste, garden refuse, and builder’s rubble as reported by the municipality) actually increased for the period 2013 – 2015. It is difficult to make any conclusive statements on the implementation of the waste hierarchy, given the short period (3 years) for which data was provided in the IWMP (at least a five year period of data would be required[1]), besides the overall generalisations made above. The detailed quantities and composition of waste disposed of at the city’s landfills are summarised in Table 1 and Figure 1.

[1] These 5 year records would need to be available as either daily landfill records which could be brought into context with floods or storms or alternatively monthly accumulated totals which could be compared to similar periods for the previous years as a comparison.

Table 1: Combined Landfilled Quantities (Source: eThekwini Municipality, 2016b)

Landfill	2013 Tons	%	2014 Tons	%	2015 Tons	%	TOTAL Tons	%
Domestic Solid Waste[2]	593 994	41	565 862	42	586 045	46	1 745 984	43
General Solid Waste[3]	168 357	12	145 994	11	143 124	11	457 498	11
Garden Refuse[4]	43 092	3	35 666	3	46 476	4	125 240	3
Builders Rubble[5]	100 330	7	76 399	6	99 718	8	276 460	7
Mixed Loads[6]	16 707	1	17 549	1	19 245	2	53 503	1
Sand & Cover Material[7]	482 135	33	434 464	32	354 558	28	1 271 223	31
Tyres[8]	1 553	0	1 600	0	1 065	0	4 218	0
Light Type Refuse[9]	326	0	653	0	1 501	0	2 480	0
Business Waste.	28 994	2	12 194	1	8 910	1	50 101	1
Purchase Cover Material[10]	8 795	1	50 189	4	11 810	1	70 798	2
Recyclables[11]	0	0	13	0	0	0	13	0
TOTAL	**1 444 283**	**100**	**1 340 583**	**100**	**1 272 452**	**100**	**4 057 518**	**100**

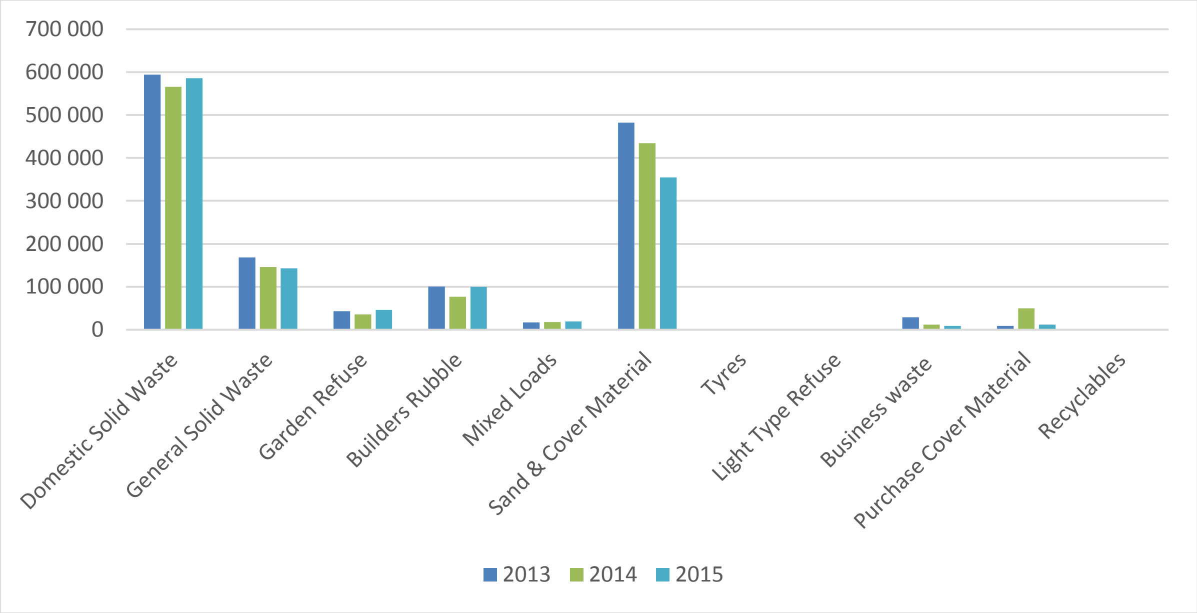

Figure 1: Graph Illustrating the Combined Landfill Waste Quantities in 2013, 2014 and 2015 (Source: eThekwini Municipality, 2016b)

The data contained in the IWMP in its current form does not provide an adequate basis to link severe storm or disaster events with the generation of solid waste within the metro. However the information provided here is important as it provides a context to solid waste generation within the metro. Future primary data collection will need to unpack and link solid waste to landfill with storm or disaster events. The following is a review on the likely housing structures at risk during severe storm or disaster events.

---

[2] Domestic Solid Waste, including commercial and industrial waste (non-hazardous) collected by municipal subcontractors.
[3] Domestic Solid Waste collected by private contractors
[4] Discarded plant/tree trimmings, grass cuttings, tree branches and trunks
[5] Non-hazardous material that from building or demolition projects, includes concrete, broken bricks and blocks.
[6] Mixture loads of general solid waste, garden refuse, builder's rubble.
[7] Soil used for cover material for the landfill cell.
[8] Discarded tyres (The REDISA Integrated Industry Waste Tyre Management Plan (IIWTMP) was first approved in November 2012).
[9] Includes plastic, polystyrene, insulation material and foam (easily wind-blown)
[10] Cover material purchased by DSW for use on the landfill.
[11] Loads of sorted recyclable material. This 13 tons of recyclable was diverted to the public drop off recycling station located within Mariannhill Landfill.

4 HOUSING STRUCTURES AT RISK DURING SEVERE STORM EVENTS

The table below (Table 2) provides some insight into the different types of housing structures within the metro. This is important as this might also provide some insights into the types of waste likely to result from severe storm incidents (i.e. primarily construction and demolition waste, and domestic or general solid waste from the make up of housing stock in the municipality). Informal housing structures in formal and informal settlements are generally not compliant with building regulations and these tend to be prone to failure and damage due to their poor structural integrity (The Housing Development Agency, 2013). It should be noted that informal dwellings within a backyard (also known as ‘shack farming’ in other cities) are also included in this percentage, these may be within an existing formal area (~4%). Whereas the second category of informal dwelling (not in the backyard at ~11.6%) are likely to be within informal settlements which together with their contents may be more susceptible during a severe storm especially if constructed within a 1: 100-year flood line or wetland. This implies that the poor are vulnerable to displacement which exposes them to additional risk because of urbanisation and encroachment, especially when located in natural ecosystems like drainage lines and on steep slopes (White, Turpie & Letley, 2017).

Table 2: Type of Dwellings in eThekwini (source: eThekwini Municipality, 2016)

Type Of Dwelling	Household	%
House or brick structure/ concrete block structure on a separate stand or yard or on a farm Traditional	592 990	62
Traditional dwelling/ hut/ structure made of traditional materials	40 188	4.2
Flat or apartment in a block of flats	95 027	9.9
Cluster houses in complex	15 704	1.6
Townhouse (semi-detached house in a complex)	10 580	1.1
Semi-detached house	17 956	1.9
House/ flat/ room in backyard	17 435	1.8
Informal dwelling (shack; in backyard)	37 981	4
Informal dwelling (shack; not in the backyard; e.g. In an informal/squatter settlement or on a farm)	111 307	11.6
Room/ flat let on a property or larger dwelling/ servants quarters/ granny flat	6 464	0.7
Caravan/ tent	733	0.1
Other	10 348	1.1
TOTAL	**956 713**	

Informal structures are frequently composed of wood, cardboard, metal sheets, mud and plastics (National Disaster Management Centre, 2017; The Housing Development Agency, 2013). These materials when damaged or contaminated beyond re-use, are likely to be generated as waste during a severe storm. It should also be noted that general household items from informal dwellings are likely to be washed away by flood events adding to the waste load generated as a result.

The severe storms driven by high winds as experienced in the metro during October of 2017, prompted this investigation into the impacts of this event on the implementation of the waste hierarchy. On 9th October 2017, eThekwini metro was hit by a massive storm which left five people dead and at least 18 others injured (Singh, 2017). The storm included extreme precipitation of more than 100 mm in 24 hours and high winds[12]. The aftermath of the storm is shown in Figure 2. Following the storm which also affected Gauteng and other parts of KwaZulu-Natal, the KwaZulu-Natal provincial government declared a disaster (Office of the KZN Premier, 2017).

The days following the storm saw debris (fallen trees, branches, construction and demolition waste, etc.) being cleared from the city roads and also from individual households. Road

---

[12] South African Weather Service (SAWS) issued a notice explaining the that the storm was caused by a cut-off low-pressure system (South African Weather Service, 2017).

access was limited in certain places, while the waste was removed[13]. Approximately 60 wards comprising 3 112 households mostly in the South of the metro were affected. Damage at Durban Solid Waste (DSW) depots including also at the landfill sites (including Mariannhill, Lovu, Buffelsdraai and Bisasar Road landfill) and other solid waste management infrastructure and plant was reported totalling R1 398 million Rand. Human Settlements reported damage of R250 million, which included informal settlements, new housing developments, retaining walls and roofs.

N2 adjacent to Isipingo and the old Durban airport[14]

Lena Ahrens Road (Manning Rd), Glenwood, eThekwini [15]

Collapsed wall outside King Edward Hospital in eThekwini [16]

Gauteng & KwaZulu-Natal were recently hit by severe storms that left a trail of destruction[17].

Figure 2: Images from press showing the storm aftermath

5 SEVERE WEATHER INCIDENTS AND SOLID WASTE

Prevention is certainly the best option. Waste prevention in this context will include limiting the housing developments at risk and the presence of informal settlements in floodplains (or drainage lines), maintenance and regular clearing of stormwater systems to avoid clogging that can result in exacerbated flooding and ensuring that dwellings and housing comply with appropriate building standards. Unfortunately, these provisions are out of the control of waste managers (although disaster management is a collective responsibility). Responsibility for implementing this lies with other line function departments (i.e. parks, housing, engineering and infrastructure) of the metro, and therefore collaboration in this regard across relevant line departments is suggested.

[13] There were localised disruptions to solid waste management service delivery while access was being restored. The disruptions were attributed to several factors including blockage of access roads because of fallen trees, flooded areas etc.
[14] Taken from https://www.news24.com/SouthAfrica/News/live-massive-storm-hits-durban-causes-flooding-chaos-20171010
[15] Image shared on twitter by Peter Mansfield (@Peterman43).
[16] Image shared on twitter by Kaveel Singh (@kaveels).
[17] Image shared on twitter by Reuters/Rogan Ward.

Brown *et al.* (2011; 2016) provide an interesting discussion on waste management options after a disaster, which are relatable to the waste hierarchy and include staging of waste, minimisation, recycling, and alternative treatment mechanisms. The temporary staging of waste provides authorities with an opportunity to better plan for recycling or other treatment operations, although this may bring into effect double handling of the debris. This could, however, mitigate the accessibility concerns allowing emergency response teams, access to affected areas requiring assistance. Care should be taken to ensure that these temporary staging areas do not cause additional negative impacts (i.e. an additional disease or vector proliferation or undue stress on communities) on the environment or on the community affected. Identifying these potential areas upfront by DSW may assist the eThekwini metro if built into the disaster management plan. The following is a discussion on mitigation of severe storm and disaster waste, including a discussion on the hazards associated with waste from severe or disaster related storms.

6 MITIGATING STORM AND DISASTER WASTE

Waste minimisation could be achieved through reuse of suitable building material such as bricks and corrugated iron. Storm-damaged fences and walls are a case in point, where the same bricks can often be reused to rebuild the wall. Uprooted vegetation should be replanted where possible and feasible, especially those plants that are resilient to being disturbed and are endemic to the area. This will not only reduce the volumes of garden waste but will also assist with the rehabilitation of the storm-damaged areas. Where large trees (or trees which contribute to a sense of place) cannot be saved, these could be composted if there are facilities for this. However, a challenge may arise if the green waste is contaminated with petroleum (fuel), chemicals (strong acids or bases).

Recycling can be applied to a number of building materials. Construction and demolition waste could also be used as aggregate for new construction or foundations for new walls or buildings. Wood waste could be used as alternatives to biofuel or sawdust (Oh & Kang, 2013). A number of authors list some advantages of recycling disaster associated waste including; reduced need for landfill space; reduced raw materials required in reconstruction; a source of revenue and resource saving; reduced need for transportation; reductions in greenhouse gas emissions (a climate change co-benefit) and even temporary job creation through the employment of communities or small local business, especially in clean-up operations (Brown *et al.*, 2011; Koop & van Leeuwen, 2017). Depending on the context there may, however, be some barriers to recycling including the long time to process the materials; possible need for specialised equipment; difficulty in separating the materials; the cost of recycling compared to other disposal options; the degree of mixing; associated hazards; community priorities; availability of funding; and compliance with disaster regulations (Brown & Milke, 2016; FEMA, 2017; Sasao, 2016).

Waste to energy may be an option with the unsorted fractions of waste (and depending on their calorific value), including wood, and large amounts of plastics if this can be done in a manner that controls atmospheric pollution (Gabrielli *et al.*, 2018). According to Agamuthu *et al* (2015: 2), "Every waste category that is generated has its own disposal challenges during normal condition. With the effect of the disaster, these … usually create new mixed categories that will increase … complexity". An understanding of the waste types (hazardous versus toxic debris like fuel, oil, other industrial raw materials that may be mixed up with the debris) and their context will assist with the best disposal options to manage the waste (Srinivas & Nakagawa, 2008; Tabata, Zhang, Yamanaka & Tsai, 2016).

Climate-related disasters often cause a large amount of waste to be generated. Despite the disruptions that inevitably take place, it is important to try and return to some form of normalcy. This includes clearing affected areas of debris, which also assist to open up transportation routes into affected areas. Malaysian authors have recently proposed 4 strategies for achieving good waste management during disasters. According to Yusof et. al. (2016), these include:

1. Proper classification of the waste material for recycling, recovery and disposal. This is to assist in the waste to be diverted to either reuse or recycling initiatives which could be initiated.
2. Improve the education and awareness of affected people to recycling and recovery options (i.e. promoting the waste hierarchy). Granted that, communities are generally traumatised and more concerned with recovery at this stage.
3. Where possible, control and decrease waste generation after a disaster, especially from households as these are the largest sources of domestic solid waste in the metro.
4. Improve where possible existing policies and legislation for waste management. This should be taking place within all of the different municipal departments.

This process of continual review and improvement assists with resilience and mitigation of the negative impacts associated with the disaster.

7 CONCLUSION

This paper sought to explore the issues related to extreme weather events on the implementation of the waste hierarchy using the case of eThekwini Municipality. The impacts of the 9th October 2017 storm provided the context of the study. The paper argues that waste associated with storms and other extreme weather events can be minimised if disaster management plans include enforcement of building regulations and regular maintenance of stormwater systems (cross-cutting responsibilities and functions as provided in the disaster management framework and act). The bulk of storm-related waste (construction and demolition waste and wood) is likely to be suitable for recycling, alternatively treatment and composting. Contaminated recyclables with high calorific values could be diverted for energy recovery if capacity is available. Service disruptions are likely to occur and the disaster management plans should provide mechanisms to address backlogs in waste collection services to avoid health and environmental impacts associated with service backlogs.

Solid waste management is an important element of disaster management including facilitating access for emergency services to affected areas. It is important where possible to plan ahead during times of calm. This can assist in managing and reducing the potential impacts of waste likely to be generated during a severe weather event. The waste hierarchy is a mechanism to inform decisions to effectively deal with wastes generated as a result of such events.

This research is part of ongoing work investigating the impact of severe storms on solid waste generation in the eThekwini metro. Based on the findings of this paper, it will be of interest to further investigate how the different categories of waste (especially construction and demolition, garden, and household waste) to landfill change with extreme weather events (i.e. wind or rain related). In order to do this, it will be necessary to interrogate solid waste generation in the metro over a longer period of time (five years compared to the three years' worth of data gleaned from the IWMP), and link this to incidents of extreme weather (i.e. either using indicators like wind speed and rainfall data available from South African Weather Services or alternatively formal declarations of weather-related disasters in eThekwini or the KZN province). A particular challenge to overcome will be the time delay between the period after a storm when waste has been generated and the time before clean-up operations start, which will, in turn, reflect in changes at the landfill site. It should be remembered that the time between the storm event and the waste arriving at landfill will vary on a case by case basis as no two storms are the same, also with regards to the areas affected and the magnitude of the damage caused. However, an improved and coordinated responses to waste management in such instances could facilitate an efficient and effective management of wastes following episodes of climate change-related extreme weather events. More particularly, the solid waste management unit should reprioritise its activities in the provision of timeous information about facilities suitable for the disposal of different categories of wastes including hazardous wastes.

8 ACKNOWLEDGEMENTS

The Authors are grateful to the CSIR for research funding towards this ongoing project (Dr. Douglass Trotter & Prof. Suzan Oelofse).

The authors are also grateful to the National Research Foundation (NRF) for the co-funding of a student intern (Ms Nombuso Qwabe) who has assisted in sourcing relevant literature for this project.

Secondary sources of information were provided by the eThekwini Metro, specifically Mr Raymond Rampersad, Mr. Robert Abbu, Mr. Logan Moodley, Mr. Dumisani Msomi (Durban Solid Waste), Mr. Kollin Citera and Garth Kloppenborg (Parks Recreation and Culture) and Mr. Stephen Hendrickse and Mr Thembinkosi Sishi (eThekwini Disaster Management Centre). Ongoing discussions between the authors and officials from eThekwini on the issue of Climate Change, Disaster Management and Solid Waste Management are taking place.

9 REFERENCES

Agamuthu, P., Milow, P., Nurul, A.M.N., Nurhawa, A.R. & Fauziah, S.H. 2015. Impact of flood on waste generation and composition in kelantan. *Malaysian Journal of Science*. 34(2):130–140.

Brown, C. & Milke, M. 2016. Recycling disaster waste: Feasibility, method and effectiveness. *Resources, Conservation and Recycling*. 106:21–32.

Brown, C., Milke, M. & Seville, E. 2011. Disaster waste management: A review article. *Waste Management*. 31(6):1085–1098.

Duku, M.H., Gu, S. & Hagan, E. Ben. 2011. A comprehensive review of biomass resources and biofuels potential in Ghana. *Renewable and Sustainable Energy Reviews*. 15(1):404–415.

Dulal, H.B. 2016. *Making cities resilient to climate change: identifying "win–win" interventions*.

EEA. 2010. *Mapping the impacts of recent natural disasters and technological accidents in Europe - An overview of the last decade*.

eThekwini Municipality. 2016a. *Municipal Disaster Risk Management Plan*. [Online], Available: http://www.durban.gov.za/City_Services/safer/Documents/eThekwini DM Corporate Plan.pdf.

eThekwini Municipality. 2016b. *eThekwini IWMP 2016 - 2021*. [Online], Available: http://www.durban.gov.za/City_Services/cleansing_solid_waste/Documents/eThekwini Municipality Integrated Waste Management Plan 2016 2021.pdf.

Ezeah, C. & Roberts, C.L. 2012. Analysis of barriers and success factors affecting the adoption of sustainable management of municipal solid waste in Nigeria. *Journal of Environmental Management*. 103:9–14.

FEMA. 2017. Public Assistance: Alternative Procedures Pilot Program Guide for Debris Removal. (Version 5). [Online], Available: https://www.fema.gov/media-library-data/1504811627145-34ecd2c18bbdfac97d78ff9ce8bac5c1/PAAP_Guide_for_Debris_Removal_v5_508_FINAL_06282017.pdf.

Gabrielli, F., Amato, A., Balducci, S., Magi Galluzzi, L. & Beolchini, F. 2018. Disaster waste management in Italy: Analysis of recent case studies. *Waste Management*. 71:542–555.

Kemausuor, F., Kamp, A., Thomsen, S.T., Bensah, E.C. & Stergård, H. 2014. Assessment of biomass residue availability and bioenergy yields in Ghana. *Resources, Conservation and Recycling*. 86:28–37.

Koop, S.H.A. & van Leeuwen, C.J. 2017. The challenges of water, waste and climate change in cities. *Environment, Development and Sustainability*. 19(2):385–418.

National Disaster Management Centre. 2017. *Annual Report 2016 to 2017*. [Online], Available: http://www.ndmc.gov.za/AnnualReports/NDMC Annual Report 2016 -17.pdf.

Newton, A., Thomas, C. & Greenhalgh, L. 2011. *Adapting Waste and Recycling Collection Systems to the Changing Climate*. [Online], Available: http://www.wrap.org.uk/sites/files/wrap/WRAP_CCA_Guide_final_Oct_2011.pdf.

Office of the KZN Premier. 2017. *Statement By Kwazulu-Natal Premier Willies Mchunu*. [Online], Available: http://www.kznonline.gov.za/index.php/component/k2/item/582-statement-by-kwazulu-natal-premier-willies-mchunu.

Oh, G.J. & Kang, Y.Y. 2013. The status of flood wastes treatment and future tasks in South Korea. *Journal of Material Cycles and Waste Management*. 15(3):282–289.

RSA. 2002. *Disaster Management Act 2002 (Act No 57 OF 2002)*. Government Gazette 39943, 22 April 2016. [Online], Available: http://www.ndmc.gov.za/Acts/Disaster Management Act (57 of 2002)(E-Book).pdf.

RSA. 2015. *Disaster Management Amendment Act 2015 (Act No 16 of 2015)*. Government Gazette 39520, 15 December 2015. [Online], Available: http://www.ndmc.gov.za/Acts/Disaster Management Amendment Act (16 of 2015).pdf.

Sasao, T. 2016. Cost and efficiency of disaster waste disposal: A case study of the Great East Japan Earthquake. *Waste Management*. 58:3–13.

Singh, K. 2017. *Massive storm, floods hit Durban, residents urged to stay indoors*. [Online], Available: https://www.news24.com/SouthAfrica/News/massive-storm-floods-hit-durban-residents-urged-to-stay-indoors-20171010 [2018, January 03].

South African Weather Service. 2017. *ABOUT TODAY'S SEVERE WEATHER SYSTEM OVER KZN: 10 OCTOBER 2017*. [Online], Available: https://www.facebook.com/WeatherServic/posts/703820006487992.

Srinivas, H. & Nakagawa, Y. 2008. Environmental implications for disaster preparedness: Lessons Learnt from the Indian Ocean Tsunami. *Journal of Environmental Management*. 89(1):4–13.

Tabata, T., Zhang, O., Yamanaka, Y. & Tsai, P. 2016. Estimating potential disaster waste generation for pre-disaster waste management. *Clean Technologies and Environmental Policy*. 18(6):1735–1744.

The Housing Development Agency. 2013. *KwaZulu-Natal: Informal settlements Status (2013)*. [Online], Available: http://thehda.co.za/pdf/uploads/multimedia/HDA_KwaZulu-Natal_Report_lr.pdf.

The Housing Development Agency (HDA). 2013. *South Africa: Informal settlements Status (2013)*. [Online], Available: http://www.thehda.co.za/uploads/files/HDA_South_Africa_Report_lr.pdf.

White, R., Turpie, J. & Letley, G. 2017. *Greening Africa's Cities: Enhancing the relationship between urbanization, environmental assets and ecosystem services*.

Yusof, N.S., Zawawi, E.M.. & Ismail, Z. 2016. Disaster Waste Management in Malaysia: Significant Issues, Policies & Strategies. *MATEC Web of Conferences*. 66(May 1994):00051.

Zimmerman, R. & Faris, C. 2010. Infrastructure impacts and adaptation. In Vol. 1196. New York Academy of Sciences *New York City Panel on Climate Change 2010 Report*. Chapter 4, 63-85.