Environmental and Socio-Economic Impact Assessment of Solid Waste Management Practices in Mbale city, Uganda

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Abstract

This study assessed the environmental and socio-economic impact of waste management practices in Mbale city. We used questionnaires, interviews, focused group discussions and field observations to collect the required data, which was analysed using basic descriptive statistics and Chi square test (χ^2). Results indicate that, the solid waste management practices employed in Mbale City resulted into degradation of air quality ($P<0.001$), water quality ($P<0.001$) and land ($P<0.101$). Socio-economic analysis indicated that costs of waste management practices outweighed the benefits. The management practices were associated with severe health issues to the households living near dumpsites and waste management employees, although revenue and employment opportunities were also created in some instances in remote areas of the city there is limited sorting of hazardous from ordinary wastes that have come with associated effects on the environment. A conclusion was reached that, despite employing many citizens, the present solid waste management practices in Mbale City responsible for injuries incurred by scavengers (waste collectors), land and air quality degradation as citizens lack knowledge of proper waste management systems. Therefore, City authorities should sensitize the masses on best waste management practices like sorting and recycling and provide incentives for collection, sorting and assemblage of recyclable non-biodegradable wastes.

Keywords: Dumping, Composting, Water pollution, Air quality degradation, Solid waste, Incineration

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Introduction

Waste management is one of the most poorly rendered services by municipal authorities in developing countries as the systems applied are unscientific, outdated, and inefficient because of the low economic returns from the trade (Beede & Bloom, 1995; Berglund, 2003). With an increase in the global population and the rising demand for food, water, and other resources, the amount of waste generated by each urban household increases daily.

One of the main aspects of concern associated with waste disposal and treatment is the pollution caused to the earth-be it lands, air, or water (Burmamu et al., 2014). Groundwater pollution occurs when hazardous substances come into contact with and dissolve in the water that has soaked into the soil. If rain or surface water encounters contaminated soil while seeping into the ground, it can become polluted and can carry the pollution from the soil to the groundwater. Groundwater can also become contaminated when hazardous liquid substances soak themselves down through the soil into the groundwater sources. This, therefore, calls for stringent sustainable urban solid waste management practices. While examining the mass-balances and life cycle inventory for garden waste windrow composting plants in Denmark, Andersen et al. (2011) observed that composting generated electricity for domestic use. However, it was associated with emissions leading to air pollution responsible for global warming and climate change.

While identifying and assessing the environmental impacts caused by waste management systems of mixed municipal waste for the city of Krakow for the year 2017, Katarzyna (2018) observed that all three management practices had a negative impact on the biophysical environment. Of all the three practices, mechanical biological treatment had little impacts as compared to incineration and refuse derived fuel. A study by Foday et al. (2013) on environmental and health impact of solid waste disposal in free town of Sierra Leone indicated that, the residents near and those far

away from the Granville damp site suffered from diseases like malaria, chest pains and cholera due to location of the damp site closer to their settlement. Ogbonna et al. (2007) assessed the impact the impact of solid waste management practice resulting from rapid population, uncontrolled and unplanned urbanization in Nigeria. The study discovered that Nigerian urban centres generated 207.3 tonnes at a per capita of 1.45kg per day. The shortfall with this study is that there was no mention of any solid waste management practice to be blamed for the environmental deterioration.

In East Africa, waste management in urban centers has for a long time been centralized (Goorah et al., 2009), involving the use of imported refuse trucks that collect wastes from sources or transfer points and deliver to designated waste dumps. Municipal solid waste management has however, evolved since the colonial days in the 50's and early 60's. Then, waste management systems were efficient owing to the lower urban population and adequate resources (Goorah et al., 2009) as compared to the status characterized by many inefficiencies. Assessment of effects of solid waste management practices on the welfare of the local community in Mombasa by Kalama (2016) indicated that, solid waste management practice led to job creation in the city and surrounding areas, was associated with health hazards, environmental pollution, soil degradation and ground water contamination.

In Uganda, waste is produced at a rate that outpaces the capacity to collect and dispose it off in a safe and environmentally sound manner in almost all of its urban centres, (Mbale city included) (NEMA, 2012).Wastes have ranged from minor litter in the urban centres that are not properly dumped in the designated collection sites to massive pollutants from the industries and human wastes not forgetting the garbage menace in urban centres like Kampala, Mbarara, Masaka and Arua cities. This has not only attracted public outcry but for a long time has attracted international

attention; a factor that has led to the implementation of various waste management practices and programmes in various parts of Uganda through mass sensitization to avert effects that come with improper waste disposal in urban areas of Uganda (NEMA, 2012). Although a study by Kalama (2016), shows that waste management practices suggested by the government of Uganda have come with a number of positive impacts on the locals. According to the World Bank (2010), these are associated with risks to human health and the environment ranging from safety hazards like explosions or fire, to increase in greenhouse gas emissions that calumniate into climate change. Despite these attempts/programmes by the government of Uganda, Mbale city has used a modified version of these practices that fits in its financial geographical- specific and socio-economic capacity of its population. The practices that have been implemented include open space dumping, river damping, incineration, rubbish pit, garbage bins. These however seem to be inadequate in controlling the effects that come with solid waste disposal in Mbale city and therefore associated with more harm than those recommended by government. This, therefore, calls for a critical assessment of each of the solid waste management practices in Mbale city on biophysical and socio-economic environment of Mbale city with a view that if they are associated with more negative than positive environmental and socio-economic effects, then better practices or further modification of the same is made.

Literature review

Most studies on the impact of solid waste management on the environment have considered one or two specific solid waste management practices, yet there is no single urban centre that utilizes only one solid waste management practice (Andersen et al., 2011; Foday et al., 2013). More so, the attempts to assess the impact of solid waste management practice have yet to be complete i.e,

they have either provided only a negative impact or only a positive impact of the practices on the environment (Nyakaana, 1997). Those that have tried assessing both positive and negative impacts have assessed the impacts on the only biophysical environment and ignored the socio-economic impact assessment hence leaving the environmental impact assessment of solid waste management practice incomplete (Kalama, 2016; Michael and Amir, 2016). According to Gumisiriza and Kugonza (2020), a complete assessment of the impact of solid waste management practices on environment should assess both socioeconomic and biophysical (both positive and negative) impacts on the environment and should consider more than two solid waste management practices. This paper contributes to the literature by assessing the impact of solid waste management practice on the biophysical and socio-economic environment of urban areas.

While identifying and assessing the environmental impacts caused by waste management systems of mixed municipal waste for the city of Krakow for the year 2017, Katarzyna (2018) observed that, all the three management practices had negative impact on the biophysical environment. Of all the three practices, mechanical biological treatment had little environmental impacts as compared to incineration and refuse derived fuel. Despite considering both positive and negative impact, this study considered only biophysical environment and did not consider the socio-economic impact assessment.

A study by Foday et al. (2013) on environmental and health impact of solid waste disposal in free town of Sierra Leone indicated that, the residents near and those far away from the Granville damp site suffered from diseases like malaria, chest pains and cholera due to location of the damp site closer to their settlement. This study's weakness was that it only considered one solid waste management practice called open damping and ignored other solid waste management practice. In addition, this study focused on only negative impacts on the biophysical and socio-economic

environment ignoring the positive aspects associated with the same. More so, the economic assessment of the practice was ignored hence an incomplete assessment.

Agarwal et al. (2005) noted that, a hierarchy of recyclable dealers plays an important role in the management of solid waste management. Recycling of waste has created business, which is a source of income for the dealers and has created employment of more than 66000 recycle dealers. While the study highlighted the positive economic impacts, it remained silent on the negative impact of recycling on the socio-economic as well as on the biophysical environment in which the recycle employees are living. In addition, unlike Katarzyna (2018), the study by Agarwal et al. (2005) concentrated on only one solid waste management practice.

While examining the mass-balances and life cycle inventory for garden waste windrow composting plants in Denmark, Andersen et al. (2011) observed that composting generated electricity for domestic use. However, it was associated with emissions leading to air pollution responsible for global warming and climate change. Despite concentrating on one method of solid waste management practice, the study assessed the socio-economic and biophysical impacts of composting on the environment.

Ogbonna et al. (2007) assessed the impact of solid waste management practice resulting from rapid population, uncontrolled and unplanned urbanization in Nigeria. The study discovered that Nigerian urban centres generated 207.3 tonnes at a per capita of 1.45kg per day. The shortfall with this study is that there was no mention of any solid waste management practice to be blamed for the environmental deterioration, no critical environmental and socio-economic impact assessment. According to Michael and Amir (2016), piles of solid wastes block drains adjacent to roads; the smells of rotting garbage and smoke from burning wastes have been reported in urban centres of Mbeya, Mwanza, Tanga, Dodoma and Moshi. In this work, there was no specific solid waste

management practice that was blamed for the negative effects on the biophysical environment. In addition, the socio-economic impact assessment of solid waste management practice still needs to be carried out.

While examining the generation, collection, and disposal of solid waste generated by 29 public technical training institutions in Kenya, Gakunga et al. (2012) observed that the 23 tonnes generated per week composed of vegetable and food remain cost the institutions from 0.13 – 0.59/week/student of the institutions. This study considered only negative economic costs but was silent about the positive economic impacts. There was no social and biophysical environmental impact assessment of the solid waste management practice. No specific solid waste management practice was mentioned in the study.

Assessment of the effects of solid waste management practices on the welfare of the local community in Mombasa by Kalama (2016) indicated that solid waste management practice led to job creation in the city and surrounding areas, and was associated with health hazards, environmental pollution, soil degradation and groundwater contamination. This is one of the studies that have exhausted a complete environmental and socio-economic impact assessment of solid waste management practice. However, the solid waste management practice in Mombasa is different from that of Mbale city due to differences in geographical location, town size and population size.

In Kampala capital city of Uganda, Nyakaana (1997) observed that the current approach of centralized, collection, transportation and disposal of waste proved to be inefficient as they are associated with heavy financial requirements. Most solid waste management practices are expensive and have been blamed for increase in municipalities' budgets. While this negative economic blame is slapped on solid waste management practice, the study was silent about

biophysical and social impact assessment of solid waste management practice. No specific solid waste management practices were blamed.

Gumisiriza and Kugonza (2020) found that in Mbarara city of Uganda, solid waste management has employed many people including but not limited to municipal technical officials, garbage truck drivers and their turn boys, garbage sorters and factory owners. In this study, recycling and open dumping are the major solid waste management practice blamed for environmental pollution. This study had a shortfall of assessing only economic and biophysical impacts and ignoring social impacts of solid waste management practice.

Materials and Methods

Study Area

Mbale City is located at the heart of Mbale District in Eastern Uganda, stretching between longitudes and latitudes 34°8'45.57"E to 34°12'29.15"E and 1°3'1.76"N and 1°6'24.70"N respectively. The city is made up of three political divisions including, Northern, Industrial and Wanale divisions (Figure 1). With an estimated population of 76493 people (National Housing and Population census 2014), the Mbale City was just recently elevated from a municipality status in July 2021. This population increase has come with increase in the per capita waste generation from 1.6 to 2.2Kg per person per day (Gumisiriza and Kugonza, 2020). The city covers an area of 518.8 Km^2 and acts as a regional administrative and commercial centre for several small towns and villages in eastern Uganda. This has made the city a garbage collection centre for the raw material supplies like food wastes, business (like shop and stationery) wastes. The city rests along the foothills of Mt. Elgon - Africa's largest and most massif solitary dormant volcanic mountain. Within this area, a bimodal type of rainfall is experienced mainly between March, June, and

September to November with average rainfall of 1500mm per annum. Temperature ranges from 7.5^0C to 27.5^0C. This is why all the inadequately solid wastes find their ways in the running rainwater and collects in the city centre that is located down slope. The city is drained by several rivers from the mountain including but not limited to Nabuyonga, Namatala and Nashibi so most of which have been used as dumping sites by some residents living adjacent to these rivers. The area has deep black volcanic soils derived from granitic gneiss rock system (NEMA, 1998).

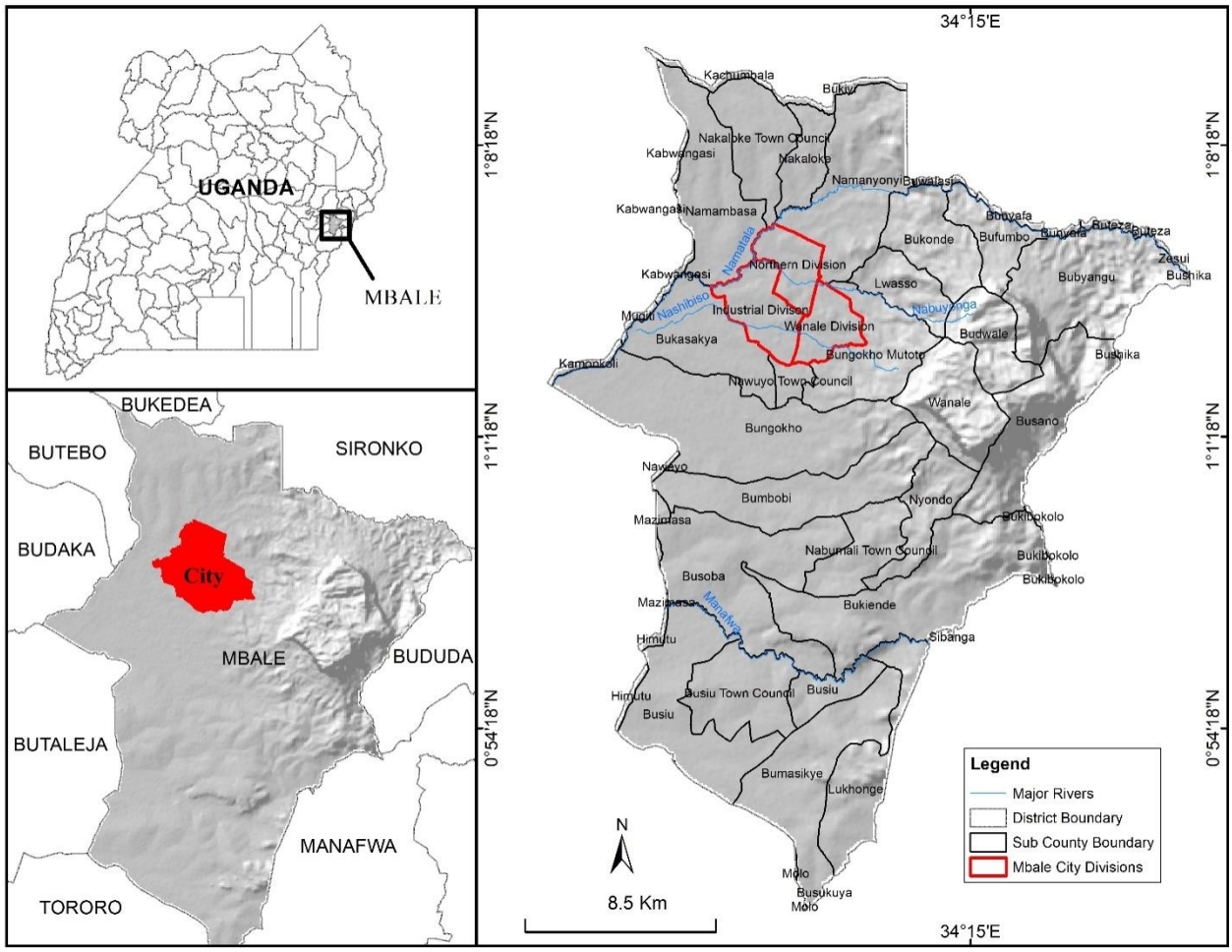

Figure 1: Location of Mbale City and its Divisions

Data Collection

This study relied on data from primary sources. Data was collected from the core city dwellers, peripheral city dwellers, city administrators and city waste managers. We used questionnaires, interviews and field observations to gain insights into the nature of the impact of waste management practices on the biophysical environment and socio-economic status of Mbale city. We recruited and trained field research assistants (10 per division) to support the administration of questionnaires to address the specific needs of this study. Questionnaires were administered to mature people above 18yrs of age. The questionnaires targeted information relating to socio-demographic data, job description, waste management practices, environmental effects of solid waste management practices and on health, and marital status.

The study made use of purposive, clustered and random sampling procedures. All the three divisions of the city were considered clusters. We subjected the population size of Mbale city of 119200people, to a sample size formula stated and described by Walter et al. (2001), and

Denoted by $S = \frac{Z^2 \times P(1-P)}{e^2 \times N} / 1 + \frac{(Z^2 \times P(1-P)}{e^2}$

Where, S is the sample size, Z is the Z-score (at 95% confidence level) , e is the margin of error (at 95% confidence level) and P is the standard deviation (at 5% margin of error) and came up with a sample size as 400.092, which we adjusted to 400.

Each of the divisions was considered as a cluster. In each of the Northern and Wanale clusters, 133 respondents were sampled given that their population sizes were almost the same, while the industrial division/cluster, we sampled134 people (owing to its bigger size than the former two) giving a total of 400 respondents. In each of these clusters, individuals were randomly selected for interview and questionnaires administration as long as they belonged to the cluster and these were

purposively selected as adults above the age of 18. This selection was because people of this age and above are the ones who have adequate knowledge about the waste management in the city. Interview and focus group discussions were held with the categories of persons mentioned above to gain insights into the opinions, attitudes and knowledge of local communities about the impact of solid waste management practices on biophysical environment and socio-economic wellbeing of people in the city. We used field observations to triangulate the questionnaire and interview responses. Questionnaires, interviews, discussions were made between December 2020 and June 2021 and responses were translated into English language. Open-ended questions were designed in simple English language, sent to respondents (residents, workers and authorities mentioned earlier), collected and later collected by our research assistants after two months). This was done to allow respondents enough time and convenience to elaborately give adequate responses needed for our study. Structured interviews were held with 4 representatives from each division administration, one community development officer of the division. Interviews were used to seek more clarification about technical information (especially recorded information including but not limited to, monthly/yearly budgetary expenditures on waste management in the city) which we would have missed if we only relied on observation and questionnaires. Data obtained from interviews and observations were tabulated as frequencies of occurrences of solid waste management practice used each cluster and added to that obtained through use of questionnaires.

Data Analysis

Data obtained from questionnaires, was analysed using statistical techniques while qualitative data collected by way of discussions, interviews and field observations were analysed qualitatively. Statistical analyses took the form of simple descriptive statistics that is, frequencies and percentages with the findings presented in tables. Owing to the categorical nature of the variables,

a Chi-square (χ^2) test was adopted to examine the most important waste management practices adopted under the different city divisions. In this test, we calculated the expected frequencies in each cell sung the formula in equation (i).

$$\chi^2 = \sum \frac{(O-E)^2}{E} \quad \text{.....(i)}$$

where $\chi^2$is the chi-square, O is the observed cell frequency, E is the expected cell frequency, and Σ is the sum of all cells in the table.

Results

Waste management practices

Waste management practices in Mbale city were categorized basing on how waste generated is spread in the city and waste treatment practices related to how waste has been handled at the final damping destination (Table 1).

Table 1: Solid waste management practices adopted in Mbale city

Practice	Number of adopters of different solid waste management practices in different divisions				Chi-Square (χ^2)	p-value
	Northern division	Wanale division	Industrial division	Total Frequency (N=400)		
Waste disposal practice						
Open space dumping	72	188	102	362	3.61	<0.001
River dumping	89	47	61	197	38.02	<0.021
Rubbish pit	95	126	48	269	42.9	<0.001
Garbage bins	34	54	-	88	243.36	<0.032
Multi-stage waste collection and transfer	39	21	18	78	259.21	<0.067
Open space burning	64	89	62	215	85.56	<0.001
Incineration	4	62	-	66	278.89	<0.083
Waste treatment practice						
Land fills	15	-	199	214	86.49	<0.001
Composting	2	-	34	36	331.24	<0.071
Recycling	-	-	99	99	226.5	<0.051

Open space dumping

Open space dumping was the most important (dominant), waste management and specifically waste disposal practice in Mbale city. This differed significantly among the three clusters at P<0.001 and a Chi (χ^2) 3.61. (Table1). The practice dominated Wanale division with 188 adopters but was least used in the Northern division with only 72 adopters. Every household, car park and shop is expected to have a waste dumpsite. For health safety purposes, these should be located 5-15 meters away from the residential house, depending on the availability of the space in a

household. The study revealed that some households in the city centre had limited spaces so they usually pile/pack their solid wastes in sacks until they are full then they can take them to bigger designated damp sites by local councils. Some people in the city centre especially the passers-by, travellers and some shopkeepers, have violated this norm by irresponsibly littering spaces with solid waste everywhere. The most dominant waste, in this case, include polythene bags, plastic bottles (for juice, water sodas), empty boxes, baby diapers and waste papers. Attempts have been made by city authorities who have employed local people to do the daily cleaning of streets by sweeping and picking rubbish, which they dispose in gazetted collection points where they are later picked by garbage collection trucks.

River damping

River damping was associated mostly with the Northern division with 89 respondents/adopters as opposed to the 47 in Wanale. Some careless homestead members and restaurant owners neighbouring rivers in the city have resorted to damping their wastes in the rivers. This was found to be done by people who lacked domestic damp site or dust bin and lack those who lacked garbage collection fees. Based on observation, Rivers Namatala, Nashibiso, Nabuyonga and other small tributary streams were seen chocked and silted by solid wastes packed in polythene bags, sacks and some plastic bottles were seen jam-floated in these rivers. It was reported by half of the total number of respondents that, these wastes are disposed in the rivers at night by unknown people not necessarily by the river neighbouring communities but also by communities from far. This practice differed significantly among the three clusters at $P<0.001$ (Table 1). Some of the dumping in the rivers was said to be committed by mad city dwellers.

Rubbish pits

Rubbish pits were mostly used in the Wanale division with 126 adopters, but not well embraced by the industrial division where only 48 people adopted the practice. Rubbish pits are constructed to manage solid waste disposal at a homestead level. The construction of rubbish pit is to avoid light solid waste from being blown by wind or easy spilling of /spreading of biodegradable wastes to the neighbourhood in case of rain fall. They are also important decomposing grounds for biodegradable wastes, which reduce on heaps (as shown in Figure 2). When the rubbish pits have accumulated a lot of rubbish, they are spread to dry so that the burnable wastes are set at blaze to reduce on the amount before transferred to another bigger collection centre. Some of the biodegradable solid wastes such as banana peels, leaves, rotting coffee husks were picked by interested farmers and taken to arable farms to enhance soil fertility. This was found to be the cheapest and second most significantly adopted practice of waste management in the city as reported by 67.3% of the total respondents. This practice differed significantly among the three clusters at $P<0.001$ (Table 1). It was however, noted that when the biodegradable rubbish are not handled well or emptied regularly, they were said to generate bad smell to the homesteads and are potential disease vector habitats.

Figure 2: A rubbish pit on residential premises in northern division in Mbale City

Garbage bins

There are bins that have been bought and used by individuals while others have been bought and distributed by city authorities in different sizes and placed in different strategic points in the city. Small sizes have been placed at points where less solid waste is usually picked, while large ones have been placed along busier places like food market streets, CBD (Central Business District) regions and abattoirs. People are encouraged to keep Mbale city clean by damping solid wastes in these bins. The wastes in these bins are periodically emptied by the city authorities, loaded on garbage trucks and taken to bigger damping sites. In some places where bins have not been placed, wastes have been heaped in open spaces (Figure 3). No single garbage bin was observed and or reported to have been used in the industrial division (Table1). This strategy concentrated in city centre as opposed to the peripheral regions as and differed significantly among the three clusters at$P<0.032$. (Table 1).

Figure 3: Open space dumping in Bugwere road market in Northern Division, Mbale City

Multi-stage solid waste collection and transfer

Very few people adopted multi-stage waste collection practice and specifically the fewest adopters (18) were found in the industrial division owing to the large amounts of wastes accumulated at ago (Table1). This practice did not differ significantly among the three clusters since P- values exceeded 0.05, i.e, $P<0.067$. In this practice, city authorities have organized multi-stage garbage collection and transfer system. Solid waste from individual household dumpsite or industry is transferred to parish collection facility from where city collection trucks pick it and transfer it to Dokho cell, which is the district treatment site for composting and land filling. Private waste management companies have also been tendered to supplement the collection of wastes although these levy a charge to the individual waste generators. The levy charged is based on the size and weight of the solid wastes generated.

Open space burning

This is practiced at all levels right from individual households to parish and city central damping sites and significantly differed from cluster to cluster at P<0.001. Accumulated wastes in the dumpsites when full are spread to dry and set at a blaze(Figure 4). Burning is done after sorting burnable from unburnable wastes. Burning at different levels reduces volumes and bulk of waste to be transferred to the central treatment facility in Dokho cell**.** The most commonly burnt solid wastes include polythene papers, empty boxes, dry banana leaves, plastics like empty bottles and fibres. Being at the core of the city with the highest open disposal, Wanale division recorded the highest use of open space burning with 89 users (Table1)

Figure 4: Open space burning of the non-biodegradable solid wastes in Mbale city.

Waste treatment practices.

Incineration

Being technical, expensive and only used in a few locations, incineration was the least popular waste management practice next to landfill used in Mbale city waste management and its

distribution from cluster-to-cluster was insignificant at P<0.083(Table 1). A rotary Kiln incinerator is used in combusting of organic substances and wastes, which were usually household wastes, clinical and hazardous wastes. Incineration method offered a solution of rapidly reducing the voluminous wastes, which were accumulating by turning them into ashes and transferred to landfill areas. Clinical and hazardous substances were best eliminated by this practice. The pathogens and harmful toxins in clinical wastes were perished in the high temperature of the incinerators. Since landfill areas are becoming limited, incineration method has become one of the useful ways of handling and managing solid wastes in Mbale City. This practice was dominant in Wanale division with 62 adopters (Table1). While Wanale division adopted only one waste treatment practice called incineration, industrial division heavily invested in landfills, compost and recycling plants.

Landfills

Landfills were the most dominant waste treatment practice adopted. This practice differed significantly among the three clusters at P<0.001. Landfills were excavations that received household (hazardous, non-hazardous) and commercial solid waste generated from Mbale city centre and peripheral regions. Five landfills in Mbale have so far handled wastes generated from Mbale city. The arrangement was such that, an excavation was made in igneous rock-based hill ensuring all possible leakages were covered with flexible geo-membranes that were put overlying 2ft compacted clay soil lining at bottom and sides (to protect ground water and underlying soil from leachate releases). Each time solid waste is delivered to this land fill, they are spread in the land fill (the ditch), compacted and covered with several inches of soil, leaving a well to be used for detecting and pumping leachate out from the land fill. Covering with the soil is to reduce odour, control litter, insects, and rodents and protect public health. When the landfill is full, it is covered, closed and protected.

Solid waste compositing

Composting solid waste in Mbale city is done on large scale using long rows of waste, moved by a tractor that uses "windrowing" equipment. Piles are managed with a manure fork, or a bucket loader attached to a tractor. Water is usually added when the waste piles dry for the microorganisms to live and work. When the temperature reaches 160^{o} F, the pile is turned. A compost thermometer with a long probe for reaching the interior of the pile is used for monitoring. When the compost texture is uniform, and turning the pile no longer results in a temperature rise, the compost is done (Figure5).

Figure 5: Composting plant in Dokho cell Mbale City

Waste recycling

Recycling wastes in Mbale city involved collection, separation, preparing the material to buyer's specifications, sale to markets, processing, and the eventual reuse of materials. In Mbale city, this

is done through intermediate markets dealers and brokers for recyclable materials who buy, pile and sell the recyclable wastes to factories/industries that convert these wastes back into usable materials. The materials recycled from Mbale city include aluminium, paper, plastics, iron and steel, scrap tires. Aluminium products that are recycled include gutters, door and window frames, flat irons, refrigerator accessories, car and motorcycle accessories, old, corrugated containers, mixed office waste, and high-grade wastepaper. Plastics are also recycled, the most common being polyethylene terephthalate (PET), or soft drink containers.

3.2 Environmental impact assessment of solid waste management practices in Mbale city

Environmental impact assessment of solid waste management practices in the study area were analysed in terms of costs of water, biodiversity, air land degradation and flooding and benefits in terms of soil fertility enhancement, ecosystem diversification and natural resources conservation with summary of the results displayed in Table 2.

Table 2: Environmental impact assessment of solid waste management practices

Environmental impact	Distribution of Environmental impacts of solid waste management practices in different divisions of Mbale city				Chi-Square (χ^2)	p-value
	Northern division	Wanale division	Industrial division	Total Frequency (N=400)		
Environmental Costs						
Water pollution	119	37	56	212	88.36	<0.001
Aquatic ecosystem degradation	10	1	29	40	324	<0.101
Air pollution	58	86	166	310	20.25	0.001
Land and soil degradation	27	88	92	207	93.12	<0.021
Flooding	23	7		98	228.01	<0.064
Environmental Benefits						
Soil fertility enhancement	29	20	3	52	302.76	<0.101
Conservation of natural resources		2	8	10	380.25	<0.071
Ecosystem diversification	5	3	9	17	366.72	<0.051

Costs

Dumping solid waste including packed rotting banana peels, dead animal carcasses (dogs and cats), heavy metals, polythene bags, plastic bottles that were observed in the rivers and streams were sources of water pollution. Leachate from Wastes dumped in open spaces also found their ways through solution (dissolved and runoff) into streams and swamps during wet season leading to water quality degradation. The degraded water quality affected humans who consumed water from these streams. This was the second most popular effect reported by the respondents. This cost differed significantly among the three clusters at P<0.001at P<0.001 (Table 2). Specifically, water

pollution was reported the most in the Northern division by 119 respondents, while the least affected division was Wanale by only 37 respondents.

The aquatic ecosystems have suffered losses of life and general aquatic ecosystem degradation. The solid waste dumped in the rivers directly and those that flow into the river as either solids or leachate of the solids from open dumpsites that have affected habitats, suffocation and eventual death of macroinvertebrates and fish thereby degrading the aquatic ecosystem health. Some fish species that used to be found in these rivers were said to no longer exist, while those that still exist have reduced in number. This was known to and mentioned by few respondents. This cost differed significantly among the three clusters at $P>0.005$(Table 2). At the division level, aquatic ecosystems were least degraded in Wanale as reported by only one respondent compared to the industrial division where 29 respondents cried for a help of their aquatic ecosystems.

The wastes dumped in rivers were seen to obstruct floating load and silting river and stream channels enhancing flooding of these rivers during rainy season. In the same way, open dumping was seen chocking engineered city drainage channels that had been made to direct rainwater away from the city. Careless disposal of solid waste directly into these channels blocked them. During the rainy season, dirty water with solid and dissolved wastes from the choked channels, flooded the city spreading the dirt everywhere making the city untidy. Wanale division being located at a higher altitude (at the foothill of Wanale ridge) was the least affected division by floods resulting from waste disposal. Conversely, industrial division located at the lowest altitude of the city received wastes from upslope, clogging water channels and flooding the division during rainy season. This was reported by 68 respondents.

Smoke from incineration at open dumpsites and from incineration equipment at Mbale major clinics and hospitals was noted to be important sources of air pollution. The burned plastic bottles,

polythene bags were said to produce greenhouse gases like carbon and methane, which affect ozone layer, and contributes to global warming. The smelly state of the environment was reported by people living near and far from the solid waste treatment and dumpsites more so during the rainy season when the smell turns like the one of a rotten egg. This has affected the majority of the city dwellers as indicated by the majority of the respondents (310). This cost differed significantly among the three clusters($P<0.001$), (Table2). As expected, air pollution was mostly felt in the industrial division with 166 reports

Land filling and open dumping of wastes were associated with spreading of non-biodegradable waste transfers of polythene bags, plastics, glasses and metallic sheets into the soil. These were found to reduce soil air and water movement as well as reducing amount of soil living organisms that help in the formation and development of soil. This has come with reduced soil fertility hence, soil and land degradation. This was found to affect more the people in city countryside- than their core counterparts. Having accommodated majority of the wastes in Mbale city, landfills were found to have significant impact on soil and land of Mbale city. This environmental cost differed significantly among the three clusters at ($P<0.002$).

Benefits

Adding compost from Mbale central waste treatment site to soil was said to increase organic matter content. This, in turn, was associated with improving many soil characteristics and allowing for the slow release of nutrients for crop use in subsequent years. This happened to be the only significant benefit of solid waste management practices among all the three clusters at $P<0.001$ (Table2). These benefits of soil fertility enhancement from solid wastes were least mentioned by 3 in the industrial division as compared to the 29 respondents from the Northern division who attested to these same benefits.

Recycling was observed to be a significant way of keeping large amounts of solid waste out of landfills. This practice did not only save on importation of raw materials, but was also seen to employ many people, conserve resources such as land and water.

The biodegradable wastes deposited in the rivers were said to have come with increase in new fish species population caught by natives at an artisanal level. The solid wastes created more habitats for the fish and macroinvertebrates. The rotting biodegradable waste produced nutrients fed on by fish and pollution tolerant macroinvertebrates thereby enhancing aquatic ecosystem health. The ecosystem diversification (alteration) arising out of solid waste management practices was more pronounced in the industrial division as indicated by 9 respondents as compared to the 3 respondents from Wanale division that attested to the same.

Socio-economic impact assessment of solid waste management practices in Mbale city

Socio-economic impact assessment of solid waste management practices was analysed in terms of health, body injuries, budgetary stress (costs) and in terms of employment and revenue generation (benefits).

Table 3: Socio-economic impact assessment of solid waste management practices

Socio-economic impact	Distribution of socio-economic impacts of solid waste management practices in different divisions of Mbale city				Chi-Square (χ^2)	p-value
	Northern division	Wanale division	Industrial division	Total Frequency (N=400)		
Socio-economic Costs						
Health effects	98	206	87	391	0.202	0.001
Physical body injuries	66	21	129	216	84.64	<0.001
Budgetary stress	12	27	18	57	294.12	<0.701
Socio-economic Benefits						
Employment	7	64	176	247	58.52	<0.001
Revenue generation	11	9	12	32	338.56	<0.671

Costs

Open dumpsites were associated with breeding of flies, rats and other vermin. During the study, it was observed that flies and cockroaches increased so rapidly that they were seen moving everywhere in homes of people living near these dumpsites. These were reported to spread diseases such as dysentery, cholera and plague. During the wet season, these same dumpsites have become breeding ground for mosquitoes, and this was the time malaria was reported to be rampant in the same area. This affected and was reported by the majority of the respondents (391). This socio-economic cost differed significantly among the three clusters at P<0.001(Table3). Negative health effects were more inflicted on the people of Wanale division as reported by 206 respondents than elsewhere in the city.

Because the city authorities do not provide separate waste collection facilities, many dangerous items such as broken glasses, razorblades, hypodermic needles and other healthcare wastes, potential explosive cans were reported to cause injuries to scavengers (workers in waste materials) and children who play in dumpsites. These injuries were mostly incurred by the 129 residents in the industrial division and least incurred by Wanale division residents. This socio-economic cost differed significantly among the three clusters $P<0.001$(Table3).

Financially, management of solid waste has absorbed a huge city budget and the cost of public cleaning, transportation and transfer of wastes from one local dumpsite to the central treatment facility is high. Payment of workers, purchase and maintenance of waste trucks and treatment facilities eats into the city's annual financial budget. The most affected was Wanale division but this socio-economic cost did not differ significantly among the three clusters since the P-values were >0.05(Table 3).

Benefits

People are employed in waste management activities ranging from sweeping streets, collecting, transporting and scavenging (sorting) and treatment of wastes at central treatment sites. The city council employs 247 men and women who are tasked with cleaning of the city daily. A number of private companies have won tenders to collect garbage from households to central collection points by employing natives. The jobs have earned people incomes that have enhanced their standards of living. It was reported that people working in the waste management activities in Mbale city earn between 3,000,000-7,200,000 Uganda shillings per annum depending on the position and activities in which one is involved. This was revealed by 247 respondents (Table3). The most employed population in solid waste management were found in the industrial and Wanale divisions with 176

and 64 waste employees respectively. This socio-economic benefit differed significantly among the three clusters at $P<0.05$

Mbale city has generated revenue from waste management practices because of taxing workers and private garbage collection companies. In addition, the compost manure generated at the central treatment facility is sold to farmers though at a subsidized price to generate revenue. Waste recycling plants also remit revenue to the government of Uganda through Mbale city financial protocols. Revenue generation from waste management practices followed the same order of magnitude as for the employment where, the highest revenue was generated from the industrial division as reported by the majority (12) respondents, while the least was generated from the Northern division. This socio-economic cost did not differ significantly among the three clusters since the P-values were >0.05(Table3).

Discussion

Environmental impact assessment of solid waste management practices in Mbale city

Dumping solid waste was associated with water pollution especially the Namatala river water. Leachate from landfills was also seen to cause water pollution through runoff. This is in conformity with Burmamu et al. (2014) who indicated that leachate liquid formed from water that trickled through the solid waste dumpsites and landfills in Jimeta-Yola during rainy season collected in the surface and ground water. Despite the similarity in the findings from both Jimeta-Yola and Mbale cities, Mbale city exhibited the worst-case scenario where wastes are introduced directly into the three rivers crossing the city irrespective of the season. This comes with increase in BOD, pH, total hardness, calcium, magnesium, sodium concentration, total dissolved solid, nitrate and total

alkalinity, which does not only affect aquatic ecosystem health but also humans that consume this water directly from the rivers.

The wastes dumped in rivers were seen to obstruct and silt river and stream channels enhancing flooding of these rivers and engineering city drainage channels during rainy season making the city untidy. Okereke et al. (2016) indicated that city waste has a potential of causing flood in urban centers. Similarly, Shekdar et al. (2009) earlier observed that open waste dumping was associated with flooding in most Asian cities. Flooding is not desired if city beauty is to be maintained. This means that the cause of this flooding should be avoided by daily cleaning the city of the waste. Although a few attempts to clean the city daily have been adopted by authorities in Mbale city, this has only concentrated on collecting light wastes dumped in the city centre, leaving that under the culverts and inside Rivers in the outskirts of the city.

According to Goorah et al. (2009), exhaust fumes from waste collection vehicles, dust stemming from disposal practices and the open burning of waste also contribute to overall health problems. In the current study, smoke from incineration at open dumpsites and from incineration equipment at Mbale major clinics and hospitals was noted to be important sources of air pollution. The burned plastic bottles, polythene bags were said to produce greenhouse gases like carbon and methane, which affect ozone layer and contributes to global warming. This practice calls for a need to copy and adopt better handling practice such as those used in the United States where, solid wastes are burned in a controlled environment, commercial fume hoods are used to control the carbons produced from fumes of the burned solid wastes.

Shekdar et al. (1991) observed that, polythene bags are not biodegradable and can remain in soils for many years without decomposing which creates eye sore in the soil environment. In the current study, we observed that, land filling and open dumping of wastes were associated with spreading

of non-biodegradable waste transfers of polythene bags, plastics, glasses and metallic sheets into the soil. These were found to reduce soil air and water movement as well as reducing soil living organisms. This has come with reduced soil fertility hence degradation.

According to Diaz et al. (2020), composting and recycling the municipal waste in the United States produced manure that contributed to agricultural soil productivity. In the current study, compost from Mbale central waste treatment site is sold to farmers at a subsidized price to soil increases organic matter content and improves soil productivity, which in turn increases on agricultural production in the region. In Mbale city, however, this composted manure produced is still in limited amounts due to the high cost of processing it. A lot more financial resources need to be invested in the practices of collecting more and producing more to reach an extent of giving out compost to farmers for free since agriculture benefits everybody directly and indirectly.

According to Sanko et al. (2013), recycling solid waste was resorted to as a solution to limited raw material (raw material substitution), this is because, solid wastes are cheaper and easier to re-use in factories than raw material. In addition, recycling was seen as a saviour of environment of accumulating solid waste. In the current study, recycling was done to save environment although at a small scale since the activity is expensive and has been left for private investors. Given the fact that the urban area has just been elevated to the city status, more financial resources are expected to be invested in the same and future for this activity is expected to improve.

The solid wastes created more habitats for the fish and macroinvertebrates. The rotting biodegradable waste produced nutrients fed on by fish and pollution tolerant macroinvertebrates thereby enhancing aquatic ecosystem health. This is in line with Turyahabwe et al. (2021) who observed that solid waste discharged from fresh food market at Nabongo created food and habitats

for pollution tolerant macroinvertebrates such as filter feeders. It should, however, be noted that was accidental and had not been intended for the same purpose.

Socio-economic impact assessment of solid waste management practices in Mbale city

Open dumpsites were associated with breeding of flies, rats and other vermin. These were reported to spread diseases such as dysentery, cholera and plague. During the wet season, these same dumpsites have become breeding ground for mosquitoes and this the time malaria was reported to be rampant in the same area. This does not differ from Foday et al. (2013) who noted that, household residents at Granville Brook Dumpsite, Freetown, Sierra Leone, especially those who are closer to the dumpsite complained that the dumpsite was too close to their houses causing them many sicknesses, smelly and filthy environment.

Sanko et al. (2013) observed that, the ills of inappropriately disposed municipal solid wastes are quite numerous including accidents, injuries and explosion of some non-biodegradable waste.Because the Mbale city authorities do not provide separate waste collection facilities, many dangerous items such as broken glasses, razorblades, hypodermic needles were reported to have caused injuries to scavengers (workers in waste materials) and children who play in dumpsites.

While carrying out economic analysis of different types of formal and informal entrepreneurs, recovering urban solid waste, in Bangalore (India), World Bank (2010) indicates that, individuals in the city had turned to waste collection as a form of employment. In our current study, we found out that in Mbale city, people have been employed in waste management activities ranging from sweeping streets, collecting, transporting and scavenging (sorting) and treatment of wastes at central treatment sites. A number of private companies have won tenders to collect garbage from households to central collection points by employing natives.

Conclusions and policy implications

The study aimed at carrying out a complete assessment of the impact of solid waste management practices on the biophysical and socio-economic environment of Mbale city. Findings indicated that there was no solid waste management practice that had only negative impacts on biophysical and socio-economic environment; most of them had both negative and positive impacts on the biophysical and socio-economic environment. The solid waste management practices used in Mbale included, open space dumping, river damping, incineration, rubbish pit, garbage bins, multi-stage waste collection, open space burning, composting, landfills and recycling. These solid waste management practices were associated with biophysical environmental degradation in the forms of water, air and soil pollution, flooding and aquatic ecosystem degradation. Socio-economically, these solid waste management practices did not only enhance health hazards like diseases, causing body injuries, but also came with financial stress on the annual city budgets. It should, however, be noted that the solid waste management practices used in Mbale have had positive impacts on the biophysical and socio-economic environment of Mbale city in the form of enhancement of soil fertility where the composted and decomposed manures are used by farmers. Solid waste management has employed over 247 people and the manure that is composted at the central composting plant is sold to farmers to generate revenue for the city, though at a subsidised price.

This study, therefore, recommended that, Mbale city authorities should make use of local media houses to sensitize people on how best they can dispose their wastes and should promote re-use (recycling) by increasing on the incentives of collection, sorting and assembling recyclable non-biodegradable wastes.

City authorities should ensure that, dump sites are located in gazetted and isolated areas of at least 20 meters away from the nearest homesteads to minimize effects of the solid wastes on the

environment such as flies and vermin encroaching on homesteads and causing diseases as well as limiting the bad smell from these rotting wastes.

City authorities should ensure regular multi-stage collection strategy is emphasised to empty collection centers in time before they over-fill and block drainage channels. This can be done by recruiting and training adequate staff for scavenging, composting and recycling of solid wastes.

City authorities need to invest in promoting awareness and advancing education to the city dwellers on the effects of improper waste disposal practices through knowledge and skills sharing platforms such as training, conferences, seminars, which can best be done by decentralizing them to the smallest political unit such as zone level. This will aid in minimizing the scattering of waste disposed in open spaces.

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References

Agarwal, A., Singhmar, A., Kulshrestha, M., & Mittal, A. K. (2005). Municipal solid waste recycling and associated markets in Delhi, India. *Resources, Conservation and Recycling, 44*(1), *73-90.*

Andersen, J. K A. Boldrin, T.H. Christensen, and Scheutz, C. (2011).Mass balances andlifecycleinventory of homecomposting of organicwaste.*WasteManagement31: 1934-1942*.DOI:10.1016/j.wasman.2011.05.004

Beede, D. N., & Bloom, D. E. (1995). The economics of municipal solid waste. *The World Bank Research Observer, 10(2), 113-150.*

Berglund, C. (2003). *Economic efficiency in waste management and recycling.* Doctoral dissertation, Luleåtekniskauniversitet.

Burmamu, B. R., Law, P. L., Aliyu, H. H., & Ibrahim, Y. (2014). Environmental impacts and management strategies of solid waste disposal in Jimeta-Yola, Nigeria. *International Journal of Environmental Engineering Science and Technology Research*, *2*(3), *3-7.*

Diaz, L. F., Savage, G. M., Eggerth, L. L., &Golueke, C. G. (2020). *Composting and recycling: municipal solid waste*. CRC Press.

Foday, P. S, Xiangbin. Y, Quangyen, T. (2013). Environmental and Health Impact of Solid Waste Disposal in Developing Cities: A Case. Study of Granville Brook Dumpsite, Freetown, SierraLeone. *Journal of Environmental Protection*, 4, 665-670 http://dx.doi.org/10.4236/jep.2013.47076

Gakunga. N. K, Gitau. A.N, Njoroge. B. N. K, Kimani. W. M (2012). Solid waste management in Kenya. A case study of public technical training institutions. *ICASTOR Journal of engineering. .5 (3),127-138*

Goorah, S. S. D., Esmyot, M. L. I., & Boojhawon, R. (2009). The health impact of nonhazardous solid waste disposal in a community: the case of the Mare Chicose landfill in Mauritius. *Journal of Environmental Health*, *72*(1*), 48-55.*

Gumisiriza, P. & Kugonza, S. (2020). Corruption and solid waste management in Mbarara municipality, Uganda. *Journal of environmental and public health.vol.2020 (10) 1-10. Doi 10.1155/2020/4754780*

Kalama. N.K (2016). Effects of solid waste management projects on the welfare of local community. A case of solid waste management projects in Mombasa city, Kenya. M.A thesis in project planning and management, university of Nairobi

Katarzyna. G. (2018). *The environmental impact of solid waste management systems. E35 web of conferences. 31(4):793-9. Doi 10.1051/e35 conf/20184500020*

NEMA (2012). *The state of environment report for Uganda,* NEMA, Kampala, Uganda.

Michael. Y, &Amir. K (2016). *Solid waste management in urban centres of Tanzania. Leap frogging towards a circular economy. A technical report. Doi. 10.13140/RG2.2.15647.15520*

Nyakaana, J. B. (1997). Solid waste management in urban centres. A case of Kampala city – Uganda. *The east African geographical review 19 (1) Pg 33-43 Doi 10.1080/00707961.*

Ogbonna, D. N., Amangabara, G. T., & Ekere, T. O. (2007). Urban solid waste generation in Port Harcourt metropolis and its implications for waste management. *International Journal of Management of Environmental Quality. (*18 (1), 71-88, doi.org/10.1108/14777830710717730*).*

Okereke, J. N., Ogidi, O. I., &Obasi, K. O. (2016). Environmental and health impact of industrial wastewater effluents in Nigeria-A Review. *International Journal of Advanced Research in Biological Sciences*, *3*(6), *55-67.*

Sankoh, F. P., Yan, X., & Tran, Q. (2013). Environmental and health impact of solid waste disposal in developing cities: a case study of granville brook dumpsite, Freetown, Sierra Leone. *Journal of Environmental Protection*.Vol.4(7), pp.665-670. doi: 10.4236/jep.2013.47076

Shekdar, A. V. (2009). Sustainable solid waste management: An integrated approach for Asian countries. *Waste management*, *29*(4), *1438-1448.*

Shekdar, A. V., Krishnaswamy, K. N., Tikekar, V. G., & Bhide, A. D. (1991). Long-term planning for solid waste management in India. *Waste management & research*, *9*(6), *511-523.*

Turyahabwe, R., Mulabbi, A., Asaba, J., & Olowo, M. (2021). Ecological Responses of Macroinvertebrates to an In-Stream Ecosystem Restoration Technique in a Tropical Stream in Eastern Uganda. *East African Journal of Environment and Natural Resources*, *3*(1), *129-144.*

Walters, S., Campbell, M**.**, & Paisley, S. (2001). Methods for Determining Sample Sizes for Studies Involving Health-Related Quality of Life Measures: A Tutorial. *Health Services and Outcomes Research Methodology.* 26(2):115-21DOI:10.1023/A:1020102612073

World Bank. (2010). *The World Bank Annual Report 2010: Year in Review.* World Bank Annual Report. *Washington, DC. © World Bank. https://openknowledge.worldbank.org/handle/10986/5906 License: CC BY 3.0 IGO.*