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Environmental Risk Indices for Municipal Solid Waste in the City of Dar es Salaam, Tanzania: Assessing Pressure-Response Relationship

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Abstract: This paper based on the previous study which used DPSIR model and analytical hierarchy process (AHP) to assess environmental risk from Municipal Solid Waste in the city of Dar es Salaam, Tanzania, by *Kazuva, et al., (2018) The DPSIR Model for Environmental Risk Assessment of Municipal Solid Waste in Dar es Salaam City, Tanzania. Int. J. Environ. Res. Public Health 15(8)*. In that study the Comprehensive Environmental Risk Index-(CERI) was categorised into five major indices of drivers-pressure-state-impact-response, as simulated from the model. Despite that each index contributed significantly to the CERI, pressure and response indices have been found with peculiar features. While pressure index showed the greatest influence to the alarming state of environmental pollution, response index found with dictating power to the trend of other indices. Therefore, this study intends to present the relationship between pressure and response indices from the established environmental risk indicator system, by using the experts' questionnaires method and the AHP. Analysis was done by computing trend of the two indices in the period of 12 years (2006-2017). Literally, pressure and response indices have been found with opposing tendencies for the entire period of assessment. The response index with all its subordinates have continued found with a controlling power over pressure index. It slows down the risk value for pressure index, thus withholding the ERI from reaching the critical point (>0.8). However, this power has not been effective and sufficient to suppress the entire pressure which was constantly increasing in upward trend, somewhat threatening ecological environment and human health in urban setting.

Keywords: Environmental Risk Assessment, Municipal Solid Waste, Pressure-response Relationship, Ecological Environment, Human Health, Urban Sustainability, Dar es Salaam

1. Introduction

Human socio-economic activities that that took place over the past two decades, have created massive changes in lifestyle and general consumption patterns. This has resulted into rapid increase in both the volume and diversity of municipal solid waste (MSW) worldwide that do not match with the available management approaches [1]. The rate of mismatch between generated and collected MSW is so wide and considered to be one of the major sources of environmental pollution in large cities [2, 3]. The concern is more serious in urban areas of developing countries as further triggered by the rapidly increasing populations and levels of urbanization, which have not been accompanied by necessary expansion of basic services [4, 5].

Dar es Salaam, the largest and main commercial city of Tanzania, urbanization stands at 5.1%, and more than 70% of its dwellers are living in slums and under-serviced settlements [6, 7]. These areas are characterized by the extremely poor management of MSW due to a number of factors, including poverty, poor infrastructure, and inadequate waste management plans and appropriate approaches [8]. The city is therefore, confronted by a problem of accommodating its rapidly growing population, providing it with basic urban services and enhancing socioeconomic development, while ensuring environmental sustainability.

As of 2017, the population of this city reached 5.78 million people [7, 9] and the MSW generation rate stood at 0.82 kg/capita/day [10]. Therefore, approximately 4,740 tonnes were produced per day, while less than 1,500 tonnes (35-40%) were collected [8]. Of the collected amount, only about 1,000 tonnes reach the final disposal location, the Pugu garbage dump site (PGDS) [10]. Often, the remaining MSW is either not collected, burnt, or haphazardly dumped in illegal areas such as in open spaces, in streets, water bodies, beaches, and river banks. This behaviour causes mortality to marine biodiversity, tend to cause persistent floods from blocked sewage systems [11], outbreaks of epidemic diseases, and other health-related problems [12, 13].

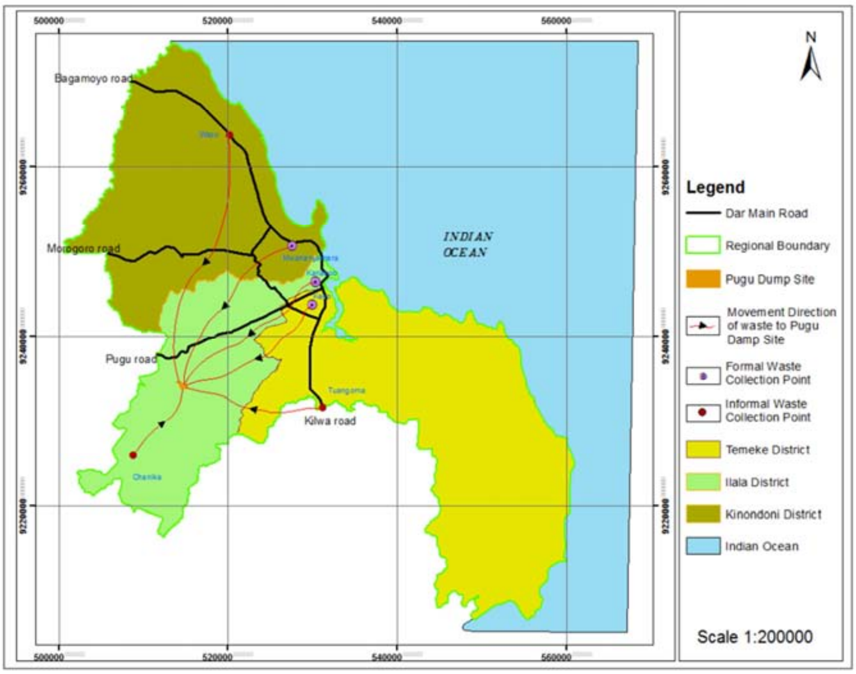
As being the trend for many fastest-growing African cities, including Dar es Salaam, their population doubles every 15 years [14]. Basing on the current per capita MSW generation rate [10], by 2030 amount of MSW generated may rise up to or above 7,500 tons/day; representing an increase of more than 63% from the current generation amount. Unless changes are made to the current management strategies, MSW will pause serious ecological-environment, and human health problems in near future. As prescribed in the previous studies, pressure index will be the leading among other causative factors for environmental risk from MSW, while response index will continue to be the controlling index for the trend of the comprehensive environmental risk index (CERI) [15, 16]. Therefore, for sustainable decision making, environmental risk assessment (ERA) of MSW is unavoidable, giving special attention to the relationship between pressure and response indices.

2. Material and Methods

2.1. Study Location

Dar es Salaam is located on a natural harbour of the eastern coast of Africa at $6^{0}48'$ South and $39^{0}17'$ East (-6.8000, 39.2833). It covers an area of 1393 Sq. km and is divided into five administrative districts: Ilala, Kinondoni, Temeke, Ubungo, and Kigamboni. The latter two districts were recently formed in 2016 after splitting up Kinondoni and Temeke, respectively. So, for clarity and easily access of the required data, consideration was made to the three districts; Ilala, Kinondoni and Temeke (Figure 1).

The city has more than 100 waste collection sites, ranging from skips collection points to large open areas [10]. Of these collection sites, only 13 are formal sites, receiving services include the monitoring of collection routines and maintenance. The rest are left with little or no pick-up services, turning into illegal dumping sites. For primary information as indicated in the previous study [16], a total of 7 sites, including a formal and an informal site, together with PGDS; the final disposal point of all MSW in Dar es Salaam, were used (See Figure 1). Researchers managed to collect valuable information from these sites. The sought information including the state of the sites, level of accessibility, frequencies of services provision, rate of material exposure to the surrounding human population, availability of MSW management facilities, workers' skills and expertise; to mention, but few.



Data Source: DLAs, 2017

Figure 1. *Map of Dar es Salaam locating the selected MSW collection points and their direction to PGDS.*

2.2. Why Pressure and Response Indices

As aforementioned, this study comes after the findings of the previous comprehensive study by Kazuva and his colleagues [16] on environmental risk assessment of pollution from MSW in the city of Dar es Salaam basing on DPSIR model, by using EQM and AHP. In that study, each entity of the model represented an independent risk index, showing its significant contribution to the CERI system for Dar es Salaam MSW. The model simulated the actual waste management system and the pollution level as being the function of driving forces, pressure, state, impact, and response indices, respectively. Of all the indices, pressure index was identified to have the greatest influence on the CERI. It was clearly indicated that, the index valued at 0.68 (risk value measure in 0-1 scale), which is a relatively high level (Level IV), denoting a poor condition of environmental state caused by large external pressure [16]

Different from other risk indices which their values indicated a continuous upward trend, the response index showed a continuous downward trend for the entire period of assessment (2006 to 2017)[16]. So, as for the current trend, the values for response index was confirmed decreasing while those for other indices were increasing. This relationship has been the motivating factor for the current study, with the intention to see whether response index has any controlling power over other indices.

Therefore, in this study, pressure index has been selected as the index with the highest influence to the CERI among others indices with homogeneous characteristics (continuous upward trend of risk values), while response index has been selected as the only index in the model showing a continuous downward trend of the risk values with influencing power over other indices [16]. The purpose of this selection is to add details and providing more insight on the variables upholding the two indices and establish a clear relationship among them as the two were identified to hold important positions in determining the CERI for current and future trend of MSW in the city of Dar es Salaam.

2.3. Data Sources for the Study

The selection of data was focused on the main objective of the study which was to assess the environmental risk that arises from inadequate management of municipal solid waste by analysing the relationship between the two selected indices. For effective ERA, the actual situation of the municipal solid waste management (MSWM) in the study area was of vital importance [17]. So, data used including the amount of waste generated and collected, major details of waste management systems: waste segregation, recycling, infrastructure systems, and risk preventive, protective, and mitigation measures. Others are human factors such as waste management experiences and workers' skills-sets; all of which were taken from 2006 to 2017 as the accepted risk assessment period (RAP) [18]. These data have been obtained from the reliable sources including the Vice President's Office (VPO)-environmental unit, the National Environmental Management Council (NEMC), and Dar es Salaam Local Authorities (DLAs). Information concerning population and demographic trends which formed the basis for risk assessment were obtained from the National bureau of statistics [6]. The study also consulted experts in the field using the EQM to obtain relative weights for the indicator system for DSM-MSW and other relevant literature sources for secondary data.

2.4. Establishing of Environmental Risk Index System for Pressure and Response Indices

For ease of analysis, the environmental risk index (ERI) system was divided into three layers: the evaluation elements layer or A-layer. This is the first layer, which comprised of two attributes of risk indices (pressure and responses), captioned as A_1 and A_2 respectively. The data indicators layer or B-layer; the second layer which consist of all indicators used to assess the evaluation elements as indicated from B_1 to B_9. The last is risk target layer or C-layer which consists of the risk evaluation factors based on the actual waste management situation in the selected sites, as indicated in from C_1 to C_{29} and other subordinates in D_{1-9} and E_{1-2} of the respective D and E sub-layers (Figure 2). From this hierarchical arrangement, a critical analysis of risk index (Category of risk used to calculate a fundamental beta like variability, vulnerability and general probability in risk analysis) from evaluation elements layer was conducted in relation to the contents of other two layers. This made possible to establish the relationship between the two indices of the subject matter.

Pressure index (A_1) refers to direct human anger to meet the basic needs for the survival of Dar es Salaam community [16]. It includes different socioeconomic activities, which result into waste generation. Indicators under this index are shown in the B-layer (B_1-B_5), which includes building and construction (B_1), population and society (B_2), institutions and services (B_3), energy and material consumption (B_4), and economic status of the place (B_5). These indicators have been divided into 18 factors, C_1-C_{18}, under C-layer and further sub-division in D and E sub-layers (see Figure 2).

With availability of pressure, the quality (state) of environment is continuously being destroyed and individuals are being exposed to the polluted environment. Majority of urban dwellers in this area are therefore subjected to the impacts related to the pollution from poor management of MSW, somewhat calls for the immediate responses. The response index (A_2), therefore, investigates the measures, plans, and approaches in terms of action or feedback from decision makers and/or the entire society to change, mitigate or restore the affected environmental quality [19]. This index involves all efforts directed to any part of the system, for the sake of restoring environmental original quality [20]. As prescribed in Figure 2, this study considers indicators for response index as institutional framework (B_6), education and publicity (B_7), governance and investment (B_8), and application of modern approaches and technologies (B_9). These indicators subordinated by factors from $C_{19\text{-}29}$ and $D_{3\text{-}9}$ from C- and D- sub layers, respectively. The fact here is that, any additional effort which puts responses attributes into a practical application, suppress the available pressure, and restoring environmental quality.

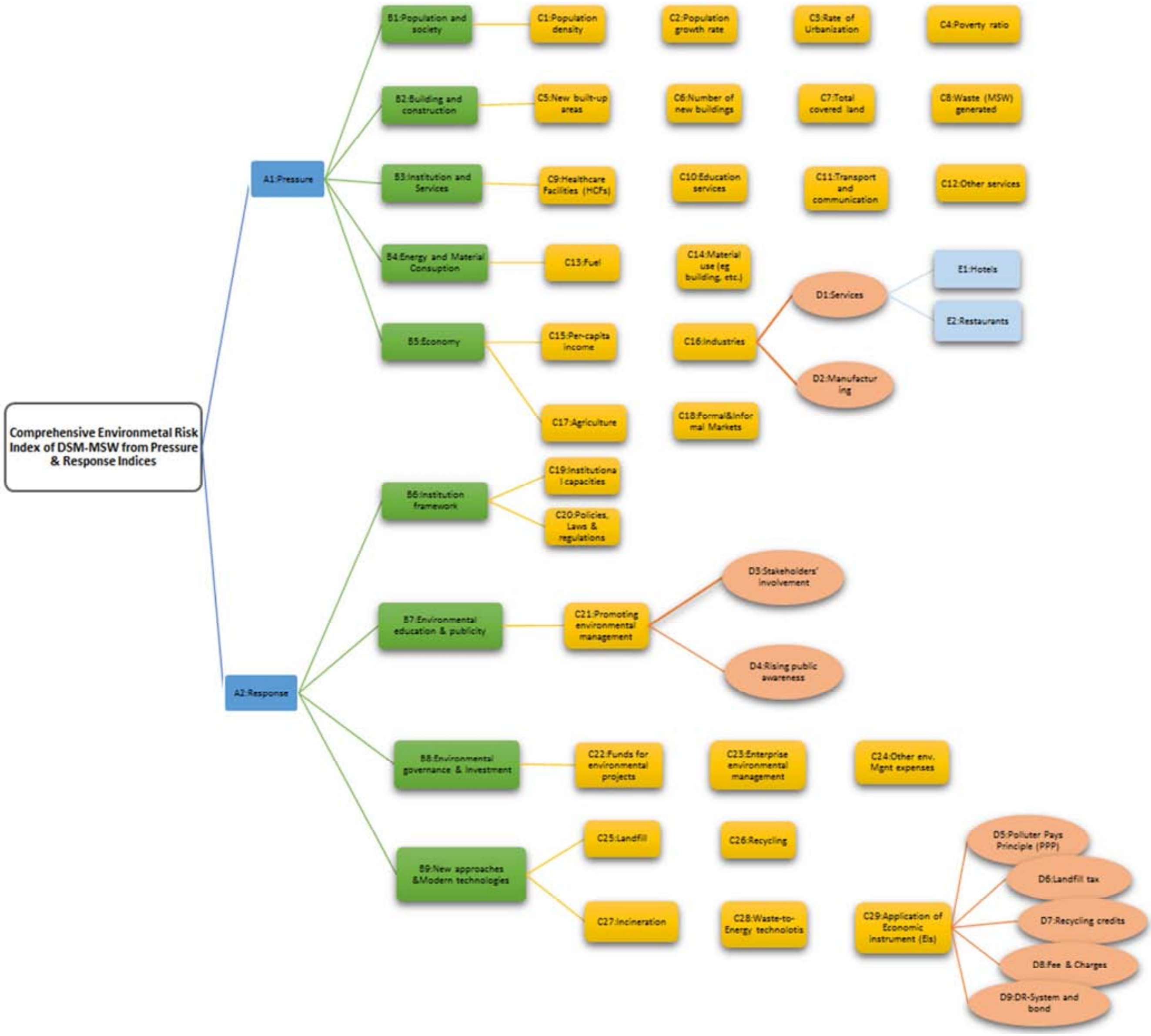


Figure 2. *Hierarchical Organization of ERI system for DSM-MSW for Pressure and Response Indices.*

2.5. Calculating ERI for DSM-MSW

As recommended by different literatures, one or a combination of methods can be used to calculate ERI for a complex system like that of Dar es Salaam [21-23]. The most common methods include the analytical hierarchy process (AHP), Fuzzy analysis, semi-structured decision making approach, grey correlation, expert questionnaires method (EQM), and scoring methods. In this study, as for the original work a combination of two techniques (AHP and EQM) were used [16].

Using the AHP and EQM

The EQM was used for generating opinions from experts in the field. In this technique, a total of 38 questionnaires were distributed among local and international experts, practitioners, and professionals, particularly in the field of MSWM in urban settings. The level of feedback reached approximately 92%, confirming it to be valid and worth using the obtained information.

The AHP was then employed for hierarchical analysis of the obtained index values, which helped to obtain the relative weights (average experts' score) for the indicator system of Dar es Salaam MSW (see Table 1). The technique (AHP) which has been extensively studied and refined, was first introduced by Thomas Saaty in the 1970s. This technique is based on a mathematical and psychological analysis which is done by combining subjective and personal preferences to organize risk factors in RA process [21, 24]. The method is considered one of the best structural techniques to process personal or subjective preferences of individuals or groups, using pairs of relevant factors to assess and analyze risk for suitable decision making [25]. The main assumption is that, "the process of making a global or other widely relevant decision on complex tasks can be performed by separating and structuring the respective complex system into several simple tasks in the form of a hierarchical structure and making the pairwise comparison of the parameters" [26-28].

For effective use of the AHP, three major steps are to be followed. These are (i) computing vectors of criteria weights, (ii) computing matrices of option scores, and (iii) ranking of options. However, for ease of analysis, researchers divided the three steps into five working steps of (i) structuring the decision hierarchy, (ii) completing a pairwise comparison of options, (iii) checking the consistency of material judgement, (iv) computing the weights of each alternative with respect to the experts' assessment, and (v) aggregating the weights to determine the rank of each alternative for decision making [23]. All these steps which have clearly elaborated in the primary work [16], were followed and the results successful obtained. The combined use of AHP and EQM was, therefore, relevant to the study, making it possible to quantify the weights of each index factor.

For decision-making purposes, the risk values were grouped into five distinctive risk levels (RL). Each level (I-V) with different thresholds, with a lowest at 0.1-0.2 and highest at 0.8-1 [29]. Table 1 shows the classification of risk levels, the remarks on pollution status of a particular level, and the ideal requires responses

Table 1. *Classification of risk level and interpretation guide.*

Risk Level	Value (weight)	Degree of Risk	State	The ideal required action
I	0.1-0.2	Extremely low	Low external pressure	Good condition, need to be maintained
II	0.2-0.4	Relatively low	Less external pressure	Good condition, need to be keen enough to avoid more disturbances
III	0.4-0.6	Medium	Environmental state is changing with external pressure	Need to work on the changing state
IV	0.6-0.8	Relatively high	Poor state with large external pressure	Immediate action & management programmes required at all levels of the system (DPSIR)
V	0.8-1.0	Extremely high	Serious damage due to great pressure	Dangerous environment for animals and human living; Urgency rehabilitation programmes are required

Classification of risk into these levels was relevant to this study, making it possible to define the exactly level that pressure and response indices fall into. The identified risk level provides insight and a reliable backings for the comparative analysis of the two indices. It was assistive for recommending suitable measures that are to be taken for sustainable environmental management in urban areas, based on the actual situation of MSW in the city of Dar es Salaam [30].

3. Results

As found in the previous study, ERI for Dar es Salaam MSW is grouped into five major risk indices simulated from DPSIR model. These are driving force, pressure, state, impacts, and response indices [16]. However, as aforementioned, this study analysed two indices (pressure and response) and their subordinates' indicators as the subsets of CERI system, shown from B- to E-layers in Figure 2. Generally, ERI for response index was found trending downward, with controlling power over pressure index which was in a continuous upward trend. To have control power of response index over pressure index is basically means that, any attempt in response to the pollution from MSW which adds more efforts to the system by energizing the response index (A_2) results into a practical suppression of pressure (A_1), which in-turn helps to maintain or restore the destroyed environmental quality, and the vice versa. The observed behaviour for each index and emphasis of their relationship are presented below:

3.1. Pressure Index (A_1)

The pressure index with its subordinates B_1 through B_5, confirmed to have the greatest influence on the overall ERI of Dar es Salaam MSW [16]. All indicators (B_{1-5}) as shown in Figure 3 are in a continuous and rapid upward trend from 2006 to 2017. However, there was observed minor fluctuation of trend of this index, mainly from B_2 (building and construction), especially between 2010 and 2016. In this indicator (B_2), the study considered factors like newly built-up areas, number of new buildings, total covered area, and waste material generated. Results shows that, this index (B_2) was the leading factor for the rapidly increased MSW in 2012 and slightly less to population and society (B_1) in 2013. The two indicators were approximately equally significant in 2014. From 2015 to 2017, there was a prominent decline in risk value from building and constriction, until it was below all other indicators except institutions and services (B_3). The underlying reason of this trend for B_2 was the remarkable shift in people's priorities from building and constructions; instead they started giving more attention to basic needs like paying for food, electricity, and water bills, paying for school fees and other basic services, since the beginning of the term of the current government regime [16]. Likewise, from 2006, all other indicators, except population and society (B_1), were increasing more or less interdependently until mid-2015, when the decrease in the risk index were apparently shown. However, despite this decrease, the trend (shown by the trend-lines) for each indicator was continued increasing upward.

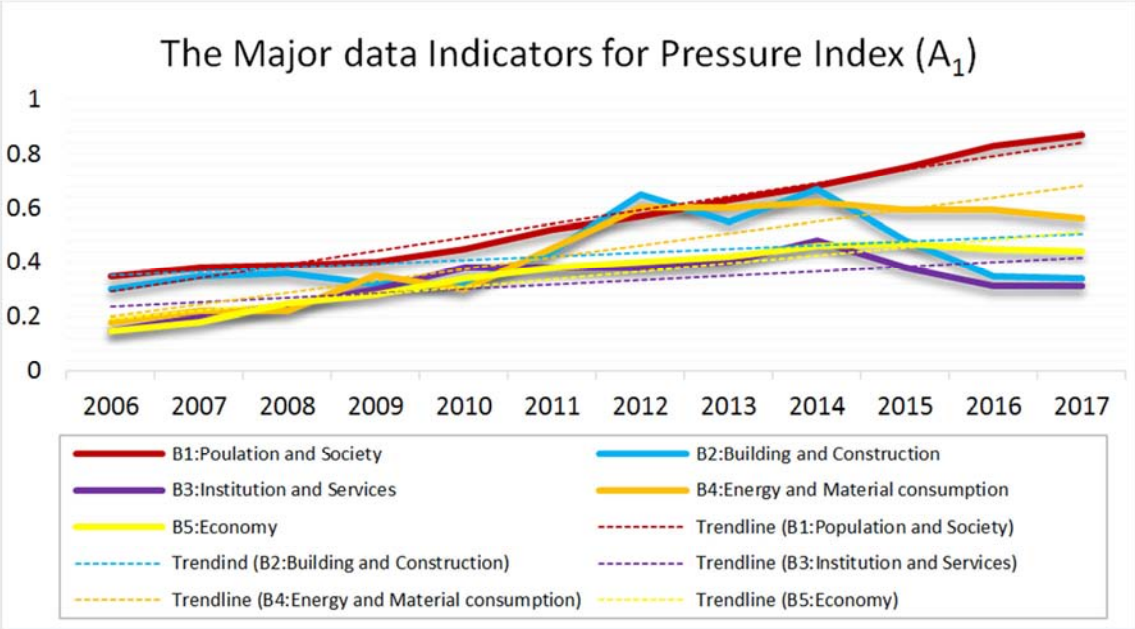


Figure 3. *The Major Data Indicators for Pressure Index- (A_1).*

Results indicate major differences of population and society (B_1) from other indicators. This indicator was found to have greatest impact on the rapidly increasing MSW in the city. It was influenced by different subordinates under C-layer, including high population density in most part of the city (C_1), rapidly growing population (C_2), high urbanization level (C_3), and poverty ratio (C_4). The trend for B_1 significantly increased from index value of 0.35 in 2006 to 0.87 in 2017. The 2017 value was greater than critical point (0.80) (ref. Table 1). However, the population living below poverty line (C_4) as one of the factors for B_1 was notably decreased between 2012 and 2017. This signifies an improving standard of living, which in-turn add to the volume of waste generated. As pointed out by Hossain and others [1]; the rate of waste generation is basically depending on a country's level of economy, the standard of social services, and individual ability to access those services (wealth of an individual). This idea is in consistent with the findings of this study which indicate that, increased per-capita income (GDP) as a subordinate under B_5 indicator in Figure 3 (also C_{15} in Figure 2), have greatly influenced the additional volumes of generated waste and so to the comprehensive ERI. Generally, the combination of behaviour for all indicators of A_1 index have influenced the upward trend of the index value is behind the continuous increasing environmental pollution in Dar es Salaam over years.

3.2. Response Index (A_2)

The response index stands for measures, plans, and approaches that are taken by government, private sectors, and general public as a feedback to the changed environmental state. The focus under response index is to change, mitigate and restore the affected environment and natural beauty. It also put much emphasis on reducing the level of vulnerability and individual exposure from the impacts of polluted environment. Results from analysis of indicators (B_6-B_9) for A_2 index indicate a continuous or fluctuating downward trend throughout the assessment period (Figure 4). The downward trend is an indication of a continuous efforts by stakeholders in capacity building for institutional framework (B_6), environment education and publicity (B_7), governance and investment (B_8) and application of new approaches and modern technology (B_9). These efforts include putting in place, the well-defined policies, laws, and regulations; and raising awareness about sustainable MSW and general environmental management (Ref. Figure 2).

From 2010 to 2017, B_7 and B_8 were observed with fluctuated downward trend, followed by increased risk level for B_8 and B_9 from 2015 to 2017 with an average increase of 0.07 and 0.03, respectively. This indicates a low level or reluctance of investing on MSW and related environmental projects ($C_{22\text{-}24}$), including application of modern technologies for MSW management [8]. Such technologies are, but not limited to building of modern landfill sites (C_{25}), recycling facilities (C_{26}), and incineration plants (C_{27}) as well as investing on waste-to-energy (C_{28}). Furthermore, the city was confirmed with low level and inappropriate application of new and modern economic instruments (EIs), Figure 2 ($D_{10\text{-}14}$) [8, 16]. Therefore, efforts made to suppress pressures and reduce the potential risk of MSW are inadequate to mitigate the problem.

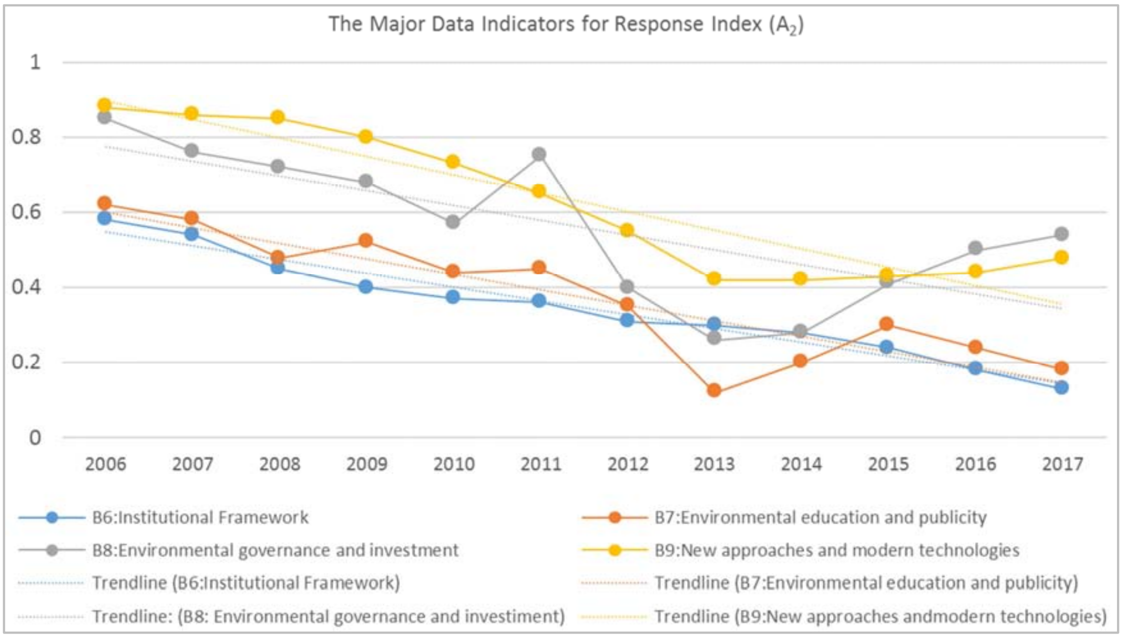


Figure 4. *The Major Data Indicators for Response Index (A_2).*

The findings indicate a significant differences between pressure and responses indices throughout the assessment period. The risk values for the indices are in contrary to one another. This behaviour signifies an interesting relationship and provide a significant information. That is to say, any attempts taken in form of response, results into a practical suppression of pressure, which in-turn helps to reduce the risk level and restore the destroyed environmental quality.

The main reason for opposing tendencies between pressure (A_1) and response (A_2) indices lie on the factors highlighted by Kazuva and his associates that, as long as human race exist and strive by engagement into different socioeconomic activities to meet the basics for living (driving forces); A_1 with all its subordinate is constantly increasing and waste is generated generation [16]. Needless to say, for human health and environmental sustainability, generated waste require effective management through sustainable use adequate treatment and disposal facilities (A_2– attributes). However, as the case for most cities in the developing countries, Dar es Salaam is confronted by low level and insufficient implementation of response index (A_2) as mainly caused by the lack of necessary infrastructures and capacity for monitoring [10, 16]. The influence of A_2 to A_1 has not been of much impact. The power of response index is not sufficient to suppress the entire pressure in the system. The value for A1 index was confirmed increasing in an upward trend, somewhat threatening ecological environment and human health in urban environment.

The researchers went further comparing the CERI for the two indices and the results indicate the same relationship. For instance, in 2006 when the responses were inadequate, the risk value counted 0.78, means the ERI was in relatively high level, approaching to a critical point (0.8-1.0). In other word, the ERI at the particular time was greatly influenced by the lack of proper and relevant response to the impacts brought by pressure index [16]. At the same time (2006), pressure index counted 0.36, a relatively low level, indicating a low level of external pressure to the system (Figure 5). So, despite the value for response index being high at this year, since the influence from pressure index was low, the ERI maintained at the relatively low level (Figure 6). This value for pressure index was slightly maintained until 2011, the year at which the two indices came into contact with a difference of 0.1, whereby response index was still preceded (see Figure 5). From mid-2011 onwards, ERI value for pressure index was high compared to that of response index until the last year of assessment (2017). This means that, despite the efforts from the government other stakeholders to reduce pollution level being evident, such effort are not sufficient to suppress all pressure from the system and so the value for pressure index is still in upward trend. The primary information indicates that the attributes for response index in this area are not effectively applied. Old and irrelevant approaches are still in-use, somewhat cause the value for pressure index to continue being high.

In all cases, the minimum value for A_1 was in 2006 (0.36) while the maximum was in 2015 (0.76). For A_2 index, the maximum value was in 2016 (0.78) while the minimum value was in 2017 (0.33). Literary, this is to say, while the response index is in continuous downward trend, pressure index is in upward trend with some fluctuations. Figure 5 compares the ERI of DSM-MSW for pressure and response indices.

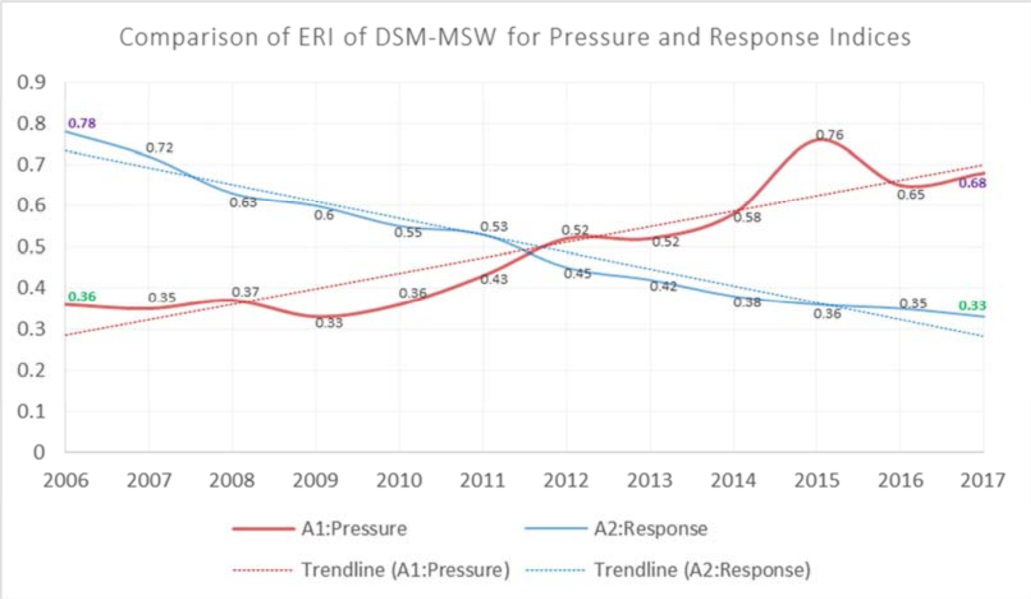


Figure 5. *Compared ERI of DSM-MSW for Pressure and Response Indices.*

3.3. Overall ERI for DSM-MSW

The comprehensive environmental risk index (CERI) for MSW in Dar es Salaam from 2006 to 2017 was obtained using multiple methods [16]. The trend-line for ERI showed a continuous upwards trend from its minimum value of 0.3489 in 2006 (See Figure 6). This value was within level II, suggesting a relatively low level of external pressures, which was a tolerable environmental conditions. However, in 2011, the ERI reached Level III with a value of 0.4351. This value was within the medium level (0.4-0.6), indicating a substantial increase in risk value due to external pressures. Astonishingly, the change from level II to III happened within a period of less than five years, signifying an increase of risk index value by approximately 0.0172 per year. As Figure 6 indicates, the CERI reached its maximum value (0.5606) in 2015, which was within level III, the medium level- (040-0.60) and close to level IV, a relatively high level of poor environmental state.

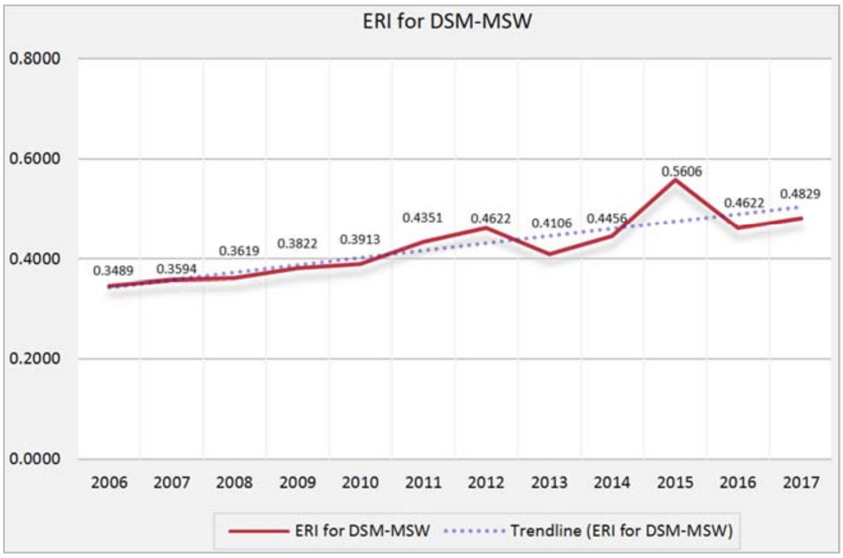


Figure 6. *Environmental Risk Index for Dar es Salaam Municipal Solid Waste.*

As Figure 6 shows, the risk index value declined in 2013 and 2016 by 0.0516 and 0.0984, respectively. This decline suggesting some improvement in management approaches (A_2). In particular, the decline reflected the responses from the government, communities, and other stakeholders through environmental management programs and campaigns slightly improved. For instance, during this period, the institutional framework (B_{18}), particularly institutional capacities (C_{59}) were improved, and environmental education and publicity (B_{19}) were greatly emphasized, therefore the risk values declined as a result (ref. Figure 4).

However, due to some factors dominated mostly by economic variables, this trend did not last long. There was a significant increase in risk value in the following years (2014 and 2017) (ref. Figure 6) despite the continued efforts from all concerned authorities to reduce environmental pollution (A_2). Therefore, this trend cannot be considered as an actual decline in risk index or decrease in environmental pollution, but rather as a merely fluctuation trend which clearly indicate that, the efforts made by implementing A_2 attributes were not enough to supress A_1 index. In addition, the final index values were still high (0.4829), featured by a continuous upward trend.

4. Discussion

The current techniques used for waste management in Dar es Salaam is not adequate so solve the existing problem. Although the effort in forms of response are patently shown, most of them are not compatible to the current demand. It is difficult to clearly state the relationship between pressure and response indices as for the trend in the least 12 years have never been stable. For instance, while response index was in downward trend showing a successive decline in risk value from 2006 (0.78) to 2017 (0.33), pressure index was in upward trend from 0.36 in 2006 with strong fluctuation especially from 2013 (Ref. Figure 5 and 6). The fluctuation was mainly influenced by building and construction (B_2), institutional and service (B_3), and energy and material consumption (B_4) (Ref. Figure 3). The primary information make it clear that the slight decline in pressure index in 2012/13 (0.52) and 2016 (0.65) from 0.53 and 0.76 respectively, was influenced by the effort made on response index, especially by improving institutional framework (B_6), put more emphasis on environmental education and publicity (B_7), and application of economic instruments (EIs), like polluter pays principle (PPP) and enforcing policies and by-laws (fees, charges and penalties- D_8). However, since these efforts were not sustainable, instead they only existed in short period of time, the decline in ERI values did not enduring as well. They were soon increased to 0.58 and 0.68, respectively. This information aids to increasing the existing knowledge on pressure-response relationship that, the response index plays an important role in modelling pressure index. It has the power to shape and influence the impacts brought by pressure attributes in all direction. Therefore, for sustainable management of MSW in the city of Dar es Salaam and other cities of homogeneous characteristics, providing more efforts, using suitable strategies and investing in modern technology are of paramount importance and inevitable.

In this manner, researchers recommend several improvement, start from the grass roots, by dealing with current response approaches. These include (i) improving institutional framework (B_6) through capacity building (C_{19}), timely formulation of demand-specific waste management policies, laws, and regulation (C_{20}); (ii) improving environmental management initiatives and investing more on environmental projects ($C_{22\text{-}24}$); and (iii) application of new approaches and modern technologies (B_9) which can be done by giving special attention to the aforementioned indicators ($C_{25\text{-}29}$ and $D_{10\text{-}14}$).

Generally, despite the current state of pressure index (being in upward trend), this study came with an important discovery that, adequate investment on A_2 index will manage to change the trend of A_1 index and work out on all the impacts of the changed environmental state and will eventually assist in controlling environmental pollution from MSW in the city. This can simply be done if the government concerned authorities are working effectively in collaboration with private sectors [31].

5. Conclusion

Being among the five fast growing cities in Africa, urbanization trend in Dar es Salaam is alarming and yet, population number is projected to double in every 15 years [14]. All these lead into a rapid increase of MSW generation rate to the level where the available management capacity cannot keep pace with it. As the result, pollution level is so high, jeopardizing the natural environment and human health. As highlighted above, pressure on natural environment in this area is so high, and if not checked, the state of environment will be even worse in near future.

In the absence of a proper waste sorting-out mechanism, the whole garbage is mixed up, leading to a higher risk to environment, service providers, and the public [32-34]. The mixed waste comprises a portion of usable materials such as waste paper, plastic, and some metals that can be directly recycled [35]. If well structured, this will not only serve as an employment opportunity to the country with high level of unemployment ration [8], but also will help to get rid of high level of pollution from MSW [36]. This suggests that, if the appropriate policies through the proposed A_2 index with its attributes ($B_{6\text{-}9}$) are enforced, waste will serve as a resource and an employment opportunity.

In general, this study highlighted the relationship between pressure and response indices as among the major indices for CERI for Dar es Salaam MSW. Currently, the relationship shows that, while values for pressure index are in upward trend, those for response index are in downward trend. However, it was also discovered that, any investment and improvement on A_2 index, change the trend of A_1 index and assist to reduce the alarming state of environmental pollution. Therefore, with an ambition to reduce the environmental and health risk attached to pollution from MSW, one has to work on all aspects of response index with special emphasis on application of new approaches and modern technology of dealing with waste.

Author Contributions

All authors contributed significantly to the preparation of this manuscript. E. K. is the principal and corresponding author of this manuscript, responsible for the collection, analysis, interpretation of data and final organization of the study results. J. Z. is co-author, responsible for sites selection, and ideas for analysis, interpretation of the study results and final revision of the document.

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Conflicts of Interest

No any conflict of interest among authors of this paper.

References

[1] Hossain, S., et al., *Clinical solid waste management practices and its impact on human health and environment – A review.* Waste Management, 2010. 31(4): p. 754-766, doi: 10.1016/j.wasman.2010.11.008.

[2] Chen, M., Xu, L., Liu, T., Huang, H., *The Ecosystem Health Assessment of Ganjiang River upstream frame model based on PSR.* Journal of Jiangxi Agricultural University, 2012. 34(4): p. 839-845.

[3] Xiao, Y., et al., *The composition, trend and impact of urban solid waste in Beijing.* Environmental Monitoring and assessment; Dordrecht 135.1-3: 21-30, 2007.

[4] Omran, A. and M. Gavrilescu, *Municipal solid waste management in developing countries: A perspective on Vietnam.* Environmental Engineering & Management Journal, 2008.

[5] Getahun, T., et al., *Municipal solid waste generation in growing urban areas in Africa: current practices and relation to socioeconomic factors in Jimma, Ethiopia.* Environmental Monitoring & Assessment, 2012. 184(10): p. 6337-6345.

[6] UN, *united Nations-World Population Prospects*. 2017, DESA / Population Division.

[7] NBS, *National Population Projections* 2018, United Republic of Tanzania- Ministry of Finance and Planning: Dar es Salaam, Tanzania. p. 13-15, 20-40.

[8] Kazuva, E. N., *Determinants of Individuals' willingness to use Economic Instruments for Solid waste Management in Dar es Salaam: The case of Mwananyamala and Mikocheni wards.* International Journal of Environmental Science & Natural Resources, 2017. 4(4): p. 8, 13-15, DOI: 10.19080/IJESNR.2017.04.555644.

[9] UN. *World Urbanization Prospects 2018*. 2018 [cited 2018 May, 22]; Available from: https://esa.un.org/unpd/wup/.

[10] Huisman, H., H. Breukelman, and B. Keesman, *Expert mission on integrated solid waste management (ISWM) to Dar es Salaam*. 2016.

[11] Sakijege, T., J. Lupala, and S. Sheuya, *Flooding, flood risks and coping strategies in urban informal residential areas: The case of Keko Machungwa, Dar es Salaam, Tanzania*. 2012.

[12] Kicińska, A. and M. Mamak, *Health risks associated with municipal waste combustion on the example of Laskowa commune (Southern Poland).* Human and Ecological Risk Assessment: An International Journal, 2017. 23(8).

[13] Omololu, O. O. and S. A. Lawal, *Population growth and Waste Management in African Cities*, in *University of Ibadan*. 2012: IbaFigure dan, Nigeria.

[14] UN-HABITAT, *Tanzania: Dar es Salaam City Profile*. 2009: Regional and information Offices, Nairobi, Kenya.

[15] Salon, E., et al., *"Life-Cycle-Based Solid Waste Management I: Model Development,"* Journal of environmental Engineering, 2002. 128(10): p. 981-992.

[16] Kazuva, E., et al., *The DPSIR Model for Environmental Risk Assessment of Municipal Solid Waste in Dar es Salaam City, Tanzania.* Int. J. Environ. Res. Public Health 2018. 15 (8), doi: 10.3390/ijerph15081692(8).

[17] Linster, M. and L. Fletcher, *Using the Pressure-State-Response Model to Develop Indicators of Sustainability*, O. E. D. S. o. t. E. Division, Editor. 2012: USA.

[18] Xie, H. and X. Zhang, *The measure and Countermeasure of ecological security in the suburban area in Beijing city of Haidian district as an example.* China Population Resources and Environment, 2004. 14(3): p. 23-26.

[19] Zebardast L, Salehi E, and A. H., *Application of DPSIR Framework for Integrated Environmental Assessment of Urban Areas: A Case Study of Tehran [J]*. International Journal of Environmental Research, 2015. 9(2): p. 445-456.

[20] Salehi, E. and L. Zebardast, *Application of Driving Force - Pressure- State- Impact- Response (DPSIR) Framework for Analyzing the Human habitat in City of Tehran* Space Ontology International Journal, 2015. 4(14s): p. 65-71.

[21] Saaty, T. L., *The Analytic Hierarchy Process*. 1980, New York, Pittsburgh. : McGraw Hill. RWS Publications International.

[22] Saaty, T. L., *Theory and applications of the analytical network process: decision-making with benefits, opportunities, costs, and risk*. 2005, University of Pittsburgh, Pittsburgh: RWS Publications.

[23] Saaty T, L., *The analytic hierarchy and analytic network measurement processes: Applications to decisions under risk.* European Journal of Pure and Applied Mathematics, 2008. 1(1): p. 122-196.

[24] Saaty T, L. and G. Vargas L, *"How to make a decision?", in Models, methods, concepts and applications of the analytic hierarchy process*. Vol. 1. 2001, Dordrecht: Kluwer.

[25] Vaidya, S. K., *"Analytic hierarchy process: an overview of applications,".* European Journal of Operational Research, vol. 169, pp. 1–29, 2006. https://doi.org/10.1016/j.ejor.2004.04.028 2006.

[26] Raybould, A., *Priciples of environmental risk assessment: reducing uncertainty in decision making*. 2010: Syngenta, p 147-168.

[27] Alonso, J. A. and T. L. Ma, *A Statistical Criterion of Consistency in the Analytic Hierarchy Process [C]*, in *International Conference on Modeling Decisions for Artificial Intelligence* 2005, Springer-Verlag. p. 67-76.

[28] Brent, A. C., D. E. C. Rogers, and M. B. Rohwer, *Application of the analytical hierarchy process to establish health care waste management systems that minimise infection risks in developing countries.* European Journal of Operational Research, 2007. 181(1): p. 403-424.

[29] Kelliher, P. O. J. and D. J. V. Wilmot. *A common risk classification system for the actuarial profession: A discussion paper* in *The Actuarial proffession: Making financial sense of the future*. 2011. Edinburgh, London, p. 1-38.

[30] Adrian, V. G. and N. M. Michek, *Integrated Raginal Risk Assessment: Consequence Assessment of Accidental Releases*. Vol. II. 1995, Dordrecht, The Netherlands: Kluwer Academic Publishers.

[31] Wilson, D. C., Velis, C., & Cheeseman, C., *Role of informal sector in waste management in developing countries.* Habitat International, 2006. 30: p. 797-808.

[32] Solomon, A. O., Oosterveer P, Spaargaren G. , *Household Solid Waste Characteristics and Management Practices in Dar es Salaam City, Tanzania [J]*. Journal of Solid Waste Technology & Management, 2010.

[33] Kihampa, C., *Environmental Exposure and and Health Concerns of Municipal Solid Waste Disposal in Dar es Salaam, Tanzania.* Journal of Sustainable development in Africa, 2013. 15(3): p. 198.

[34] Yhdego, M., *From a Sanitary landfill to a Dump site: Pugu Kinyamwezi Community Curse in Dar es Salaam, Tanzania*. 2017, ERC- Environmental Resources Consultancy Dar es Salaam.

[35] Zhang, Y., et al., *Urban city life garbage treatment technology status and management countermeasures.* Journal of Ecological Environment, 2011. 20(2): p. 389-396.

[36] Oberlin, A. S., *Resource recovery potential: a case study of household waste in Kinondoni municipality, Dar es Salaam, Tanzania.* Journal of Natural and Applied Sciences, 2013. 4(1): p. 563-574.