Journal of Environment and Earth Science www.iiste.org
ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online)
Vol.8, No.8, 2018

Solid Waste Management at University Campus (Part 5/10): Characterization and Quantification of Waste, and Relevance of the Waste Hierarchy in its Management

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Abstract
This is a-fifth-piece in a-series of 10, which is focused on the-following-issues, at the-subject-university: (1) solid-waste-characterization (composition-profiles, in %); (2) solid-waste-quantification; and (3) evaluation of the-relevance/applicability of Waste-Hierarchy-approaches to the-identified, by-the-study, waste- categories. To-characterize the-composite-solid-waste, from the-identified-waste-generators, the-ASTM D5231-92(2003): Standard-Test-Method for Determination of the-Composition of Unprocessed Municipal- Solid-Waste was applied, while UNEP-guidelines were used for waste-reduction, in-samples preparation. The-study revealed that: (a) the-largest-share (37%) of the-total-waste is food-waste; and (b) cumulative 62% are recyclables, or waste-materials, that have the-potential to-be-recyclable. The-study also-estimates, that the-university generates about 5, 111. 65 tons, of mixed-waste, per-year, on-average. Out of which: (i) Food-waste, which is compostable, accounts to 1,891.31 tons/per year; and (ii) Recyclables, included: paper (mixed & corrugated) - 32% (1,635.73 tons/per year); glass - 13% (664.43 tons/per year); plastic and metals, each - 8% (408.93 tons/per year); and E-waste and other-*non*-combustibles, each - 1% (51.12 tons/per year). Every-day the-university is literally throwing-away profit, as the-waste is just disposed-off at the-dumpsite, without any-formal waste-reduction, separation, at-source, recycling, or composting. The-study offers some-practical-recommendations on the-management of the-identified-recyclables and compostable materials, based on the-Waste-Hierarchy-options; areas for further-research are also identified. The-findings of this-research provide a-necessary-baseline-data, for the-five-subsequent-studies, in the-series, and also, hopefully, add to-the-body of knowledge, on the-subject-matter.
Keywords: Institutional solid waste management; Kenya, recycling, composting.

1. Introduction.

1.1. Waste, its-variability, and waste-stream-analysis.

According-to Zaman & Lehmann (2011); and Ezeah (2010), *waste* is 'abandoned-materials' that are deemed to *no* longer have a-functional-use, or economic-value, by the-owner, or producer, of the-waste. Numerous-factors influence the-characteristics of solid-waste, including (Liu & Wu, 2011): the-degree of urbanization and industrialization, social-customs, per-capita-income, and other-factors such-as: geology, geography, and climate. On-the-other-hand, Starovoytova (2018 a; 2018 b); Moore (2012); and Sembiring & Nitivattananon (2010), point-out, that waste is a-perception-based-subject; what represents waste, to-one-person, may-be-seen as an-appreciated and valued-resource, to-another.

Besides, by its-nature, waste is a-heterogeneous-material, in-terms of substances, materials, and products, and is, therefore, difficult to-describe, define, and classify (Williams, 2005). For-example, contents found, at the-subject-university-dumpsite, included: leftover-food; vegetable and fruit peelings/remains; animal-manure; grass-clippings; street-sweepings; polythene-papers and busted/turned-bags; packaging materials, used/broken-plastics and glass, rubber, old/turn clothes, small-pieces of charcoal, old-newspapers documents/examination-scripts/turned-pieces of books, used-photocopying and duplicating-papers, pieces of broken-furniture, metals, and pieces of artificial-hair, from beauty-salons, among-many-others.

The-composition and quantities of generated-waste is extremely-variable, as a-consequence of seasonal, lifestyle, demographic, geographic, and legislation-impacts, income-levels, lifestyle, household size, age, consumer-purchasing-habits, as-well-as energy-sources. This-variability makes defining and measuring the-composition of waste more-difficult, and at-the-same-time, more-essential (Mugo *et al.,* 2016; Katiyar *et al.,* 2013; Singare, 2012; Arsad *et al.,* 2006; Zekkos *et al.,* 2010; and Gidarakos *et al.,* 2005).

On-the-other-hand, the-final-output, of this-series, is focused on the-developing an-Integrated Solid-Waste-Management (ISWM)-model/system, for the-university-campus. At the-start of ISWM planning, it-is-important to-know, who the-waste-generators are, where they are located, how-much and what-types of waste they generate, and what their-current-knowledge, attitudes, practices, and experiences, are on-SWM. These-information is crucial to-the-development of the-key-strategies and components of an-ISWM-plan. Implementation of the-resource-based WM-model requires accurate-quantitative information as to the-character and composition of waste-streams (Baldwin & Dripps, 2012; Okeniyi & Anwan, 2012; Zhang *et al.,* 2011; Smyth *et al.,* 2010; de Vega *et al.,* 2009; Chang & Davila, 2008; Burnley, 2007; and Yousuf & Rahman, 2007).

Besides, according-to de Vega *et al.* (2008), SWM-program, based on the-knowledge, of the-waste-composition, and alternatives for waste-materials-recycling, is more successful, than ambitious-program, copied-from-elsewhere. Equally-important is the-knowledge of waste *quantities*, for calculating the-need for and the-size of waste-disposal-facilities, such-as incinerators, landfills, and recycling-facilities. Knowledge of both; waste-quantities and waste-composition is, therefore, vital for monitoring-progress, towards the-best waste-management-option, in *any* community (Osei-Mensah *et al.,* 2014). Thus, it-is paramount to-know the-generation-rates and composition of the-waste, prior to *any* campus-tailored-recommendations for the-ISWM-program, to be-made.

Reliable-SWM-data provides an-all-inclusive-resource for a-comprehensive, critical, and informative-evaluation of WM-options in-all WM-programs (Hancs *et al.,* 2011; Chang & Davila, 2008; Qdais *et al.,* 1997). Unfortunately, reliable-data is lacking, in many-developing-countries (Buenrostro *et al.,* 2001), and where the-data is available, it is largely-inconsistent (Ranjith, 2012; Couth & Trois, 2011; IPCC, 2006), due-to variation in-reporting-mechanisms (Burnley, 2007). For-example, Diaz *et al.* (2002) have pointed-out, that: "…in most developing countries there is a very limited amount of reliable information dealing with the characteristics of the waste generated," and moreover, that, "only a limited number of properly planned and executed waste characterization programs have been carried out". Kenya is *no* exception of this-data-deficit-problem.

Effective-management of solid-wastes requires a *complete* understanding of composition of wastes, as-well-as activities, involved in-its-generation (Farmer *et al.,* 1997). To-achieve a-sustainable-solution to-SWM, reliable-*first-hand*-information, on its-characteristics, is necessary (Ejaro & Jiya, 2013; Burnley *et al.,* 2007), to-estimate material-recovery-potential (Gidarakos *et al.,* 2005). Besides, analysis of waste flows, within-universities and institutions, is the-first-step in-designing successful and comprehensive waste management-system (de Vega *et al.,* 2008), towards environmental-protection (Smyth *et al.,* 2010).

The-Ecological Solid-Waste-Management-Act, Section 17, defines *waste-characterization* as "the identification of constituent materials which comprise solid waste generated and disposed of within an area. It identifies constituent materials by volume, percentage in weight or its volumetric equivalent, material type and source of generation which includes residential, commercial, industrial and institutional". Waste stream-analysis can be-defined as any-program, which involves a-logical and systematic-approach to obtaining and analyzing-data, on one, or more-waste-streams or sub-streams. The-analysis also-provides an-estimate of solid-waste-quantity and composition, referred-to-as waste-characterization.

In-addition, McCartney (2003) pointed-out, that there are a-variety of reasons, for conducting institutional-waste-characterization-studies: (i) to-guarantee regulatory-compliance; (ii) to-evaluate current practices, according-to best-practice-procedures; (iii) to-establish baseline-generation-data; (iv) to-identify waste-minimization-opportunities; and (v) to-develop indicators of institutional-sustainability.

Besides, according-to de Vega *et al.* (2009), there is a-need for standardized-waste-indicators, which universities can-use to-understand their-current-performance, track-changes, over-time, compare themselves with other-institutions, and share-sampling-methods and strategies, for SWM-plans. Waste composition-information has widespread-applications. It can-be-used for solid-waste-planning, designing of waste-management-facilities and establishing a-reference-waste-composition, for use as a-baseline to-monitor progress, towards diversion and recycling-targets, to-inform collection-systems and choice of alternative-waste treatment-technology (AWTT) options (ASTM, 2008; Dahlen & Lagerkvist, 2008). Moreover, according-to Oumarou *et al.* (2012); HEFCE (2012); Aguilar-Virgen *et al.,* (2010); and Crowe & Carty (1996) conducting a-waste-stream-analysis can-provide a-useful-baseline, by which to-measure progress, identify areas, where simple-changes could-make big-impacts, on-cost and environmental efficiency, and help-achieve national and international-legislative-compliance.

This-study establishes necessary *baseline* waste-generation-data, for promoting sustainable campus waste-management.

1.2. Previous-studies and purpose of the-research.

Many-studies on waste-characterization (at-different-levels, details, and scales) were done, at country and city-levels, all-over-the-world. For-example: ISTC (2014); Abramowitz & Yu (2012); Kahmeyer *et al.* (2011); CDM (2010); Hodoval *et al.* (2009); Green-Solutions (2009); and Nagawiecki (2009) - in the *U.S.A*. (mainly large-scale-studies); Adeniran *et al.* (2017); and Ejaro & Jiya (2013) - *Nigeria*; UNEP (2013) - *Sudan*; Omari (2015) - *Tanzania*; Mohee (2005) - *Mauritius*; Ozcan *et al.* (2016); and Nas & Bayram (2008) – *Turkey*; Oelofse & Muswema (2016) - *South-Africa*; Moniruzzaman *et al.* (2011) – *Bangladesh*; Ezeah *et al.* (2015); Burnley (2007) - *U.K.*; Croset (2014) - *Namibia*; Arazo (2015) – *Philippines*; Moore *et al.* (2012) – *Australia*; Smyth (2005); and Tetra-Tech (2016) – *Canada*; Marmolejo *et al.* (2010) – *Columbia*; Gidarakos *et al.* (2005) – *Greece*; Edjabou *et al.* (2014) - *Denmark*; Mugo *et al.* (2016) – *Kenya*; Mengesha & Dessalegn (2014); and UNEP (2010) - *Ethiopia*; AbdAlqader & Hamad (2012) – *Gaza-Strip*; Miezah *et al.* (2015); and Osei-Mensah *et al.* (2014) - *Ghana*; Ramakrishna (2016); Katiyar *et al.* (2013); and Harilal *et al.* (2007) - *India*; Taghizadeh *et al.*

(2012); and Damghani *et al.* (2008) – *Iran*; Gomez *et al.* (2009); and Hernandez-Berriel *et al.* (2008) – Mexico; Gu *et al.* (2015) - *China*; Thanh *et al.* (2010) – *Vietnam*; Forouhar & Hristovski (2012) – *Afghanistan*; Burnley *et al.* (2007) – *Wales;* Boer & Arora, 2010; Waste-Watch (2005) – England; and Parizeau *et al.* (2006) - *Cambodia,* among-others.

Review of the-listed-publications, revealed, that very-few-studies, however, were done on the-waste-characterization (composition), at a *university* context. Only a-small-number exist for the institutional-sector, mainly health-care-institutions (Mohee, 2005; McCartney, 2003; Farmer *et al.,* 1997), and even fewer-studies have-assessed the-composition of solid-waste, within institutions of higher-education (Armijo *et al.,* 2008; Mason *et al.,* 2004; Felder *et al.,* 2001). Besides, the-author, of this paper, was *not* able to-trace any-studies, done of waste-characterization in-Kenyan-university perspective.

More-attention must-be-paid to SW-characterization-studies and SWM on-campuses, since higher education-institutions are a-special-case of study, because: (1) *not* much has-been-reported on-this-issue; (2) being-autonomous, to a-great-extent, campuses can accommodate innovative-SWM- approaches; (3) since SWM on campuses involve students, at-various-levels it can-serve to-sensitize as-well-as informally-train them in-good SWM-practices; and (4) SWM-practices, adopted by higher-education-institutions have a-great-potential of being-adopted, by surrounding-communities, because these-institutions generally are held in-high-esteem (Armijo *et al.,* 2008).

Characterizing and understanding the-composition of waste-streams is also often-viewed as a-critical-first-step, toward the-development of successful and effective-WM-strategies, across university campuses (Smyth *et al.,* 2010). Percentage-wise-composition-data also enable the-comparison, of waste composition, from different-areas (Egozcue & Pawlowsky - Glahn, 2011). The-findings of this-study may, thus, be-used to-develop WM-strategies that may be replicated in-other-universities, in-Kenya.

Besides, Kahmeyer *et al.* (2011) pointed-out, although many-universities have a-rough-idea of the-amount of waste, they generate, little-information exist as to the-*actual*-character and composition of the-waste, arising. According-to EPA (1996), however, regular-characterization of the-waste, generated, on a-site, is recommended, which should, ideally be-carried-out every 3 years.

To-address this-information-gap, and using the-Moi-University as a-case-study, this-research is intended to-examine the-composition and quantity of materials, discarded (the-types and quantities of potentially-recoverable and compostable-materials, in-the-university MSW-stream), and to-identify opportunities for materials-recovery. In-particular, the-study will focus on three-issues, at the-subject university, such-as: (i) solid-waste-characterization (solid-waste-stream composition-profiles, in %); (ii) solid-waste-quantification; and (iii) evaluation of the-relevance/applicability of Waste-Hierarchy- approaches to the-identified, by-the-study, waste-components.

2. Materials and Methods.

2.1. Background.

The-study was conducted at the-Moi-University (MU), situated at Kesses-Constituency, the-Uasin Gishu-County, Kenya. MU is the second-largest-public-university, after the-University of Nairobi. As of 2007, it had over 20,000 students, including 17,086 undergraduates. It operates eight-campuses and two-constituent-colleges (Starovoytova & Cherotich, 2016 b). The-study was conducted over a-four-week sampling-period, in-2017 calendar-year, across the-MU, *main*-campus.

Analogous to Starovoytova (2017), interested-readers could-refer to Starovoytova *et al.* (2015) to-find informative-synopsis regarding Kenya, and its-educational-system. Besides, study by Starovoytova & Cherotich (2016 a), provides valuable-particulars, on MU, where the-study was conducted. The- geographical-position on the-subject-university can be accessed *via* Starovoytova & Namango (2018a).

The-method, employed in-this-study is source-specific-characterization and quantification of the-waste. Analysis of the-total-quantity of waste, in the-entire-university waste-stream, by-weight or by-volume, is known as *waste-quantification*. Analysis of the-composition of the-waste-stream, by material-type (e.g., glass, paper, metal, etc.) or by product-types (e.g., glass-containers, magazines, cans, etc), is referred-to-as *waste-characterization*. The-daily solid-waste generated, as a-result of normal university-operations, is broadly divided into-two-categories: (i) general-education-waste; and (ii) *non* general-education-waste. The-solid-waste, generated, was collected from the-source of generation, before disposal, without compacting, and transported to a-sorting-facility. Samples were collected, at-source, from the-identified-waste-generators (see **Figure 1** and **Figure 2**).

Figure 1: Position of the-identified-waste-generators, within the-campus.
Key: 1--Student-hostels; 2-- MU-clinic; 3--Administrative-Offices; 4--Laboratories; 5--Stage-market; 6--Canteens/restaurants/eateries; and 7—Elimu-mill.

Figure 2: Position of the-canteens/eateries sub-generators, within the-campus.
Key: 1 - Ngeria Eatery; 2 - Administration Block Eatery; 3 - Students' Center Eatery; 4 - Library Eatery; 5 - ICDC Complex Eatery; 6 - Soweto Eatery; and 7 - School of Information Sciences Eatery.

2.2. The-Standard and the-terminology, used.
Widely-accepted-approach to-waste-characterization is direct-waste-analysis (DWA), also referred-to-as the '*sample-and-sort*' method. Following this-approach, waste-samples are sorted, typically by-hand, into previously-selected material-categories and weighed (Yu & Maclaren, 1995). Each-sorting-sample weighed 91kg and was prepared properly (mixed, coned, and quartered). Sample-characterization was carried-out, using, as a-basis, the-traditional material-based-classification-approach, as adopted by Roberts *et al* (2010). After sampling, hand-sorting applied for the-classification of MSW into-categories. Each material-category is then weighed and registered in-the-data-sheet. The-list of complete-material-categories and their descriptions are included in-the-

Table 1.

Table 1: Complete-material-categories (ASTM D 5231—92 (2003)).

Category	Description
Mixed paper	Office paper, computer paper, magazines, glossy paper, waxed paper, and other paper not fitting the categories of newsprint and corrugated
Newsprint	Newspaper
Corrugated	Corrugated medium, corrugated boxes or cartons, and brown (kraft) paper (that is, corrugated) bags
Plastic	All plastics
Yard waste	Branches, twigs, leaves, grass, and other plant material
Food waste	All food waste except bones
Wood	Lumber, wood products, pallets, and furniture
Other organics/ combustibles	Textiles, rubber, leather, and other primarily burnable materials not included in the above component categories
Ferrous	Iron, steel, tin cans, and bi-metal cans
Aluminum	Aluminum, aluminum cans, and aluminum foil
Glass	All glass
Other inorganics/ non-combustibles	Rock, sand, dirt, ceramics, plaster, non-ferrous non-aluminum metals (copper, brass, etc.), and bones

The-quality of the-waste-composition-data is highly-affected by the-sampling-procedure (Petersen *et al.,* 2004); this-study, therefore, has followed, precisely, the-sampling-procedure, stipulated in the-ASTM D 5231--92 (2003): Standard-Test-Method for Determination of the-Composition of Unprocessed Municipal-Solid-Waste, throughout-the-process. This-test-method applies to-determination of the-mean composition of SW, based on the-collection, and manual-sorting, of a-number of samples of waste, into individual waste-components, data-reduction, and reporting of the-results.

Terminologies adopted, in this-study, are:

Unprocessed municipal solid waste—solid-waste, in its-discarded-form, that is, waste that has *not* been size-reduced or otherwise-processed;

Composite item—an-object, in the-waste, composed of multiple-waste-components, or dissimilar- materials, (e.g., disposable-diapers and female-pads, bi-metal beverage-containers, electrical conductors, composed of metallic-wire, encased in-plastic-insulation, etc.);

Solid waste composition or waste composition—the-characterization of solid-waste, as represented by a-breakdown of the-mixture, into specified-waste-components, on the-basis of weight-percent;

Sorting sample—a 200 to 300-lb (91 to 136-kg) portion, deemed to-represent the-characteristics of a-waste-generator;

W*aste component*—a category of solid-waste, composed of materials of similar-physical properties and chemical-composition, which is used to-define the- composition of solid-waste (e.g., ferrous, glass, aluminum, etc.)

2.2. Basic-steps.

The-characterization-process involves collecting, manual-sorting, and categorizing-waste, in-order to obtain a-statistical-profile of the-quantities of waste. To-achieve the-waste-characterization objective, of the-study, the-following-sequential-steps, were performed:

1) The-number of samples, to-be sorted is calculated, based on statistical-criteria, selected by the-investigators.
2) A-sorting-sample is collected, from the-waste-generators, at the-MU. 7 generators and 10 sub-generators have already-being-identified, at the-campus (**Figure 1 and 2**); for-details see Starovoytova & Namango (2018 a).
3) The-sample is sorted-manually into waste-components.
4) The-weight-fraction, of each-component, in the-sorting-sample, is calculated, from the-weights of the-components; the-weight, taken immediately after sorting.
5) The-mean waste-composition is calculated, using the-results of the-composition, of each of the-sorting-samples.
6) The-cumulative-composition of the-total-waste is calculated.
7) Results are reported and analyzed.

8) After the-completion of each-characterization-exercise, the-waste was disposed-off at the-MU-dumpsite. *Research-Instruments*, used in-the-study, are: Metal and Plastic-mobile-containers (240 liters-capacity, each), labeled accordingly; (ii) Mechanical-weigh-scale, with a-capacity of 100 kg, and precision +/- 0.005 kg, calibrated, according to the-manufacturer's instructions, before the-actual-exercise; (iii) 3 Sorting Tables; (iv) Heavy-Duty Tarps, Shovels, Rakes, Push-Brooms, Dust-Pans, Hand-Brooms, Magnets, and other-small-tools; and (v) Personal protective-equipment/tools (PPE) (because sorting of waste-streams is a-potentially-hazardous-operation), such-as: Safety-Glasses, Puncture-resistant heavy-duty rubber-gloves, disposable-latex-gloves; Disposable face-mask; Rubber-Boots, as-well-as First-Aid-Kit.

In-addition, review on the-hazards and procedures, with the-operating and sorting-personnel (Research-Assistants, SOE), was done, prior to-conducting the-field-activities.

Sample-size calculations:

The-number of sorting-samples (n), required to-achieve a-desired-level of measurement-precision, is a-function of the-component(s), under-consideration and the-confidence-level. The-governing-equation for n is as-follows (ASTM, 2003):

$$\boldsymbol{n} = (\boldsymbol{t} * \frac{s}{e} . \tilde{x})^2$$

Where:

$t*$ = student t statistic corresponding to the-desired-level of confidence,

s = estimated-standard-deviation,

e = desired-level of precision, and

$\tilde{x}$= estimated-mean.

The-sample was reduced to-a-more manageable-size, by a Coning and Quartering-technique, as the-actual-classification of materials will-be-carried-out by hand. This involves the-following-procedure (EPA, 1996; UNEP (nd)): The-sample is placed on the-floor and thoroughly-mixed, by mechanical-shovel; The-sample is then placed in a-uniform-pile of approximately 0.8 m high; The-pile is divided into-four quarters, using straight-lines, perpendicular to each-other; Either-pair of opposite-corners is removed, to-leave half the-original-sample; The-process is repeated, until the-desired-sample-size i.e. 91kg is obtained. **Figure 3** shows the-summary of the-procedure.

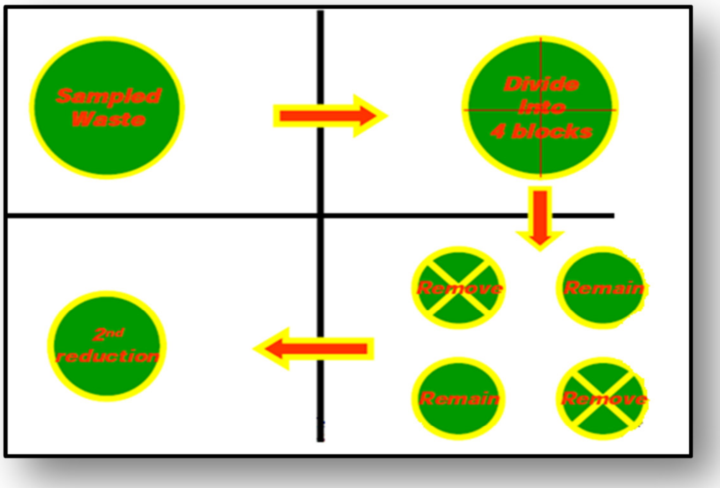

Figure 3: Waste-reduction (UNEP (*nd*)).

On-the-other-hand, Starovoytova (2018 c); Dahlen & Lagerkvist (2008); and Maxwell (2005), list possible-sources of error, in SW-characterization, to-include: fundamental-errors, grouping and segregation error, increment-delimination-error, increment-extraction, preparation-error, and errors, due to-spatial and environmental-conditions. Kahmeyer *et al* (2011) believe that such-errors may-result in an-inaccurate- profile, of the-studied waste-stream. With regards to this-study, suitable-training, on the-use of equipment, was-given to-all, involved, in this-research, moreover, waste-samples were-sorted and tested, within 24 hours, to-avoid errors, due-to physical and chemical-changes (according-to Baldwin & Dripps, 2012; Smyth *et al.,* 2010; Dahlen & Lagerkvist, 2008; Burnley, 2007; and Mason *et al.,* 2004).

Waste quantification

Estimation of the-waste-component generation-rate, based on the-percent-composition, and the-per-capita waste-generation-rate/coefficient, can be formulated as below:

$\mathbf{G_T = G_R M * 10^{\wedge -3} * 365}$ (Eyinda & Aganda, 2013).

Where: G_T: Generation of MSW of the-city/town/municipality (ton/day);
G_R: MSW Generation-Coefficient (kg/person/day); and
M: population in the city//town/municipality.

MS-Excel-based linked-templates were used, which are designed to-systematize-data-entry and automatically-generate estimates and data-summaries. Data was analyzed *via* Descriptive-Statistics, represented as: mean, range, frequency, and percentage-values.

3. Results and Analysis.

3.1. Number of samples.

Table 2 shows the-number of samples for waste-characterization, according to the-Standard-procedure (see ASTM D 5231—92 (2003)), with 90 % confidence-level and desired-precision of 10 %.

3.2. Characterization of solid-waste at the-generators.

Zhang *et al.* (2011) believe, that the-number of main/sub-categories depends on the-objectives, and time frame, of a-particular-study, as-well-as resources, available. As-such, the-material-classification, presented in-**Table 1** was modified. Waste-stream from each generator/source was segregated according to: Glass, Plastic; Mixed-paper and Corrugated-paper; Ferrous and Non-ferrous-materials; Textile-waste, and E-waste. The-following-pie-chats (**Figure 4 - 7**), show the-composition of the-waste, from each-generator; where the-reported-findings, are based on a-the-combination, of hand-sorted and visually-characterized, samples.

Table 2: Number of sorting-samples.

Component	SD(s)	Mean ($\bar{x}$)	Precision (e)	Confidence level (t*)	N	n_o (N SQRD)	t* n_0	N'	n' (N' SQRD)	No. of samples
Newsprint	0.07	0.1	0.2	1.645	5.76	33.15	1.70	5.94	35.28	**36**
Corrugated	0.06	0.14	0.2	1.645	3.53	12.43	1.80	3.85	14.81	**15**
Plastic	0.03	0.09	0.2	1.645	2.74	7.52	1.92	3.20	10.23	**11**
Yard Waste	0.14	0.04	0.2	1.645	28.79	828.72	1.65	28.79	828.72	**829**
Food Waste	0.03	0.1	0.2	1.645	2.47	6.09	2.02	3.02	9.14	**10**
Wood	0.06	0.06	0.2	1.645	8.23	67.65	1.67	8.34	69.47	**70**
Other Organics	0.06	0.05	0.2	1.645	9.87	97.42	1.66	9.96	99.20	**100**
Ferrous	0.03	0.05	0.2	1.645	4.94	24.35	1.71	5.14	26.44	**27**
Aluminum	0.004	0.01	0.2	1.645	3.29	10.82	1.81	3.62	13.13	**14**
Glass	0.05	0.08	0.2	1.645	5.14	26.43	1.71	5.34	28.49	**29**
Other Inorganics	0.03	0.06	0.2	1.645	4.11	16.91	1.75	4.37	19.05	**20**

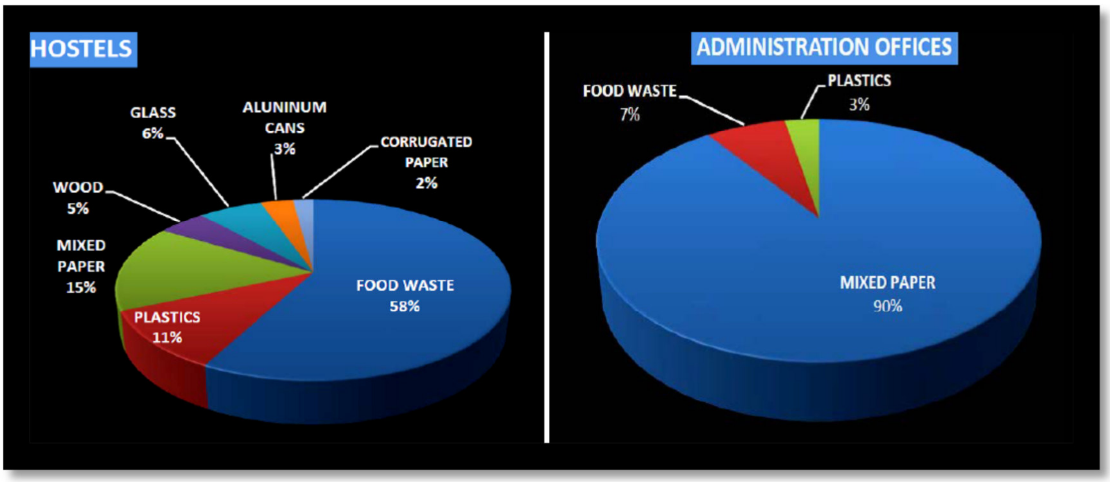

Figure 4: Waste categorization from the-hostels (*left*) and Administration Offices (*right*).

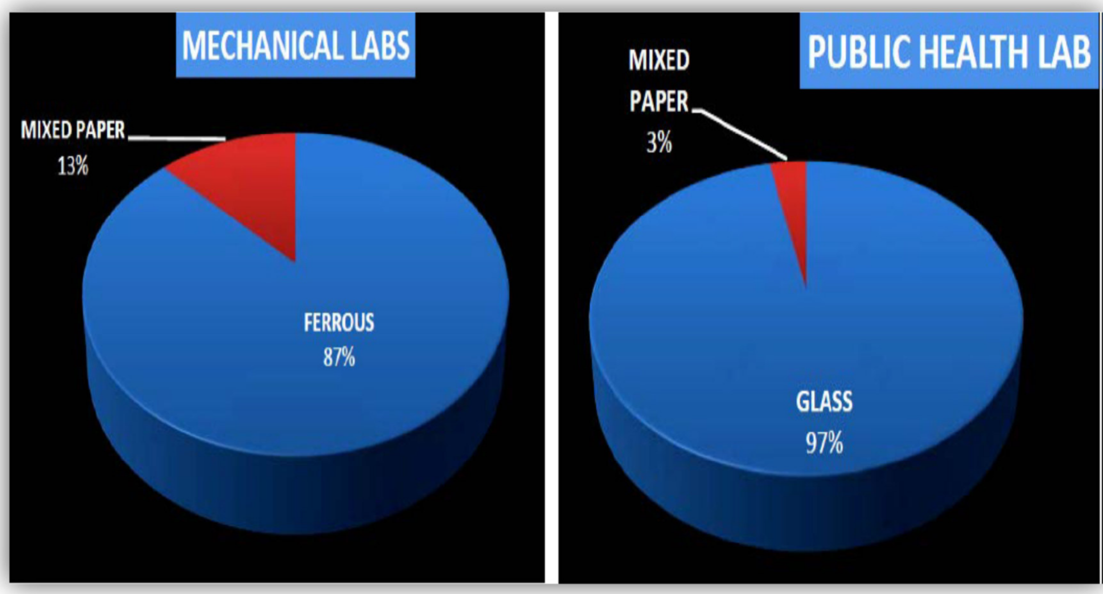

Figure 5: Waste categorization from the-Mechanical-laboratory (*left*) and Public-Health-laboratory (*right*).

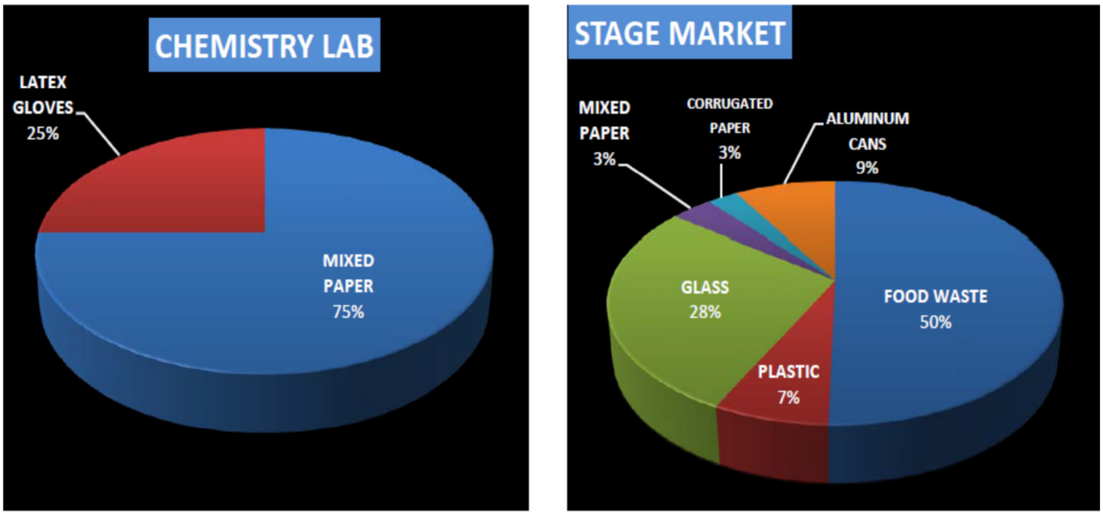

Figure 6: Waste categorization from the-Chemistry-laboratory (*left*) and Stage-market (*right*).

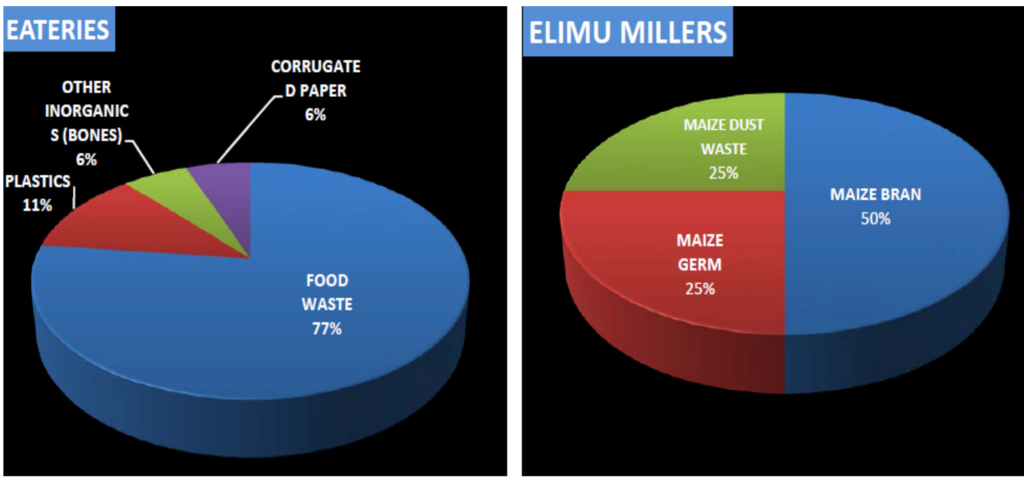

Figure 7: Waste categorization from the-Eateries (*left*) and Elimu-millers (*right*).

3.2. Quantification of Waste.

Recent-study by Starovoytova & Namango (2018 b) stated, that *self-reported* waste-generation-rates, at the-campus was found from 0.14 to 1.4 kg/day/ per-student, and 1.7 kg/day/per-vendor, on-average, which is comparable-with estimations for waste-generation-rates, in-sub-Saharan-Africa. In-contrast, according-to Gakungu *et al.* (2012), the-per-capita waste-generation is highest, for Institutes of Technology at 0.71kg/ week/student, while National-Polytechnics have the lowest-per-capita waste-generation of 0.28 kg/ week/student. These-rates are lower, that estimated by the World-Bank (2012); Global SW-generation, by-region, reported that SSA (Sub-Saharan-Africa)-region generates 0.5 - 0.65 kg/capita/day. The-waste generation-rates, in-sub-Saharan-Africa, per-capita, is generally-low, with an-average of 0.65 kg/capita/day, *but* spans a-wide-range, from 0.09 to 3.0 kg/capita/day, depending on economic-status (see Starovoytova, 2018 a).

In-the-absence of consistent-data on waste-collection, at the-campus, and to-avoid any-discrepancies with the-previous-studies, the-rate of 0.5 kg/capita/day, was chosen, for further-calculation of waste generation-rates, at the-campus (see **Table 3).**

The-introduction of free-primary-education, lowering the-entry-point, and starting of privately sponsored degree-programs (PSSPS), have resulted in-massive-increase in-students-population, in all-public universities. In-MU, for-example, according to the-Kenya-National-Bureau of Statistics, on university enrolment, total-enrolment to the-university, has been on-increase, from 12,159, in-2007/2008 academic year, to 21,142, in-2016/2017. Assuming this-trend will-continue, waste-generation, by the-MU, will correspondingly increase.

Table 3: Waste quantification.

MOI UNIVERSITY WASTE QUANTIFICATION			
YEAR	POPULATION	FORMULATION (GR X M X O.001 X 365)	AMOUNT (TON/YEAR)
2009/2010	20721	0.625 x 13721 x 0.001 x 365	4726.98
2010/2011	20900	0.625 x 13900 x 0.001 x 365	4767.81
2011/2012	38723	0.625 x 31723 x 0.001 x 365	8833.68
2012/2013	40578	0.625 x 33578 x 0.001 x 366	9282.22
2013/2014	41361	0.625 x 34361 x 0.001 x 365	9435.48
2014/2015	41031	0.625 x 134031 x 0.001 x 365	9360.20
2015/2016	23162	0.625 x 16162 x 0.001 x 366	5298.31
2016/2017	21142	0.625 x 14142 x 0.001 x 365	4823.02
	AVERAGE		**7065.96**
FORECAST STUDENT POPULATION (3%GROWTH RATE)			
2017/2018	21776	0.625 x 14566 x 0.001 x 365	4967.71
2018/2019	22430	0.625 x 15003 x 0.001 x 365	5116.74
2019/2020	23102	0.625 x 15453 x 0.001 x 366	5284.68
2020/2021	23796	0.625 x 15917 x 0.001 x 365	5428.35
2021/2022	24509	0.625 x 16394 x 0.001 x 365	5591.20
	AVERAGE		**5277.74**

4. Discussion.

4.1. Analysis of the-results.

4.1.1. Waste Characterization.

Figures 4 – 7 are self-explanatory-charts. Two-comments, however, need to-be-made, on: (i) **Figure 2** shows seven-canteens/eateries and cafeterias, situated at the-main-campus, MU. All-of-them, do provide three meals, seven-days a-week, to-both; students and university-workers. The-menu and the-prices are similar, therefore, the-largest one—called Ngeria-eatery--was chosen as-a-representative-sample, where the actual-analysis was conducted; (ii) the-Elimu-Millers, produces maize-flour, animal-feeds (dairy and pigs), and poultry-feeds. 100% the-waste, originated from the-maize-flour-production, indicated in-**Figure 7 (**maize-dust, maize-bran, and maize-germ**)**, is utilized for the-production of animal-feeds. Those-values, therefore, were *not* included in the-calculation of cumulative-waste-composition, as in-essence, there is *no* residual-waste. **Figure 8** shows cumulative-composition of the-total-waste at-the-campus.

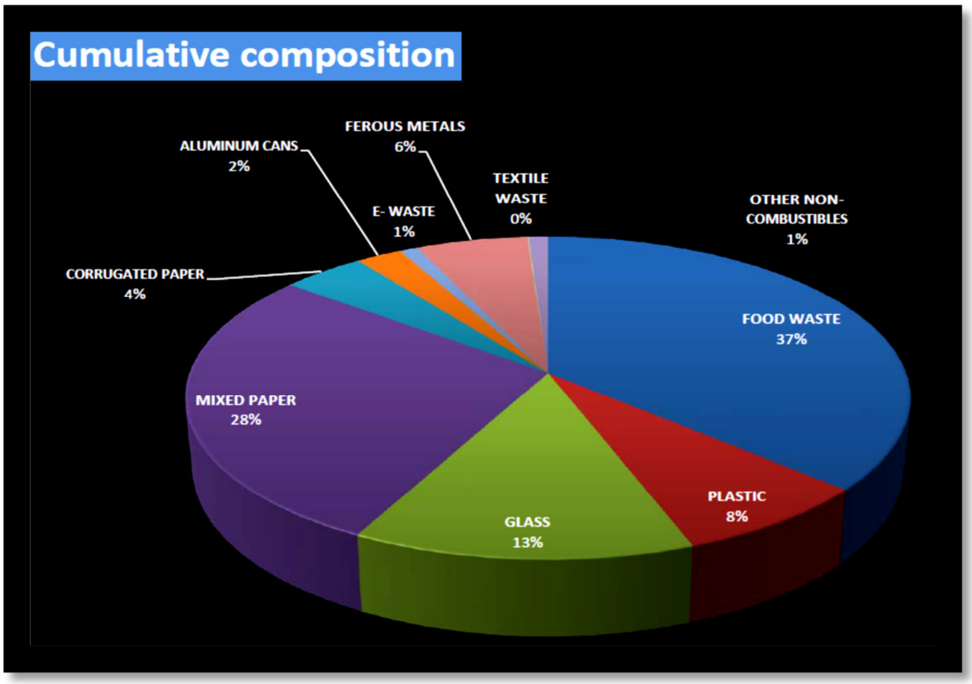

Figure 8: Cumulative-composition of the-total-waste at-the-campus.

Figure 8 shows, that: (i) 37% of the-total-waste is biodegradable-materials (food-waste); and (ii) 62% of the-total-waste, including Glass, Plastic; Mixed-paper and Corrugated paper; Ferrous and Non-ferrous-materials; and E-waste, can be-recycled, or have the-potential to-be recyclable.

This-study revealed that 37% of current-waste has the-potential to-be-composted (as a-biodegradable-food-waste). If *not* composed, disposal of such-rapidly-degradable-material will create climate-change-impact, through emission of methane-gas, from landfill, where these-type of waste is disposed-off, in the-absence of landfill-gas recovery-system (Fauziah & Agamuthu, 2012; Lou & Nair, 2009; Machado *et al.*, 2009).

On-the-other-hand, according-to Wagner & Bilitewski (2009); and Ghose *et al.* (2006), waste differs-widely, from-place-to-place, the-most-striking-one being their-organic-contents-percentage. The-following-examples reinforce the-statement, for-example: at three-Canadian-universities, waste-audits revealed, that compostable-organics represented between 17-29% of the total-campus waste-stream (see van Adrichem, 2007; and Thompson, 2005). However, Royal-Roads-University (RRU), in-Victoria, British-Columbia, found that compostable-organics represented 60% of the-campus waste-stream (Czypyha, 2004), while study on-East-African urban-centers, by Okot-Okumu (2012), revealed compostable organic-materials to-be even-higher, in-the-range of 65–70%. Likewise, the-following-studies, by UNEP (2013); Forouhar & Hristovski (2012); Kalanatarifard & Yang (2012); Roberts *et al.* (2010); Damghani *et al.* (2008); Hernandez-Berriel *et al.* (2008); and Parizeau *et al.* (2006), also-found, that the-high-percentage of organic-material is typical of waste, from developing-countries.

Using institutional-organic-waste to-make compost, on the-university-campus-site, or outside, has become a-common-practice, within the-higher-education-sector (Smyth *et al.,* 2010; Creighton, 1998; Diaz *et al.,* 1993). As an-example, universities in United-States such-as Allegheny college (Meadville, PA); Appalachian-State-University (Boone, NC); and Guilford-College (Greensboro, NC) execute the-composting-program, of their-wastes, at their-sites (Sullivan, 2010). Some-universities, such-as Michoacán-University of San-Nicolas-Hidalgo (Mexico), are using the-wastes, generated in-the-gardens, to-produce-compost, in order to-help-sustaining their-green-areas, within the-campus (Sánchez-Yánez *et al.,* 2005; Westerman & Bicudo, 2005). Since organic-waste is such a-large-portion of the-waste-stream, implementing a-food-scraps-collection would be an-option to-explore. Also mixing food-waste and yard-waste, to-make-compost, was proposed by Tiew *et al.* (2010). The-use of such-compost, produced for soil-amendment-needs, is an-alternative to-potentially-harmful artificial-fertilizers; composts could-be-used at MU-farm, and also supplied to farmers, or sold, at a very-subsidized-price, in-order-to-recover cost of maintenance of the-composting-system. In-addition, the-composting-efforts could be-extended with an-installment of one-unit of 100 kg/day capacity of anaerobic-digester, to-produce biogas, from separated-food-waste.

On-the-other-hand, results presented in-**Figure 8**, shows that large-proportion of MSW, generated in-MU, can-be-recycled or is potentially-recyclable. With-regard-to recyclable-materials, the-findings of this-study are comparable-with previous-studies by: Mbuligwe (2002), who reported a-waste recovery-potential of 71% in three-institutions of higher-education, in-Tanzania. Study by HEFCE (2012), also identified that 90% of the-wastes, produced on the-campuses, were potentially-recyclable. Ezeah *et al.* (2015) indicate that about 73% of waste, could be recycled, 25% could be composted and/or sent for anaerobic-digestion, while the-remaining 2% could be incinerated and/or sent-to-landfill; Baldwin & Dripps, 2012; Taghizadeh *et al.,* 2012; Kahmeyer *et al.,* 2011; Smyth *et al.,* 2010; Armijo de Vega *et al.,* 2009; also-found that 61-82% of the-waste-stream could-be-recycled, composted, or reduced. De Vega *et al*. (2008) found almost 65% of generated-solid-waste, in-university-campus, to-be-recyclable. A-study at the-University of Newcastle (2010) also-found, that two-thirds (by weight) of waste on campus, was recyclable, or compostable. Besides, a-study on selected-universities in-developing-countries reported, that there is waste-recovery-potential of 71%, and it can be further-increased by utilization of food-waste as-animal-feed, which could-result in-significant-cost-saving (Mbuligwe, 2002).

In-particular, this-study reported that 32% of the-waste-stream was attributed to *paper-waste*. A-general-picture of significant-variations, with-regard-to the-proportion of paper, in-campus-waste streams, was identified on-examining of selected-studies, on the-matter. Considered side-by-side, the-findings by Okeniyi & Anwan (2012); Taghizadeh *et al.* (2012); O'Donnell (2002); Kahmeyer *et al.* (2011); and Smyth *et al.* (2010), found that paper accounts for 10.52%, 14.45%, 22%, 28.2%, and 29% respectively. In-contrast, Baldwin & Dripps (2012) revealed that paper made-up *only* 8% in a-waste-audit conducted at Furman-University, USA. While study by Okot-Okumu (2012), revealed that waste, in-East-African urban-centers, is generally-comprised of 5–9% of paper. When sorted properly into-different-categories and with access to-markets, recycled-paper can also-provide a-source of revenue (Fournier, 2008; Bagchi 2004), that can-be-used to-fund additional-campus waste-reduction-programs.

In-this-study *glass*-waste accounts for 13% of the-total-waste, with is much-higher than glass-contribution, identified by other-selected-studies. For-example, glass accounted, in the-study by Ezeah *et al.* (2015) on the-average for 5%, while similar-investigations by Okot-Okumu (2012); Armijo de Vega *et al*. (2009); and Kahmeyer et al (2011), found that glass constitute only 0.7–4%, 3.3%, and 1.5% respectively.

This-study identified 8% as metals, in-the-total-waste-stream. This is comparable with the-findings by Ezeah *et al.* (2015) of 6%, including 4% cans-content.

Plastics-waste constituted another-significant-category, of materials in the-waste-stream, accounting on the-average, for about 8% of waste-samples, across the-campus. Previous-investigations, at other-higher-education-institutions, by Baldwin & Dripps (2012); Okot-Okumu (2012); and Smyth *et al.,* (2010), revealed that waste, is generally-comprised of 6-12% of plastic.

The-percentage of *textiles* from waste-samples, were identified in-this-study as less that 1%. This-finding is compatible with Taghizadeh *et al.* (2012), who discovered a-textile-waste of 1.32%.

On-the-other-hand, according-to Katiyar *et al.* (2013); Zekkos *et al.* (2010); and Arsad *et al.* (2006), the-waste-composition is influenced by external-factors such-as: geographical-location, the-population's lifestyle, energy-sources, and weather. Smyth *et al.* (2010), emphasize that although activities, in-most-campuses, appear-to-be the-same, all-year-round, in-reality, there could-be marked differences, in-terms-of student-numbers, and waste, arising between-terms. Furthermore, the-composition of waste may be-different, depending-on-seasonality (Taghizadeh *et al.*, 2012). This-study was conducted when students were on session, and after rainy-season; in-this-regard, further-studies, during long-rainy season (where temperature is usually much-lower, than in dry-season), and during semester breaks, are therefore recommended, to-establish the-composition-difference (if any).

4.1.2. Waste quantification.

Regarding waste-generation-rates, the-out-lies in-the-Table 3 -- the-academic-years 2012/2013 to 2014/2015 were double-student-intake academic-years, conducted as an-experiment, ordered by the-government. This can be considered as one-time-event, never to be repeated, hence, these-values were excluded from the-calculation of the-annual-average waste-generation-rate, at the-campus. The-study estimates, that the-university-campus generates on-average 5, 111. 65 tons of mixed-waste, per-year. Out of which: (i) Food-waste, which is compostable, accounts to 1,891.31 tons/per year; and (ii) Recyclables, included: paper (mixed & corrugated) - 32% (1,635.73 tons/per year); glass - 13% (664.43 tons/per year); plastic and metals, each - 8% (408.93 tons/per year); and E-waste and other-*non*-combustibles, each - 1% (51.12 tons/per year).

From Starovoytova & Namango (2018a) *no* reduction of waste, at source, *no* formal recycling, and *no* composting is being carried out, at the-campus; and hence, MU, is *not* utilizing this-great-potential, and in-turn, losing money. In-addition indiscriminate-waste-dumping can negatively-affect public-health and the-environment. The-university, hence, clearly needs restructuring its-WM-system to-maximize waste-diversion.

4.2. Waste-diversion potentials.

Recyclable-materials are referred-to as *any* product, or material, which can be-processed into-new-products. This-applies to a-wide-range of materials, for-example: paper, metal, plastic, glass, textiles, electronics, and construction and demolition debris, like wood, concrete, and bricks. Other-important-products to-recycle, included: automotive-products like motor-oil, tires, and car-frames, as-well-as hazardous-materials such as-fluorescent light-bulbs, paints, batteries, and pesticides (US-EPA, 2009). Recycling of these-valuable materials, from the-generated-waste, reduce greenhouse-gas-emissions; moreover, recycling has economic benefits *via* job-creation and as-raw-materials to-industrial-consumption. The-items denoted as *non recyclable* include, but were *not* limited-to dirty-film, used-feminine-products and diapers, as-well-as residuals, and fines. Currently, there are either *no,* or limited-recovery-options, available for these- particular-items (Pappu *et al.,* 2007; USEPA, 2002).

WM-programs, in higher-education-institutions, in-industrialized-countries, began more-than 20 years-ago, and vary from voluntary and local-efforts to-institutionalized-programs (Armijo *et al.,* 2003). Some of the-higher-education-initiatives, focused on recycling and waste-reduction, have been very- successful (Armijo *et al.,* 2008). For-example: some-universities, such-as Autonomous-University of Metropolitana, has implemented recycling-programs, for their-recyclable-plastics (Espinosa *et al.,* 2008); Composting and recycling-initiatives as-well-as waste-reduction are all-available-options for the developing-world, to-take-advantage of. Examples of these-waste minimization-activities have already-begun to be looked at as-viable-options in reducing the-amount of waste for disposal, in places such-as Cameroon (Parrot *et al.,* 2009).

While recycling is a-very-important-aspect of waste-management, authorities in-developing countries tend to-overlook the-significance of waste-minimization-strategies, leading-to-situations, where more-waste than necessary is sent to-disposal-sites or recycling facilities. Somalia, Botswana, Uganda, Kenya, Tanzania, Eritrea, and Ethiopia, among-others, have already placed an outright-ban on plastic-bag use. This is a-great-example of attacking waste, at the-source. Waste-minimization is an-excellent opportunity for all-countries, both; developing and developed, to-stop waste, at its-source (Yire, 2012).

According to O'Connell (2011), "the most important determinant of recycling behavior is access to a structured, institutionalized program that makes recycling easy and convenient". The-importance of 'visible' and accessible recycling centers as-well-as financial-incentives, to-encourage participation in- recycling, is supported by many-studies as an-effective-measure in-improving SWMS (Bolaane, 2006). This-approach could also create informal-employment-opportunities. Moreover, according-to Omari (2015); and Amutenya *et al.* (2009), waste-recycling, which includes photocopying-papers, plastics, can, glass, aluminum, and other-metals, is cheap and saves resources, money, energy, and reduces emissions.

As already mentioned, the-university clearly needs restructuring of its-WM-system, to-maximize waste-diversion. In-the-same-line, there is a-need for a-proactive-approach to environmental-management, across the-world (González-Benito, 2006; Daily *et al.,* 2001; Jabbar *et al.,* 2010), where the-Waste Hierarchy can provide a-useful-guide, on sustainable-SWM-practices, at the-campus. The-next-section provides tailored-recommendations on the-sustainable-SWM-practices, at the-campus.

4.3. Waste-Hierarchy, and its-options, for the-categorized waste-types, alongside-with selected-benefits.

The-so-called *Waste Hierarchy* is widely-accepted as a-normative-guide to-best-SWM-practice (Fagan *et al.,* 2001). The-waste-hierarchy takes-into-account the-impact of the-different WM-options on: climate- change, air-quality, water-quality, and resource-depletion (WRAP, 2011). **Figure 9** shows the-*waste hierarchy.* The-most-preferable-option 'prevention', is at the-top, and there are a-range of other-options, which should be applied, wherever-possible, before the-least-preferable option of '*disposal*' at the-bottom. More-details, on Waste Hierarchy-options, can be-accessed *via* Starovoytova & Namango (2018 a).

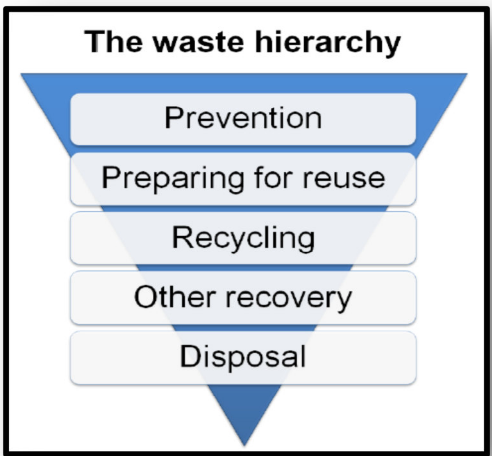

Figure 9: Waste-Hierarchy (WRAP, 2011).

Waste-Hierarchy-Guide, by WRAP (2011), was tailored to the-research-findings; the-next-sections present Waste-Hierarchy-options, for *each* of the-waste-groups, characterized, alongside-with the-benefits of applying the-Waste-Hierarchy.

(i) Food.

This-study revealed that 37% of the-total-waste is food-waste. Waste-Hierarchy-options, for food-waste, are:

Prevention: Wasting food, wastes the-resources, which have gone into growing, processing, and transporting of that-food. Consider donating unwanted-good-quality edible-food, which would otherwise be-wasted, to-different-organizations, working with disadvantaged/needy people.

Preparing for reuse: currently, there-are *no* economically-viable-options, for preparing food-waste, for reuse.

Recycling: Food-waste, alone, or in-combination-with garden-waste, can be-composted; care should taken to-completely separate food-waste from all-products of animal-origin.

Other recovery: Options for treating food-waste include, in-order of environmental-benefit, anaerobic-digestion, composting (in-vessel or home/local composting), and incineration, with energy- recovery. In-this-case, a-recovery-option (anaerobic-digestion) is better, in-environmental-terms, than a-recycling-option (composting). This is a-departure-from the-normal-order of the-waste-hierarchy, shown previously in-**Figure 9**. During anaerobic-digestion, food-waste is microbiologically-broken-down, in enclosed-containers, in the-near-absence of oxygen. The-outputs produced, are: (i) *digestate* - which can-be-used instead of fertilizers, produced using-fossil-fuels; and (ii) *gas* - which can be used for vehicle-fuel, heating, electricity-generation, fuel for combined-heat and power-plant, or refined and directly-injected into-the-gas-grid. The-combination of both-outputs means that anaerobic-digestion is environmentally-preferable to-composting and is the-best-available treatment-option, for food-waste. Food- waste can also be-used in energy-from-waste plant, which reduces the-need for fossil-fuel-generated energy.

Edible-foods, that go-to-rendering-plants for authorized-uses, such-as the-manufacture of pet-food, is also a-form of recovery. Waste-oils, from restaurants and catering-facilities, can-be turned into-bio-fuels. Food-waste is combustible and, as a-renewable-material, it can replace the-burning of fossil-fuels, when energy is recovered. Even in-incineration-facilities, where *only* electricity (and *not* heat) is produced, combustion offers some-environmental-benefit. Segregated and non-segregated food-waste may also-be a-suitable-feedstock, for the-production of renewable-transport-bio-fuels, renewable heat-power, and/or renewable-chemicals, through advanced-bio-fuels and bio-refinery-technologies. These can often provide greenhouse-gas-savings and reduce demand for resources. Another-process, called 'Rendering' is a-treatment-process, through which, food-waste and other-animal by-products are 'cooked' at high-temperature, sometimes under-pressure, to-remove moisture, and until the-fat (tallow) can-be separated from the protein-material. Tallow can-be-used to-produce tires and paint, fertilizers, fuel, and small-amounts may-also be- used in-feedstuffs. The-protein element can be-dried to-produce-meat and bone-meal that can-be-used, subject to animal by-product controls, as a-protein-source in pet-food manufacture and as a-fuel.

Disposal: Food-waste should-be-diverted from landfill, wherever-possible, because it degrades, over a-short-period of time, in-landfill, which gives rise to methane-emissions. Even where methane is captured for flaring or energy-recovery, the-overall-impact is still-negative.

(ii) Paper and board.

This-study revealed that 32% of the-total-waste is mixed-paper and corrugated-paper/cardboard. Waste-Hierarchy-options, for paper-waste, are:

Prevention: Preventing paper-waste, by reducing the-use of paper, in-the-first-place, or reusing-paper, has significant-environmental-benefits, in-terms of greenhouse-gas (GHG) emissions, resource-use, and energy-consumption. Examples of approaches: use less board-packaging; Reuse packaging; Print less often; Print double-sided; and Collect paper, that has-been-printed, on one-side-only, to-make notepads. In-particular efforts should-be-made to-explore paperless-processes (ISTC, 2014). Using both-sides of paper can-reduce use by up to 50%; it should be ensured, that all-printers are set to-double-sided-format, as-default. Besides, reminder-posters, near-printers and photocopiers, should-be put.

Preparing for reuse: Paper should be-segregated and shred, or just manually-compressed, for resale. Enabling others to-reuse the 'waste' paper and board, has similar-benefits, to-those, outlined-above, for the-prevention of paper-waste. Care should be taken to-remove labels or any-sensitive-information. Preparing the-waste-paper or board, for reuse, and finding a-useful-outlet for this-waste, will be-helping to-reduce the-environmental-impact and costs, associated-with paper and/or board production.

Recycling: Waste-paper and board should be-segregated for recycling, and sorted, by grade, to-maximize the-cost-effectiveness of recycling-collections, as the-benefits of recycling-paper and board vary with grade; the higher the-quality, the-greater the-benefit of recycling. Paper and board may-also be-composted; for further-information on composting, visit the-Association for Organics Recycling website. Research consistently-shows, that more-energy is saved, by recycling paper and board (thus avoiding the-use of virgin-fibres), than by using waste-paper-products to-replace fossil-fuels in-energy-production. Typically, twice-the-amount of energy is saved, as would, otherwise be-produced.

Other recovery: Where paper is contaminated (e.g., with grease from food) it-is less-suited to recycling, and more-suited to-energy-recovery. Such-paper should be segregated. Paper and board, used to-generate-energy are classed as renewable-fuels. They offset the-use of fossil-fuels, which provides environmental-benefits, in-terms of avoided-resource-use, and reduced-contribution to-acidification, relative to landfill.

Disposal: Paper and board should be-diverted, from landfill/dumpsite wherever-possible. As they degrade in landfill, they can also emit methane-gas. However, if it is the-only practical-option, the-waste should be compacted, to-reduce the-volume of waste, send to-landfill, hence reducing the-frequency of collections-required.

(iii) Glass.

This-study revealed that 13% of the-total-waste is glass-waste. The-majority of consumer-glass is clear, amber, and green; coming in the-forms of jars, bottles, containers, etc. Glass-waste also arises from architectural-glass (e.g., windows), automotive-glass (e.g., windscreens), and from-electrical-equipment. Waste-Hierarchy-options, for glass-waste, are:

Prevention: Use returnable-bottles, wherever-possible, or bottles that can-be-refilled on-site (e.g., 'house water' bottles for the hospitality-industry). Large-glass-containers can also be offered on reuse websites, sold, or auctioned. Waste-glass should be-segregated, for collection, washing where applicable, and reuse (e.g., waste-drink-bottles from the-hospitality-sector). Minimizing the-amount of glass, used and reusing-glass, have significant-benefits, because raw-material use and energy for manufacturing are avoided.

Preparing for reuse: The-benefits, associated-with reusing glass (i.e., the-reduced-need for raw-materials and energy, to-manufacture-glass), far-outweigh the-environmental-impacts of collecting and washing glass, ready for reuse.

Recycling: Segregate and color-sort glass-waste, to-get the-best-price, to-maximize the-potential for it to-be recycled into-new high-value-products. Lower-value recycling-options include the-segregation of glass-waste to-be mixed-with-aggregate. Glass can be-recycled an-infinite-number of times. There are two-main-options for glass recycling: (i) closed-loop-recycling, through re-melt, where glass 'cullet' is collected for recycling and used in-new-glass products. This eliminates, or reduces, the-need for virgin-glass, and significantly-reduces the-amount of energy, required to-make new-glass-products. Closed-loop-recycling also reduces the-environmental-impacts, associated-with transportation, as raw-material-extraction and transport, is replaced with-transport of glass 'cullet'; and (ii) open-loop recycling (e.g. through the-reuse of aggregates), where glass is blended with other-aggregates, for various applications, such-as road-surfacing. The-environmental-benefits, of using glass in-this-manner, are negligible, because of the-relatively-low-impact of the-material-aggregate being-replaced. To-maximize the-benefits of glass-recycling, glass should be-sorted, to-meet the-quality-requirements, of the-re-melt application. The-WRAP-website includes the-guidance-note 'Clear-steps to a-cleaner-collection' and further-information on-recycling different-types of glass. Where these-quality-requirements *cannot* be met, recycling into-aggregates may be one of the-only-options, available.

Other recovery: *No* energy can be-recovered from waste-glass. Some-value may be-recovered if the-incinerator bottom-ash can be used (e.g., in-construction), but in-environmental-terms the-benefits are negligible. Where glass is present in-mixed-waste, destined for energy-recovery, it should be-removed, either by encouraging greater-recycling by businesses and householders, or by-sorting, before the-energy recovery-process.

Disposal: As an-inert-material, glass does *not* degrade, in-landfill. However, it-is lost to the-resource-economy, and takes-up landfill-space; therefore, every-effort-should be-made to-separate it, for recycling.

(iv) Metals.

This-study revealed that 8% of the-total-waste is metals. Most waste-metal, arising-from-households is in-the-form of packaging (cans for food, pet food, and beverages), old-cars, white-goods (washing machines, refrigerators, cookers, etc.), and brown-goods (televisions and video-players, etc.). Waste Hierarchy-options, for metal-waste, are:

Prevention: Lean-production and product-light-weighting can-prevent metal-waste being produced. For-example, the-second-hand-market for vehicles is well-established, and provides a-market for unwanted-vehicles, that are still-functional. Metals require significant-quantities of energy and raw-materials in-their-extraction and manufacture; this varies-enormously, for different-types of metal.

Preparation for reuse: Opportunities are available for metals to-be-reused by businesses (e.g. reconditioning drums, containers, and machinery). The-reconditioning of intermediate-bulk-containers (IBCs) has a-well-established and effective-international-infrastructure, for ensuring the-reuse over multiple-cycles. The Industrial-Packaging-Association provides a-list of international-businesses, which manufacture and recondition bulk-containers (http://www.theipa.co.uk/download/members.pdf). Reusing metals avoids the-environmental-impacts, associated with their-production, however, metal-products may-require-refurbishment to-make-them suitable for reuse.

Recycling: The-environmental-benefits of recycling-metals are unequivocal, across a-range of environmental-indicators, including greenhouse gas (GHG) emissions and resource-depletion.

Other recovery: No energy can-be-recovered from waste-metals. If they pass-through the-energy recovery process, they can-subsequently be extracted from the-ash, for recycling. However, every-effort should be-made, to-remove them, from the-recovery-fraction, either by encouraging greater-segregation and recycling, or by-sorting, before the-recovery-process.

Disposal: Most waste-metal has a-value for reuse or recycling. However, where it-is *not* possible to-segregate-metals, it should be-disposed, without harming the-environment. Metals may-rust, in-landfill, and break-down, or may remain in-situ. As there is *no* opportunity to-recover-value, landfill remains at the-bottom of the-waste-hierarchy.

(v) Plastics.

This-study revealed that 8% of the-total-waste is plastics. The-major-markets are for use in-packaging, construction, and automotive-products, but plastics are also used in-furniture, electrical-items, toys retail-displays, including clothes- hangers and agricultural-films. Plastics may be-derived from fossil-based oil or from plant-materials (bio-degradable-biopolymers). 'Oxo-degradable' plastics are made of fossil-fuel and contain additives, which allow them to-degrade-faster, than conventional-plastics. They are *not* suitable for composting and may *not* be suitable for conventional-recycling. Waste-Hierarchy-options, for plastic-waste, are:

Prevention options are to: Review-opportunities to-use returnable-transit-packaging (e.g., crates, sleeves), or refillable-packaging, rather-than single-trip-packaging. Reduce the-quantity of plastics in-products, through design-improvements, such-as light-weighting. Reduce the-quantity of waste-plastics, through more efficient-procurement, materials-management, and manufacturing-processes. Taking-into account the-whole-system (including collection, sorting, and cleaning of plastics) prevention provides environmental-benefits, due-to the-avoidance of using raw-materials and energy, required to-manufacture new-plastics.

Preparation for reuse: The-reconditioning of intermediate-bulk-containers (IBCs) has a-well established and effective-international-infrastructure, for ensuring the-reuse over-multiple-cycles. Preparing plastics-waste, for reuse, provides environmental-benefits through avoided-raw-material and energy-use, in the-manufacturing-process. The-Industrial-Packaging-Association provides a-list of businesses, which manufacture and recondition bulk-containers (www.theipa.co.uk/download/members.pdf).

Recycling: Plastics, collected for recycling, are sent to-a-variety of markets. Recycling plastics avoids a-significant-amount of raw-materials and energy-use and reduces greenhouse-gas (GHG) emissions, even when transport is taken-into-account. The-exact-impacts depend on the-material, being replaced and the-relative-life of the-alternative-product. Some-plastics, made from bio-based-materials, may also-be suitable for recycling. To-maximize the-environmental-benefits of a-recycling-scheme, plastics should be delivered with low-levels of contamination, to-allow ready-sorting of polymers. Contaminated-plastics can be-suitable for recycling, after additional-processing. The-use of bailers, to-reduce the-volume of plastics, that need-to-be-stored, on-site, the-transportation-costs, and also the-frequency of collections, required.

Other recovery: Where plastics *cannot* be recycled (perhaps due-to-difficulties in-segregating waste), it may be-possible to-send them for use in-energy-recovery-operations. Plastics have a-high-calorific-value, relative-to other-wastes, so they can-generate a-large-amount of energy, when combusted, gasified, or paralyzed. However, when plastics are made from fossil-fuels (i.e., oil), the-GHG-emissions, from recovering-energy, are far-higher than any-other waste-management-technique for plastics. When sent to-energy-recovery, bio-based-plastics substitute for fossil-fuels, leading to-environmental-benefits, over landfill. Some bio-based-plastics may be-suitable for anaerobic-digestion, but this will-depend on the-specific-characteristics of the-polymer.

Disposal: Conventional-plastics will degrade very-slowly, if at-all, in landfill-conditions. However, they are lost to-the-resource-economy, and take-up landfill-space. In-terms of GHG-emissions, sending plastics to-landfill is preferable to conventional-energy-recovery, but is less-preferable, in-terms of all-other-environmental-indicators, commonly considered in life-cycle-assessment. Overall, disposal remains the-bottom of the-waste-hierarchy. Plastics, that are designed-to-degrade, may or may *not* break-down, in-landfill, depending on their-properties, and the-landfill-conditions; but if the-materials do-decompose they are likely-to-lead to-emissions of methane. A-proportion of this is captured for energy-recovery, but much also escapes into the-atmosphere. For loose-plastic-packaging, such-as shrink-wrap, plastic-ties, or plastic-bags, that *cannot* be handled by any of the-options, outlined-above, a-compactor, or bailer, to-reduce the-volume of waste, should be considered, to-reduce the-frequency of collections, required.

(vi) Waste Electrical and Electronic Equipment (WEEE).

This-study revealed that 1% of the-total-waste is E-waste. Electronic-waste has recently-become a-regulated and a-recyclable-waste. It-is generally-described as discarded, surplus, obsolete, broken electrical or electronic-devices. For-example: computers, entertainment-device-electronics, mobile-phones, and other-items, such-as television-sets and projectors (University Controller, 2006). If the-disposal is *not* handled properly, the-items pose a-risk to-environmental and human-health, because they contain heavy-metals, such as-lead and cadmium, and possibly other-environmental-contaminants (Hodoval *et al.,* 2009). Metals are, by far, the-largest-component of WEEE. Plastics, metals/plastics-mixtures, and glass from-screens, are the-next-largest-groups. The-hazardous-components that can arise, in some-WEEE, require specific-waste-treatment. For-example, cathode-ray-tubes in-televisions, monitors, and flat panel-displays require specialist-treatment. These-hazardous-components should be-removed from the-WEEE, and treated-separately. The-remainder can then-be-recycled, through the-normal-channels. Waste-Hierarchy-options, for e-waste, are:

Prevention options are to: Retain and use items for longer; Sell or donate unwanted-items; Purchase second-hand items; Lease rather than purchase electrical-equipment.

Preparing for reuse: There is a-thriving-market, for reconditioned-large-appliances, and IT-equipment. Repair and refurbishment avoid the-environmental-impacts of manufacturing new-goods. To-maximize-activities, that prepare WEEE for reuse, collection-methods must avoid (further) damage to-the-equipment.

Recycling: WEEE should be-segregated and arranged, for recycling. WEEE-recycling proves to-be clearly-advantageous, from an-environmental-perspective, compared-with incineration or landfill. This is because the-benefits of recycling, the-metallic and uncontaminated-plastic-fractions, of WEEE, outweigh the-impacts of the-recycling-process, in-terms of greenhouse-gas-emissions and resource-depletion. Recent-demonstration-work has shown a 50% to 75% reduction, in-emissions, from using recycled-WEEE- plastics, rather-than virgin-plastics. In-addition, it-is-estimated that only 1% of ‘specialty’ metals (or ‘rare and precious metals’), used in-electronics, are recycled. Besides, it was suggested, that microchip manufacturers use more-than 60 of these-metals, with demand for indium, for-example, expected-to-double by 2020. Recycling these- metals is between 2 and 10 times more-energy-efficient, than smelting the-metals form virgin-ores (which are also to-be-found in-very-few places on-Earth).

Other recovery: Recyclable-components, should be-removed, from WEEE, before sending the-residual-combustible-waste for energy-recovery. Once the-metal-fraction, printed-circuit-boards, and high-quality-plastic-fractions have-been-taken-out, for recycling, incineration with energy-recovery is preferable, for the-residual-combustible-waste, from WEEE. Any-hazard, associated with the-material, will require consideration, before sending this-material for further-recovery.

Disposal: Any-residual-waste, from WEEE, that *cannot* be reused, recycled, or recovered, have to-be then disposed, as a-last-resort.

In-addition, several-examples of successful-implementation of the-approaches of the-Waste Hierarchy, to different-type of waste, is presented in-WRAP (2011).

5. Conclusion and Recommendations.

The-study revealed that: (a) the-largest-share (37%) of the-total-waste is food-waste; and (b) 62% are recyclables or waste-materials, that have the-potential to-be-recyclable. The-study estimates, that the-university-campus generates on-average 5, 111. 65 tons of composite/mixed-waste, per-year. Out of which: (i) Food-waste, which is compostable, accounts to 1,891.31 tons/per year; and (ii) Recyclables, included: paper (mixed & corrugated) - 32% (1,635.73 tons/per year); glass - 13% (664.43 tons/per year); plastic and metals, each - 8% (408.93 tons/per year); and E-waste and other-*non*-combustibles, each - 1% (51.12 tons/per year).

Every-day the-university is literally throwing-away profit, as the-waste is just disposed-off at the-dumpsite, without any-formal waste-reduction, at-source, recycling, or composting, at the-campus. In-this-regard, the-study offers the-following recommendations:

(1) Given that organic-waste is such a-large-portion of the-waste-stream, implementing a-food-scraps-collection would be an-option to-explore.

(2) In-addition, the-composting-efforts could be-extended with an-instalment of one-unit of 100 kg/day capacity of anaerobic-digester, to-produce biogas, from separated-food-waste.

(3) Proper records of waste-collection, at the-campus, should also be kept.

Besides, tailored-recommendations on the-management of the-identified-recyclables and compostable-materials, based on the-Waste-Hierarchy-options, were made (see section 4. 3).

Moreover, areas for further-research are also identified, as follows:

(i) Moisture-Content and Energy-Potential of the-waste, at the-campus, should be examined, as a-next-logical-step.

(ii) This-study was conducted when students were on session, and after rainy-season; in-this-regard, further-studies, during long-rainy-season (where temperature is usually much-lower, than in dry-season), and during semester-breaks, are therefore recommended, to-establish the composition difference (*if any*); and

(iii) Further-studies, where main-waste-categories will-be sub-divided into-*sub*-categories, to-give more-detailed-information.

The-findings of this-research provide a-necessary-baseline-data, for the-five-subsequent-studies, in the-series, and also, hopefully, add to-the-body of knowledge, on the-subject-matter.

6. Acknowledgment.
The-author wishes to-thank Research Assistants, MIT, SOE, MU, Oyuga Victor Otieno and Ogelo Jared Ong'idi, for their-help in-data-collection.

References

AbdAlqader, A. and Hamad, J. (2012). "Municipal Solid Waste Composition Determination Supporting the Integrated Solid Waste Management in Gaza Strip", *International Journal of Environmental Science and Development,* Vol. 3, No. 2.

Abramowitch, H. and Sun, Y. (2012). Municipal Solid Waste Characterization Study for Indiana. The Indiana Recycling Market Development Board.

Adeniran, A.; Nubi, A. and Adelopo, A. (2017). "Solid waste generation and characterization in the University of Lagos for a sustainable waste management", *Waste Managemnt*., 87.

Aguilar-Virgen, Q.; Armijo de Vega, C.; Taboada-González, P.; Ojeda-Benítez, S. (2010). "Municipal Solid Waste Generation and Characterization in Ensenada, Mexico", *The Open Waste Management Journal*, 3.

Amutenya, N.; Shackleton, C. and Whittington-Jones, K. (2009). "Paper recycling patterns and potential interventions in the education sector: a case study of paper streams at Rhodes University, South Africa" *Resources, Conservation and Recycling,* 53(5).

Arazo, R. (2015). "Compositions Of Solid Wastes Generated From A School Campus", *IJRET: International Journal of Research in Engineering and Technology*; e-ISSN: 2319-1163; Vol. 4(10).

Armijo, C.; Ojeda-Benitez, S. and Ramirez-Barreto E. (2003). "Mexican educational institutions and waste management programs: a University case study", *Resour, Conser & Recy*., 39.

Armijo, C.; Ojeda-Benitez, S. and Ramirez-Barreto, E. (2008). "Solid waste characterization and recycling potential for a university campus", *Waste Management*, 28.

Arsad, H.; Sulaiman, S. and Rahmat, A. (2006). "Combustion behaviour of poultry and plastics waste in as bench scale combustor," University Technology Malaysia.

ASTM International (2008). A Standard Test Method for Determination of the Composition of Unprocessed
Municipal Solid Waste. In ASTM D5231 (Reapproved 2003). American Society for Testing and Materials, USA.

Bagchi, A. (2004). Design of landfills and integrated solid waste management. New Jersey: J Wiley.

Baldwin, E. and Dripps, W. (2012). " Spatial Characterisation and Analysis of the Campus Residential Waste Stream at a Small Private Liberal Arts Institution", *Resources, Conservation and Recycling*, 65.

Boer, G. and Arora, V. (2010). "Geographic aspects of temperature and concentration feedbacks in the carbon cycle", *J Clim*., 23.

Bolaane, B. (2006). "Constraints to promoting people centred approaches in recycling", *Habitat International*, 30 (4).

Buenrostro, O.; Bocco, G. and Cram, S. (2001). "Classification of sources of municipal solid wastes in developing countries", *Resour. Conserv. Rcycl*., 32.

Burnley, S. (2007). " The use of Chemical Composition Data in Waste Management Planning – A Case Study", *Waste Management*, 27.

CDM (2010). City of Chicago Department of Environment: Waste Characterization Study.

Chang, N. and Davila, E. (2008). "Municipal solid waste characterization and management strategies for the Lower Rio Grande Valley, Texas", *Waste Manage*., 28.

Couth, R. and Trois, C. (2011). "Waste management activities and carbon emissions in Africa", *Waste Manage*., 31 (1).

Creighton, S. (1998). Greening the Ivory Tower: improving the environmental track record of universities, colleges, and other institutions. Cambridge, MA: The MIT Press.

Crowe, M. and Carty, G. (1996). Municipal Solid Waste Characterisation. [Online] Available: http://www.epa.ie/pubs/reports/waste/wastecharacterisation/EPA_municipal_waste_characterisation.pdf. (July 9, 2018).

Croset, E. (2014). Opportunities and challenges of a Sustainable Solid Waste Management in Tsumeb, Namibia, Master of Science Thesis, Stockholm.

Czypyha, B. (2004). Royal Roads University Waste Audit. [Online] Available: http :/ /www.royalroads.ca/NR/rdonlyres/ pdf. (July 27, 2018).

Dahlen, L and Lagerkvist, A. (2008). "Methods for households waste composition studies", *Waste Management,* 28.

Daily, B., & Huang, S. (2001). "Achieving Sustainability through Attention to Human Resource Factors in Environmental Management", *International Journal of Operations & Production Management*, 21(12).

Damghani, A.; Savarypour, G.; Zand, E. and Deihimfard, R. (2008). "Municipal Solid Waste Management in Tehran: Current Practises, Opportunities and Challenges", *Waste Management*, 28.

De Vega, C.; Benitez, S. and Barreto, M. (2008). "Solid waste characterization and recycling potential for a university campus", *Waste Management,* 28.

De Vega, C.; Benitez, S. and Barreto, M. (2009). "Solid Waste Characterisation and Recycling Potential for a University Campus", *Waste Management*, 28.

Diaz, L.; Savage, G.; Eggerth, L. and Golueke, C. (1993). Composting and recycling municipal solid waste. Boca Raton, FL, USA: Lewis Publishers; 1993.

Diaz, L.; Eggerth, G. and Golueke C. (2002). The role of composting in the management of solid wastes in Economically Developing Countries. In: Appropriate Environmental and solid waste management and technologies for Developing Countries., ISWA 2002 Conference, Vol. 2, Local quantification and characterization represents a basic tool for integrated residential solid waste management.

Edjabou, M.; Jensen, M.; Götze, R.; Pivnenko, K.; Petersen, C.; Scheutz, S. and Astrup, T. (2014). "Municipal Solid Waste Composition: Sampling methodology, statistical analyses, and evaluation of case study", *Waste Management journal.* [Online] Available: http://www.sciencedirect.com/science/article/pii/S0956053X14005261(July 7, 2018).

Egozcue, J. and Pawlowsky-Glahn, V. (2011). Basic Concepts and Procedures, in Compositional Data Analysis: Theory and Applications (eds V. Pawlowsky-Glahn and A. Buccianti), John Wiley & Sons, Ltd, Chichester, UK.

Ejaro, S. and Jiya, S. (2013). "Source Specific Quantification, Characterisation and Management Of Solid Waste In Lapai, Niger State, Nigeria", *Ethiopian Journal of Environmental Studies and Management,* Vol. 6(5).

EPA (1996). Environmental Protection Agency: Municipal Waste Characterisation. Published by the Environmental Protection Agency, Ireland.

Espinosa, R.; Turpin, S.; Polanco, G.; De laTorre, A.; Delfin, I. and Raygoza, I. (2008). "Integral urban solid waste management program in a Mexican university", *Waste Manage*.; 28.

Eyinda, M. and Aganda, A. (2013). Municipal solid waste composition and characteristics relevant to the waste – to-energy disposal method for Nairobi city. Nairobi: Global Institute for Research & Education.

Ezeah, C. (2010). Analysis of Barriers and Success Factors Affecting the Adoption of Sustainable Management of Municipal Solid Waste in Abuja, Nigeria. Ph.D. Thesis, University of Wolverhampton.

Ezeah, C.; Fazakerley, J.; Roberts, C.; Cigari, M. and Ahmadu, M. (2015). " Characterisation And Compositional Analyses Of Institutional Waste In The United Kingdom: A Case Study Of The University Of Wolverhampton", *Journal of Multidisciplinary Engineering Science and Technology (JMEST),* ISSN: 3159-0040 Vol. 2(7).

Fagan, H.; O'Hearn, D.; McCann, G. and Murray, M. (*Amended Version*) (2001). Waste Management Strategy: A Cross-Border Perspective. National Institute for Regional and Spatial Analysis (NIRSA).

Farmer, G.; Staniewicz, N.; Michael, B.; Wojcik, A.; Lim, Y.; Ivokovic, D. and Rajakulendran, J. (1997). "Audit of waste collected over one week from ten dental practices: a pilot study", *Aust Dent J.*, 42(2).

Fauziah, S. and Agamuthu, P. (2012). "Trends in sustainable landfilling in Malaysia, a developing country", *Waste Management & Research,* 30(7).

Felder, M.; Petrell, R. and Duff, S. (2001). "A solid waste audit and directions for waste reduction at the University ofBritish Columbia, Canada", *Waste Manage Res*., 19.

Forouhar, A. and Hristovski, K. (2012). "Characterization of the municipal solid waste stream in Kabul, Afghanistan", *Habitat International*, 36.

Fournier, R. (2008). Recycle this! A look at campus recycling programs. In: Simpson W, editor. The green campus: meeting the challenge of environmental sustainability. Alexandria, VA: APPA.

Gakungu, N.; Gitau, A.; Njoroge, B.; Kimani, W. (2012). "Solid waste management in Kenya: a case study of public technical training institutions", *ICASTOR Journal of Engineering,* Vol. 5(3).

Ghose, M.; Dikshit, A. and Sharma, S. (2006). "A GIS based transportation model for solid waste disposal – A case study on Asansol municipality", *Journal of Waste Management* , 26 (11).

Gidarakos, E.; Havas, G. and Ntzamilis, P. (2005)."Municipal Solid Waste Composition Determination Supporting The Integrated Solid Waste Management System in the Island of Crete", *Waste Management*, Vol. 26(6).

Gomez, G.; Meneses, M.; Ballinas, L. and Castells, F. (2009). "Seasonal Characterization of Municipal Solid Waste (MSW) in the City of Chihuahua, Mexico", *Waste Management*, 29.

Gonzalez-Benito, J. and Gonzalez-Benito, O. (2006). "A Review of Determinant Factors of Environmental Proactivity", *Business Strategy and the Environment*, 15 (2).

Green-Solutions (2009). Hurston County Waste Composition Study 2008 – 2009.

Gu, B.; Wang, H.; Chen, Z.; Jiang, S.; Zhu, W.; Liu, M.; Chen, Y.; Wu, Y.; He, S.; Cheng, R.; *et al*. (2015). "Characterization, quantification and management of household solid waste: A case study in China", *Resour. Conserv. Rcycl.*, 98.

Hancs, A.; Novak, P.; Dvorak, M.; Habart, J. and Svehla, P. (2011). "Composition and parameters of household bio-waste in four seasons", *Waste Manage.,* 31.

Harilal, C.; Pradeep, G.; Kumar, A. and Ravindran, C. (2007). A Project Report On Quantification, Characterization And Management Of Solid Waste From Mahe, Union Territory Of Pondicherry.

HEFCE (2012). Higher Education Funding Council for England (Measuring Scope 3 Carbon Emissions: Waste and Water. A Guide to Good Practice. [Online] Available: http://www.hefce.ac.uk/media/hefce/content/pub.pdf. (July 28, 2018).

Hernandez-Berriel, M.; Marquez-Benavides, L.; Gonzalez-Perez, D. and Buenrostro-Delgado, O. (2008)."The Effect of Moisture Regimes on the Anaerobic Degradation of Municipal Solid Waste from Metepec, Mexico", *Waste Management,* 28.

Hodoval, K.; Carter, H.; Alyson Byrne, A. and Townsend, T. (2009). Audit of Solid Waste Management Practices and Generation at the University of Florida. University of Florida, Office of Sustainability.

IPCC (2006). IPCC Guidelines for Greenhouse Gas Inventories. Intergovernmental Panel on Climate Change (IPCC). [Online] Available: http://www.ipcc-nggip.iges.or.jp/public/2006gl/index.html. (July 14, 2018).

ISTC (2014). Illinois Sustainable Technology Center Baseline Waste Stream Characterization Study.

Jabbour, C.; Santos, F. and Nagano, M. (2010). "Contributions of HRM throughout the stages of environmental management: methodological triangulation applied to companies in Brazil", *The International Journal of Human Resource Management*, (21).

Kahmeyer, M.; Miller, C.; Neppel, K.; Ronnebaum, G.; Webber, J. and Zinke, B. (2011).Waste Characterization Study for KSU Recycling.

Kalanatarifard, A. and Yang, G. (2012). "Identification of the Municipal Solid Waste Characteristics and Potential of Plastic Recovery at Bakri Landfill, Muar, Malaysia", *Journal of Sustainable Development*. 5.

Katiyar, R.; Suresh, S. and Sharma, A. (2013). "Characterisation Of Municipal Solid Waste Generated By The City Of Bhopal, India", *International Journal of ChemTech Research*, CODEN (USA): IJCRGG ISSN: 0974-4290; Vol.5, No.2.

Liu, C. and Wu, X. (2011). "Factors influencing municipal solid waste generation in China", *Waste Manag Res*; vol. 29 (4).

Lou, F. and Nair, J. (2009). "The impact of landfilling and composting on greenhouse gas emissions: A review", *Bioresource Technology,* 100.

Machado, S.; Carvalho, M.; Gourc, J. ; Vilar, O. and Nascimento, J. (2009). "Methane generation in tropical landfills: simplified methods and field results", *Waste Management,* 29.

Marmolejo, L.; Rafael, A.; Klinger, A.; Carlos, A.; Madera, P.; Olaya, O.; Marcos, C. and Ordóñez, J. (2010). "Local quantification and characterization represents a basic tool for integrated residential solid waste management", *Ingeniería E Investigación,* Vol. 30(2).

Mason, I.; Oberender, O. and Brooking, A. (2004). "Source separation and potential re-use of resource residuals at a university campus", *J. Resour. Conserv. Recycl*., 40: 155-172. DOI: 10.1016/S0921-3449(03)00068-5.

Maxwell, J. (2005). *Qualitative research design: An interactive approach* (2nd ed.). Thousand Oaks, CA: Sage.

Mbuligwe, S. (2002). "Institutional solid waste management practices in developing countries: a case study of three academia institutions in Tanzania", *Resources, Conservation and Recycling,* 35(3).

McCartney D. (2003). "Auditing non-hazardous wastes from golf course operations: moving from a waste to a sustainability framework", *Resour Conserv and Recy*., 37.

Mengesha, H. and Dessalegn, B. (2014). Solid waste Characterization and Recycling Potential in Hawassa University, Ethiopia.

Miezah, K.; Obiri-Danso, K.; Kádár, Z.; Fei-Baffoe, B. and Mensah, M. (2015). "Municipal solid waste characterization and quantification as a measure towards effective waste management in Ghana", *Waste Management*, 46.

Mohee, R. (2005). "Medical wastes characterisation in healthcare institutions in Mauritius", *Waste Management*, 25.

Moniruzzaman, S.; Bari, Q. and Fukuhara, T. (2011). "Recycling Practises of Solid Waste in Khulna City, Bangladesh", *Journal of Solid Waste Technology and Management*, 37.

Moore, S. (2012). "Garbage matters: Concepts in new geographies of waste", *Progress in Human Geography*, 36(6).

Mugo, N.;. Nyaanga, D.; Owido, S.; Owino, G. and Muniu, J. (2016). "Classification and Characterization of Solid Waste – Case Study of Egerton University and its Environs, Kenya", *International Research Journal of Engineering and Technology* (IRJET), e-ISSN: 2395 -0056, Vol. 3(11).

Nagawiecki, T. (2009). *University of Idaho: Waste Characterization*. University of Idaho, Sustainability Center, USA.

Nas, S. and Bayram, A. (2008). "Municipal solid waste characteristics and management in Gumushane, Turkey", *Waste Manag*., 28.

O' Donnell. M. (2002). British Columbia Institute of Technology Burnaby Campus Waste Audit. [Online] Available: http://www.bcit.ca/files/green/pdf/bcitsolidwastereport. pdf (July 24, 2018).

O'Connell, E. (2011). "Increasing public participation in municipal solid waste reduction", *Geographical Bulletin*, 52(2).

Oelofse, S. and Muswema, A. (2016).The changing face of waste management – considerations when conducting a waste characterisation study. Proceedings of the 23rd WasteCon Conference 17-21 October, Emperors Palace, Johannesburg, South Africa.

Okeniyi, J. and Anwan, E. (2012). "Solid Wastes Generation in Covenant University, Ota, Nigeria: Characterisation and Implication for Sustainable Waste Management", *Journal of Materials and Environmental Science*, 3.

Okot-Okumu, J. (2012). Solid waste management in African cities—East Africa. In L. F. Marmolejo Rebellon (Ed.), Waste management—an integrated vision. [Online] Available: http://www.intechopen.com/books/waste-management-an-integrated-vision/solid-waste-management-in-african-cities-east-africa. (July 22, 2018).

Omari, A. (2015). "Characterization of Municipal solid waste for energy recovery. A case study of Arusha, Tanzania", *Journal of Multidisciplinary Engineering Science and Technology,* Vol. 2 (1).

Osei-Mensah, P.; Adjaottor, A. and Owusu-Boateng, G. (2014). "Characterization of Solid Waste In The Atwima-Nwabiagya District Of The Ashanti Region, Kumasi-Ghana", *International Journal of Waste Management and Technology*, Vol. 2(1).

Oumarou, M.; Mohammed, D.; Abdulrahim, A. and Abubakar, A. (2012). "Characterization and generation of municipal solid waste in north central Nigeria", *International Journal of Modern Engineering Research,* 2.

Ozcan, H.; Guvenc, S.; Guvenc, L. and Demir, G. (2016). "Municipal Solid Waste Characterization according to Different Income Levels: A Case Study", *Sustainability*, 8, 1044; doi: 10.3390/su8101044.

Pappu, A.; Saxena, M. and Asolekar, S. (2007). "Solid wastes generation in India and their recycling potential in building materials", *Building and Environment*, 42(6).

Parizeau, K.; Maclaren, V. and Chanthy, L. (2006). "Waste Characterization as an Element of Waste
Management Planning: Lessons Learned from a Study in Siem Reap, Cambodia", *Resources, Conservation and Recycling,* 49.

Parrot, L.; Sotamenou, J. and Dia, B. (2009). "Municipal solid waste management in Africa: Strategies and livelihoods in Yaoundé, Cameroon", *Waste Management*, 29(2).

Petersen, L.; Dahl, C. and Esbensen, K. (2004). "Representative mass reduction in sampling—a critical survey of techniques and hardware", *Chemometrics and Intelligent Laboratory Systems*, 74.

Qdais, H.; Hamonda, M. and Newham, J. (1997). "Analysis of residential solid waste at generation sites", *Waste Manage. Res.*, 15.

Ramakrishna, V. (2016). "Municipal Solid Waste Quantification, Characterization and Management in Rajam", *The International Journal Of Engineering And Science* (IJES), Vol. 5(2).

Ranjith, K. (2012). Sustainable solid waste management in India, A thesis submitted to the Department of Earth and Environmental Engineering, in partial fulfillment of the requirement for the degree of MSc in Earth Resource Engineering, Fu Foundation School of Engineering and Applied Science, Columbia-University.

Roberts, C.; Watkin, G. and Ezeah, C. (2010). "Seasonal Variation and Municipal Solid Waste Composition – Issues for Development of New Waste Management Strategies in Abuja, Nigeria", *Journal of Solid Waste Technology and Management,* 36.

Sanchez-Ynez, J.; Carrillo-Amezcua, J.; Manzo, Z. and Leal-Lozano, L. (2005). A proposal for an integrated waste management system at the Campus of the Universidad Michoacana de San NicolasHidalgo. Morelia, Mich., Mexico.

Sembiring, E. and Nitivattananon, V. (2010). "Sustainable Solid Waste Management toward an Inclusive Society: Integration of the Informal Sector", *Resource, Conservation and Recycling*, 54.

Singare, P. (2012). "Quantification Study of Non-Biodegradable Solid Waste Materials Accumulated in the Mangrove of Mahim Creek, Mumbai", *Journal of Marine Science*, 2(1).

Smyth, D. (2005). Sustainability and Solid Waste Management In Higher Education: An Inquiry Into The Composition And Management Of Solid Waste At The University Of Northern British Columbia, Prince George Campus. Master-Thesis in-Natural-Resources and Environmental-Studies, University of Guelph, Canada.

Smyth, D.; Fredeen, A. and Booth, A. (2010). "Reducing solid waste in higher education: The first step toward 'greening' a university campus", *Resour, Conser & Recy.*; 54.

Starovoytova, D. and Namango, S. (2016 a). "Factors Affecting Cheating-Behavior at Undergraduate Engineering", *Journal of Education and Practice*, Vol.7, No.31, ISSN 2222-1735 (Paper) ISSN 2222-288X (Online).

Starovoytova, D. (2018 a). "Solid Waste Management (SWM) at a University Campus (Part 1/10): Comprehensive-Review on Legal Framework and Background to Waste Management, at a Global Context", *Journal of Environment and Earth Science,* ISSN (Paper) 2224-3216, ISSN (Online) 2225-0948, Vol. 8 (4).

Starovoytova, D. (2018 b). "Solid Waste Management (SWM) at a University Campus (Part 2/10): Review on Legal Framework and Background to SWM, in-Kenya", *Journal of Environment and Earth Science*, ISSN (Paper) 2224-3216, ISSN (Online) 2225-0948, Vol. 8 (5).
Starovoytova, D. (2018 c). Mastering Scientific Research Writing and Dissemination. LAP Lambert-Academic-Publishing, Germany. ISBN: 978-3-330-08000-3.
Starovoytova, D. and Namango, S. (2018 a). "Solid Waste Management (SWM) at a University Campus (Part 3/10): Waste Generators, Current Practices, and Compliance with Relevant-law-provisions", *Journal of Environment and Earth Science*, ISSN (Paper) 2224-3216, ISSN (Online) 2225-0948; Vol. 8 (6).
Starovoytova, D. and Namango, S. (2018 b). "Solid Waste Management (SWM) at a University Campus (Part 4/10): Solid Waste Management at University Campus (Part 4/10): Perceptions, Attitudes, and Practices of students and vendors", *Journal of Environment and Earth Science*, ISSN (Paper) 2224-3216, ISSN (Online) 2225-0948; Vol. 8 (7).
Starovoytova, D. (2017)."Scientific Research, Writing, and Dissemination: (Part 3/4)-Scientific Writing", *Journal of Education and Practice*, ISSN 2222-1735 (Paper), ISSN 2222-288X; Vol. 8, No.28.
Starovoytova, D. and Cherotich, S. (2016 a). "Analysis of Masculinities Across Engineering Disciplines", *Research on Humanities and Social Sciences*, Vol.6, No.18, ISSN 2224-5766(Paper).
Starovoytova, D. and Cherotich, S. (2016 b). "Challenges Faced by Female-Students in Engineering Education", *Journal of Education and Practice (U.S.A.)*, ISSN 2222-1735 (Paper) ISSN 2222-288X (Online), Vol.7, No.25, 2016.
Starovoytova, D.; Tuigong, D.; Sitati, S.; Namango, S. and Ataro, E. (2015). "Potential of Theory of Innovative Problem Solution (TRIZ) in Engineering Curricula", *International Journal of Innovative Science, Engineering & Technology*, Vol. 2 Issue 5, ISSN 2348 –7968.
Sullivan, D. (2010). "Colleges Scrape the Plate, Close The Loop", *BioCycle*, 51(7).
Taghizadeh, S.; Ghassemzadeh, H.; Vahed, M. and Fellegari, R. (2012). Solid waste characterization and management within university campuses case study: university of Tabriz, *Elixir Pollution,* 43.
Tetra-Tech (2016). Solid Waste Stream Composition Study: Reducing solid waste in higher education: The first step towards 'greening' a university campus. File No.: 704-SWM.SW P03315-01.
Thanh, N.; Matsui, Y. and Fujiwara, T. (2010). "Household solid waste generation and characteristic in a Mekong Delta city, Vietnam", *J. Environ.* Manag., 91.
Thompson, K. (2005). University of Western Waste Audit Results. London.
Tiew, K.; Kruppa, S.; Basri, N. and Basri, H. (2010). "Municipal Solid Waste Composition Study at Universiti Kebangsaan Malaysia Campus", *Australian Journal of Basic and Applied Sciences,* 4(12).
UNEP (2010). Framework of global partnership on waste management, Note by Secretariat.
UNEP (2013). United Nations Environment Program: Municipal Solid Waste Composition Analysis Study: Juba, South Sudan.
UNEP (*nd*). United Nations Environment Program Division of Technology, Industry and Economics. Mapping Solid Waste – II: Sample Collection & Analysis. By Dr. Mushtaq Ahmed Memon. [Online] Available: www.unep.or.jp (July 11, 2018).
University Controller (2006). Reducing, Re-Using and/or Recycling University of Florida Electronic Equipment.http://fa.ufl.edu/uco/handbook/handbook.asp?doc=1.4.9.17 (July 4, 2018).
USEPA (2002). United States Environmental Protection Agency, U., *Solid Waste Management: A Local Challenge With Global Impacts*. May, 2002.
US-EPA (2009). U.S. Environmental Protection Agency: Recycling. [Online] Available: http://www.epa.gov/epawaste/conserve/rrr/recycle.htm (July 1, 2018).
van Adrichem, A. (2007). University of Guelph Solid Waste Reduction Work Plan. Guelph, ON: University of Guelph.
Wagner, J. and Bilitewski, B. (2009). "The temporary storage of municipal solid waste - Recommendations for a safe operation of interim storage facilities", *Waste management*, 29.
Waste-Watch (2005). Resource Management in the Education Sector – key findings from a study, England.
Westerman, P. and Bicudo, J. (2005). "Management considerations for organic waste use in agriculture", *Biores. Technol.,* 96.
Williams, P. (2005). Waste Treatment and Disposal (*2nd ed.).*John Wiley & Sons Ltd. England.
World Bank (2012). What a waste: A Global Review of Solid Waste Management. Urban Development Series. World Bank Group, USA.
WRAP (2011). Waste Hierarchy Guide. Applying the waste hierarchy: A-guide to business.
Yire, I. (2012). Banning plastic bags in Ghana and the way forward. [Online] Available: http://opinion.myjoyonline.com/pages/feature/201206/88817.php (July 21, 2018).
Yousuf, T. and Rahman, M. (2007). "Monitoring quantity and Characteristics of Municipal Solid Waste in Dhaka City", *Environmental Monitoring and Assessment*, 135.

Yu, C. and Maclaren, V. (1995). “A comparison of two waste stream quantification and characterization Methodologies”, *Waste Manage Res*., 13.
Zaman, A. and Lehmann, S. (2011). “Challenges and Opportunities in Transforming a City into a “Zero Waste City”, *Challenges*, 2.
Zekkos, D.; Kavazanjian, E. ; Bray, J.; Matasovic, N. and M. Riemer, M. (2010). “Physical characterization of MSW for geotechnical purposes,” Journal of Geotechnical and Geoenvironmental Engineering, vol. 136, (9).
Zhang, N.; Williams, I.; Kemp, S. and Smith, N. (2011). “Greening Academia: Developing Sustainable Waste Management at Higher Education Institutions”, *Waste Management*, 31.