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ORIGINAL PAPER

Characterization of solid wastes in higher education institutions: the case of Kotebe Metropolitan University, Addis Ababa, Ethiopia

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Abstract

The issue of Integrated Solid Waste Management is not limited to campus sustainability, but it is primarily a concern of public health and aesthetic impression to Higher Education Institutions in Ethiopia and elsewhere. To manage such wastes in an integrated approach, characterization of waste is a critical step. Knowledge of the sources and types of solid wastes, along with data on the composition and generation rate, is basic to the design and operation of the later management. In that regard, this study attempts to determine the composition and generation rate of solid waste in Higher Education Institutions. To do that, a standard sorting sheet and methods from related published sources have been applied. Accordingly, the major components of the waste in the university are food (84.41%), other organic (8.99%), paper (3.65%), plastic (1.83%), and the rest accounted 1.12%. The corrected solid waste generation rate is 0.093 kg/capita/day. The major sources of generation were the students' canteen, the duplication center, laboratories, offices and the general workshop. The solid waste generation and composition studied in two phases did not show a significant difference between seasons (p value > 0.05, on a 5% significance level), while over 93% of the waste generated is compostable. Therefore, the university and other Higher Education Institutions can target a minimal waste policy and stable management plan toward sustainability.

Keywords Compostable · Generation rate · Management · Sorting · Sustainability

Introduction

Generally a sound solid waste (SW) management is important not only from efficient use of the natural resources perspective but also from an environmental and public health points of views, in fact together with the liquid wastes (Ghazvinei et al. 2017; Changara et al. 2018; Lagerkvist and Dahlén 2012; Spinazzè et al. 2017). A thorough decision towards efficient management of the SW and conduction of further related studies depend on the knowledge of the characteristics of the SW, especially in higher education institutions (HEIs), as they are expected to stand as a model and generate technologies (Kassaye 2018; Ghazvinei et al. 2017; Owamah et al. 2017; Han et al. 2018). In doing so, Kotebe Metropolitan University (KMU) in particular and other HEIs in general have to play a pioneering role in the management of SW in Addis Ababa city or other cities in the country.

In addition to that, the SW generated by HEIs takes considerable share from resource management point of view. Indeed, the SW generated in a given community is a reflection of the activity and the available natural resources therein. Consequently, the SW generated in HEIs is different from process industries, and that from developing countries is characteristically different from the industrialized ones, the former being more organic by content (United Nations Environment Program 2005; Coker et al. 2016).

In Ethiopia, there are about 31 public and 76 private HEIs (Arega 2016). In the city of Addis Ababa, institutional SW takes 20% of the share of all the SW generation. KMU as a HEI, established in 1959, hosts over 10,000 students under diverse academic programs in different modalities (Ministry

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of Education of Ethiopia 2016) and is under expansion. The country has proclaimed to enhance capacity at all levels to prevent the possible adverse impact of SW while creating economically and social beneficial assets (Ministry of Urban Development and Construction of Ethiopia 2012) that requires scientific evidence.

In fact, an integrated solid waste management (ISWM) is a key issue not only from public and environmental health perspectives but also due to the urging sustainability of HEIs (Armijo de Vega et al. 2008); wastes discarded carelessly will end up with soil and water pollution as well as air pollution and depletion of the natural resources (Vasanthi et al. 2008). It is an issue related to resource use efficiency (Vrancken et al. 2017). In that regard, a comprehensive management is imperative for which the first critical step is to know each and every component of the composite SW and its generation rate (Smyth et al. 2010; Nagawiecki 2009) of the later management.

Widely, solid waste management (SWM) remains to be an issue in the developing world because of its raising release, poor management and the subsequent environmental pollution. The decaying nature of the waste, its non-degradable fraction and accident potential are some of its visible impacts. The impact is ranging from esthetic problem to insect breeding and scavengers attraction (Al-Khatib et al. 2010) posing a threat to public health (Ziraba et al. 2016). An ISWM is a challenge to a sustainable development (Armijo de Vega et al. 2008). In that regard, knowledge on the source and types of the SW, along with data on the composition and the generation rate, is basic to the design and operation of the functional elements associated with the management of SW (Techobanaglous et al. 1977; Phuntsho et al. 2010).

Further, information on the composition of SW is important to develop guidelines that will evaluate equipment needs, system efficiency and the management programs and plans (Kiely 2007). Thus, knowledge of the composition of the wastes is an essential element in: (1) the selection of the type of storage and transport most appropriate to a given situation, (2) the determination of the potential for resource recovery, (3) the choice of a suitable method of disposal and (4) the determination of the environmental impact exerted by the wastes if they are improperly managed (Pokhrel and Viraraghavan 2005). Moreover, understanding of the amount of SW generation is also necessary to develop management strategies in order to effectively handle those wastes (Techobanaglous et al. 1977; Ghazvinei et al. 2017) in the long run.

Despite that, former works did consider either only sorting or composting component of an ISWM leaving gap in the holistic view of institutional SW, including its other physical parameters, for the later management alternatives (Smyth et al. 2010; Desta et al. 2014; Gakungu et al. 2012). Some of the past studies did not follow authorized sorting format and failed to address seasonal variability; hence, the generation rates are not specific to different components of the SW and also the biodegradable fraction with respect to composting potential is less described (Mbuligwe 2002; Armijo de Vega et al. 2008; UNEP 2009).

Moreover, the local context is even worse, KMU dumps its SW near offices, and the SW is irregularly transported to land fill and no record of quantity and composition of SW is available. Therefore, this study, conducted between August and October 2016, is aimed to determine the SW generation rate, volume and bulk density, in KMU as well as characterize the waste's composition or nature in terms of biodegradability, compost potential, volume, density and their possible integrations.

Materials and methods

Study area

Kotebe Metropolitan University is laid on a little over 15 hectares of land in Yeka sub-city of Addis Ababa city, Ethiopia (Fig. 1).

Regarding infrastructures, the university has old and new blocks, while few are still under construction. It has about 88 office rooms, 97 class rooms, 24 laboratories, 68 sanitation facilities, 147 dormitories, two cafeterias, four sport fields, one staff lounge and one clinic in the study period (KUC 2015).

Sampling

Direct sampling methods is common in the field of SW study (Kiely 2007; Ghazvinei et al. 2017; Weichgrebe et al. 2017; Martin et al. 1995). This study on SW in KMU applied direct sampling and includes a statistically representative size of offices, class rooms, the students' cafeteria, and the students' dormitories, main corners, the libraries, as well as garages and the sport fields. Currently there are assigned janitors, waste baskets and cleaning schedules for every service unit of the university. The sample collection is applied along with the existing system of waste collection of KMU that, in fact, contributes to practicality of the study. Proportionate sampling is applied to get a proportion that represents the size of that particular category since KMU has different categories of activity areas; thus, this research has to ensure the representation of each type of activity area. Thus, activity areas that are high in number had higher proportion of the sample size. However, to those types where only one or two activity areas present, the researchers judgmentally took all of those study units.

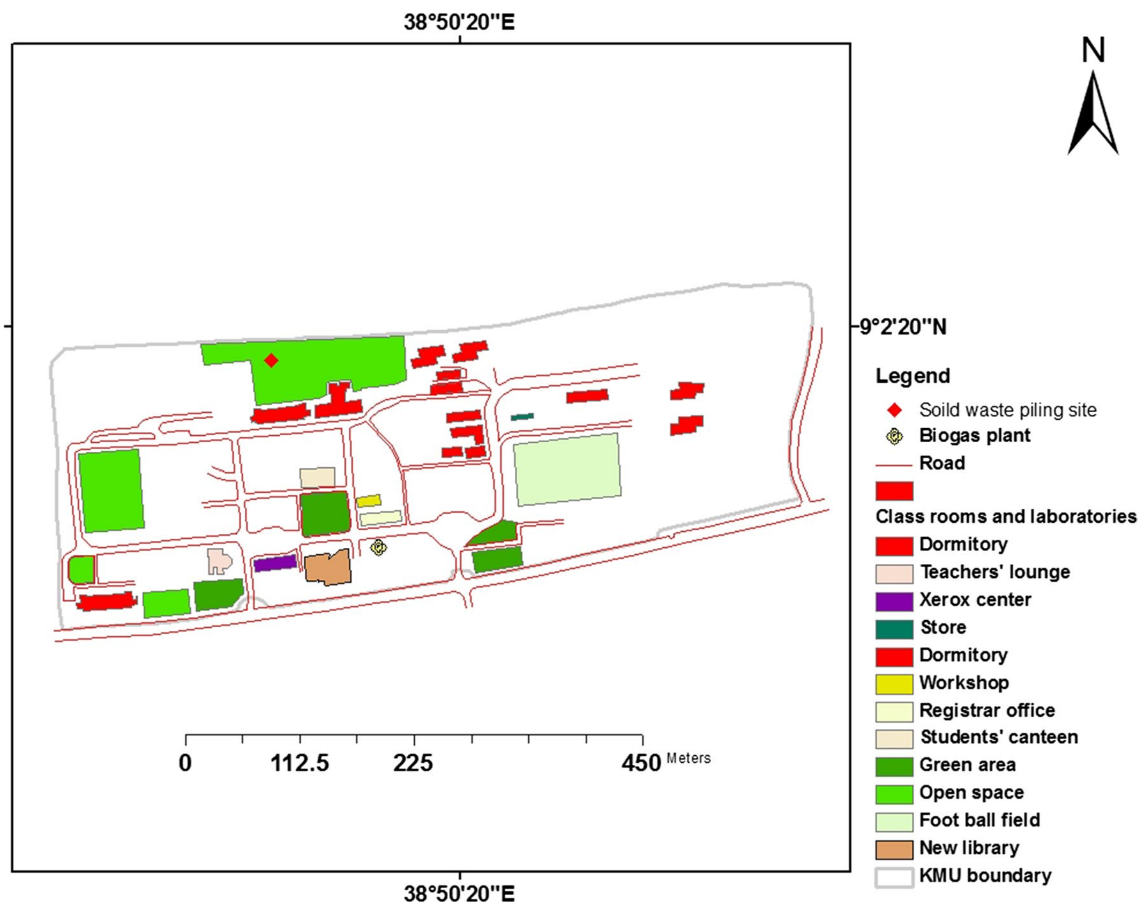

Fig. 1 Map of KU based on Google earth and ArcMap10 with a scale of 1:2500 (ArcMap 10)

Sample size

Based on the KMU's bulletin published in 2015, there are 431 units of infrastructures in eight different activity units (KUC 2015). Therefore, the overall sample size of 90 calculated using the formula:

$$n = N/\left(1 + N * x^2\right),$$

where n = sample size; N = study population (total number of infrastructures); x = level of precision (0.1); accordingly, the category of samples based on activity in the university is summarized (Table 1).

The waste audit took place in two periods that considered the regular and the summer modalities of the university. The first period was between August 23, 2016, and August 29, 2016, and the second period was between October 27, 2016, and October 31, 2016.

The SW was collected and aggregated by contracted janitorial staff guided by undergraduate students into large garbage bags which were taken as the sample units in this study. The janitors contracted were based on minimal academic requirement of high school graduates, and those selected were trained for a day long on waste sorting, weighing and recording. All the collection bags were labeled according to the date, activity area and collection shift and were weighed

Table 1 Category of activity areas and the corresponding sample size

Activity area	Sample number	Total number	Remark
Offices	17	88	Approximate
Cafeteria	2	2	Judgment
Dormitory	28	147	Approximate
Staff lounge	1	1	Judgmental
Class roams	18	97	Approximate
Laboratory	6	24	Approximate
Sanitation	13	68	Toilets
Copy center	1	1	Judgment
Student street	1	4	Minimum
Sport field	1	4	Minimum
Store	1	2	All
Workshop	1	1	As it is
Total samples	90		

and sorted daily except the volume measurement that was taken when the garbage barrel of 1.1 m^3 volume is full. Thus, the samples were collected per functional unit, and the proportion of waste contributed by functional unit was also determined. In addition to that, the bulk density of the SW generated by KMU is calculated using a defined volume container and following the weighing of the waste.

Materials

A range of equipment types was used in this study. During data collection, labeled baskets, personal protective equipment, weight scales, stationery materials, record sheets, transfer carts, volumetric collectors, plastic bags and other equipment were used.

During the waste audit, the total weight generated in each activity area was determined using a digital scale (accuracy $\pm$ 0.099 kg). Plastic bags in baskets were used to collect the rubbish at the sampled unit and finally transported to the shade where weighing and registering following sorting is taking place which was followed by the filling of a known volume container at site and at the same date where part of the SW is collected and weighed twice a day.

Analysis

The SW sample was categorized using authorized classification format developed by the United Nations Environment Program (2009). Gravimetric and volumetric analysis was performed on the SW sample following manual sorting. At the same time, numerical analysis was performed to determine generation rate by category as well the bulk density. After data collection, the finding is compared and contrasted with state of the art in those similar institutions studied elsewhere. Further, the data are analyzed using the statistical software R.

Results and discussion

Current state of SWM in KMU

KMU's SWM does not sound unlike its floral beauty. The wastes are not well isolated from some original materials and are even dumped indiscriminately without the necessary care. Presently, KMU transports its SW out of campus irregularly to the nearby municipal haul container using push cart handled by municipal SW pickers. Also, the SW is dumped into ditches in the campus, on the open field and also inside abandoned containers as well as it is open fired in the compound.

One can find car tires, left pillows, cardboards and different pipes among others. Worse is the pile of metals, used chairs, oil jars, tins, demolition wastes and others in the campus. As a matter of fact, KMU is using asbestos for its building roofing material and is existent together with the demolished wastes which include its spill in the campus motor ways (Fig. 2).

SW sorting and generation rate

Sorting in this study is based on the collection of wastes at the source, since the subsequent result provides the clear whereabouts of the source of waste, and the categorization of wastes by type is easier at the source. Further, the latter waste minimization efforts can be applied at the source of generation (Smyth et al. 2010). The challenges in managing SW include reducing generation of waste, separation, change

Fig. 2 The asbestos material haphazardly disposed in the campus

in habits, collection, transport, treatment, reuse and disposal (Gakungu and Gitau 2012); thus, the finding from this sorting study can contribute to any of the waste management functions (Table 2).

Generation rate study is important to enhance at all levels of capacities to prevent the possible adverse impacts while creating economically and socially beneficial assets out of SW (Lohri et al. 2014) using valorization technologies. Moreover, KMU is a university committed to the sustainable development of the city of Addis Ababa. In that regard, one of the major municipal services that the city provides to its inhabitants is the SWM. In view of providing trainings to such human resource capacity demand of the city, the university should first be a role model (Hoornweg and Bhada-Tata 2012). Therefore, quantifying the SWM variables enables the university to provide fact-based community services, and this study is aimed to introduce the 'language' of ISWM as detailed in "Characterization study" section.

The characterization study

The per capita daily SW generation at KMU can be calculated from the grand total generation rate and the number of regular students in 2015/2016 academic year which is 3634 (Table 2), which gives a value of 0.054 kg/capita/day. This finding on per capita SW generation rate for KMU falls within the range 0.04–0.1 kg/capita/day reported by a related study conducted in public technical training institutions in Kenya (Gakungu et al. 2012). This Kenyan report does match not only with the generation rate of this current study but also with the composition that the dominant, over 80% in both cases, component of the SW is food waste. Whatsoever, promoting environmentally sustainable society is a unique role to be played by HEIs of which SW Environmental Management System is getting acceptance as SW is a good indicator of consumption (Smyth et al. 2010).

Table 2 shows that the leading generation point of SW in KMU is the students' cafeteria followed by laboratories, the general workshop and offices. This helps to design management alternatives that can receive separate SW from the point of generation.

The composition pie chart depicts the other organic and paper wastes follow the dominance which suggests recovery technologies can be applied for the organic fraction; as a result, a big portion of the SW can be recovered (Fig. 3).

Though the recoverable waste part is the far dominating segment, it is clear (Fig. 3) that the single largest component of the recyclable material in KMU is paper followed by plastic waste. Based on the existing practice in the university, the plastic bottles are diverted informally either for reuse or for other purpose by janitors themselves and others that may have reduced the real share by the plastic portion of the SW. The paper waste dominating the recyclable fraction of the SW is not unique to this university (Smyth et al. 2010). Further, the existence of metal waste to this proportion (up to 0.4%) alarms recycling alternative as it is a valuable but rare resource.

It is important to identify the sources of the SW generation in any institution in order to act on the subsequent management options of the wastes of which minimization and sorting have great importance. As it is shown in Table 2 and Fig. 4, the sources of the SW generated were dominated by the cafeterias and the students' canteen where the regular

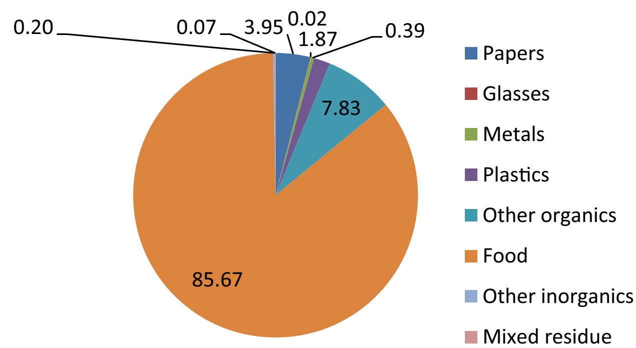

Fig. 3 Pie chart on the type of waste generated at KMU during the first-phase study

Table 2 Result of sorting and weighing the SW in KMU

Category	Average total (kg)	Average generation rate (kg/day)	Percent generation
Paper	43.9	7.23	3.65
Glass	0.35	0.06	0.03
Metal	9.1	1.67	0.84
All kinds of plastics	21.84	3.64	1.83
Other organic	104.45	17.82	8.99
Food	1004.75	167.39	84.41
Other inorganic	2.5	0.42	0.21
Mixed residue	0.5	0.07	0.04
Sum	1187.39	198.30	100.00

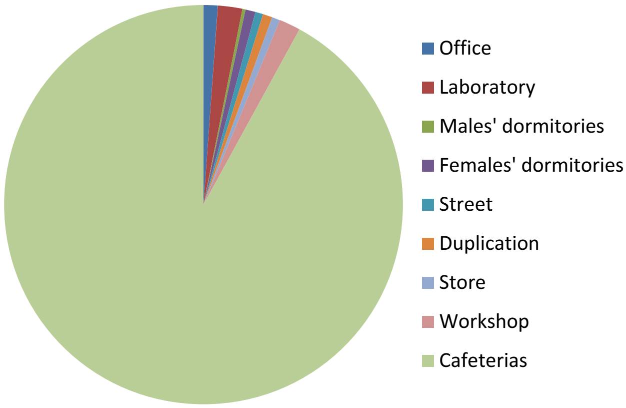

Fig. 4 Contribution of the SW by functional unit in KMU

students of the university cater and leave huge leftovers. Laboratory facilities, the general workshop and offices are also considerable generators. The less dense wastes accompanied by paper as a dominant type and volume are generated by the offices. In that regard, targeting office holders toward minimization and sorting of the SW is a relevant intervention.

Knowing the generation rate of the wastes by type can further help size the later management facilities that perform nutrient and energy recovery operations. To that effect, the generation rates of the different type of wastes at KMU are quantified (Fig. 5) obviously dominated by the food waste followed by other organic and paper wastes.

As stated earlier, the dominant generation rate, composition and source is the food waste from the students' canteen. Such result suggests that KMU can apply a SWM alternative that largely deals with the organic fraction, and hence, it is possible to recover nutrient and energy as well as intermediates of biochemical products by applying the right biotechnology (Palanivel and Sulaiman 2014). The application of recovery or valorization technology to the food waste is urgent because not only KMU benefits out of it but also it minimizes the challenges from extending the storage, transport and disposal of such putriscible waste even contributing to city level (Desta et al. 2014).

In a related fact, KMU can apply compost technology to sustainably manage its SW. Composting is one of the nature ways of material recovery that can be an option in an ISWM contrary to the traditional thermal or chemical technologies that are famous for their secondary pollution (Ren et al. 2018). Further composting improves bioavailability of organic pollutants over soil conditioning. Figure 6 portrays that a significant portion of the waste in KMU is compostable or recoverable. Therefore, KMU can have a sustainable waste management strategy and be a good model as well as pioneer in use of such related technologies for the city as well as the nation in general. The compost product and byproduct can further be studied and be applied in the context of urban agriculture including in the city of Addis Ababa in Ethiopia (Hara et al. 2010, Oberlin and Szántó 2011).

Further, it is necessary to measure the gross volume and the bulk density of the waste as they are important variables in SW characterization as it will potentially affect the later management including composting (Zhao et al. 2012). In that regard, the relative density of the food waste is significantly higher than that of the non-food wastes, which were 279.6 and 33.7 kg/m^3, by comparison as it is laden with moisture (Table 3). The density of the SW studied especially the organic fraction lies within the range studied in Addis Ababa city (205–370 kg/m^3) (Desta et al. 2014).

Thus, the finding of this study can serve as a reference for KMU to decide on, start and document an ISWM system. The Facilities and General Services Department of the university has to implement the advice and the facts of this study by developing workable guideline that encompass all the elements in an ISWM system. Furthermore, this university and related others can extend their community services based on documented studies on SWM and through establishing a technology transfer center.

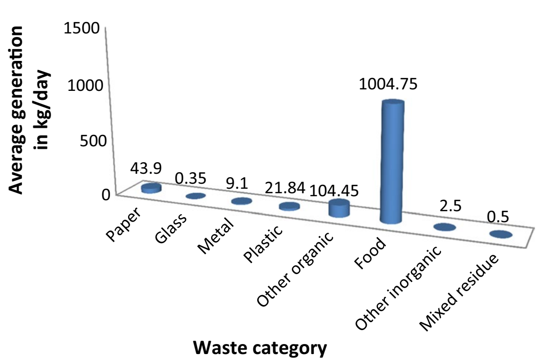

Fig. 5 SW generation rate in kg/day by waste category

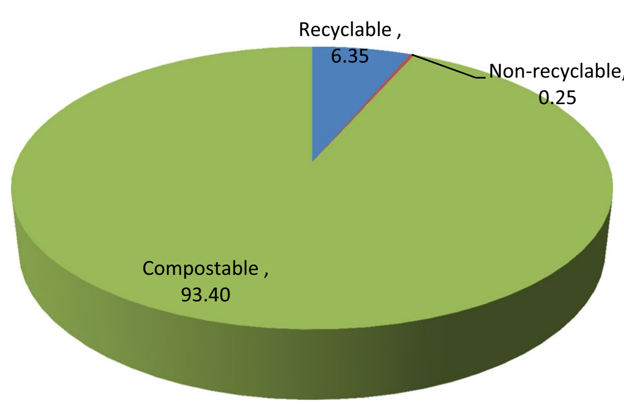

Fig. 6 Percentage composition of the SW by management interest

Table 3 Composition, generation rate, volume and bulk density of food and non-food wastes in KMU

Category	Mean generation rate (kg/day)	Weight (kg)	Volume (m^3)	Bulk density (kg/m^3)
Paper	26.8	80.4	3.3	33.8
Glass	0.1	0.4		
Metal	1.1	3.2		
Plastics	9.2	27.7		
Food and other organic	301.9	905.6		
Total	339.1	1017.3		

Conclusion

Knowing the characteristics of SW in HEIs is a precondition to support the later sustainable waste management options and to do further research. The waste category as well as the SW generation rate in KMU did not show significant variation during the summer and the winter seasons, implying that the university can design a year-round management alternative based on a stable input as SW. Further, the 93.4% of the SW generated by KMU is organic and compostable and hence KMU may apply robust biological technology to recover the nutrient from the compostable SW fraction. Regarding the recyclable fraction, it is possible to integrate with recycling firms in the city where the university is located so as to divert that fraction. In general, KMU as well as similar such HEIs can go for 'minimal waste' policy and practice based on this study, and by doing so, these institutions can implement sustainable waste management system that can contribute to their overall sustainability.

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Compliance with ethical standards

Conflict of interest All authors declare that there is no conflict of interest among authors and/or other associated in this current research work.

Ethical statement Before commencing the work, the research proposal was evaluated and approved by the Institutional Research Ethics Board of Kotebe Metropolitan University Institutional Ethical Review Committee that is run by: Dr. Elazar Tadesse Bala: Chair person, Mr. Daniel Zewde: Secretary, Mr. Engida Tade: Member, Dr. Tadesse Gemechu: Member, Dr. Teferi Bogale: Member, Dr. Teshome Belay: Member. The above-mentioned committee approves also that it does not have any objection to the submission of the manuscript for the International Journal of Environmental Science and Technology.

Informed consent All authors declare that they have consented on the work fully to be submitted to the International Journal of Environmental Science and Technology.

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