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CITIZEN SENSING OF SOLID WASTE DISPOSALS: CROWDSOURCING AS TOOL SUPPORTING WASTE MANAGEMENT IN A DEVELOPING COUNTRY

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SUMMARY: Large sub-Saharan African cities are characterized by serious and persistent environmental problem of Solid Waste Management (SWM). The city of Kinshasa, in Democratic Republic of the Congo has a long lasting and major concern of SWM. More worryingly, with rapid population growth and urbanization, waste generation, both domestic and industrial, is expected to rise with great potential of health and environmental problems. Therefore, with an objective of bringing a possible solution that reduces the increasing problem of SWM, we explore in the present study the use of crowdsourcing as a possible mechanism to identify, localize, characterize solid waste landfills. The proposed approach allows (i) creating a spatial and temporal database through a participatory process to support data collection and information generation, and (ii) visualizing the spatial and temporal distribution of observations through an interactive map. Our database holds 187 observations of solid waste disposals across Kinshasa within two years with estimated volume of solid waste accounts of 587'920 m^3. These observations include 61 public disposals (e.g., transit center), and 151 wild dumps, of which, 174 active and 3 inactive disposals. The approach developed in this study is a proof-of-concept and a successful implementation was achieved. Our conception and results provide new tool and mechanism to collect data and generate useful information on solid waste landfills in the city of Kinshasa that was not available before. The results of this study indicate that

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crowdsourcing can be a valuable mechanism to involve citizens in collecting data on solid waste landfills in the city of Kinshasa, which can be applied in similar urban cities.

1. INTRODUCTION

Solid waste management (SWM) is a global environmental issue and major unsolved problem in many parts of the world, particularly in dense populated areas of developing countries (Henry et al., 2006; Rachael et al., 2013). Although many efforts have been performed for the implementation of Integrated Solid Waste Management (ISWM) in the last decades, a chronic urban waste problem endures in African cities and there is little understanding of the interface between actors of SWM and their governances (Mbiba, 2014; Ezeah and Roberts, 2014). The increasing population in major cities, rapid urbanization, inequality and the rise in community living standards, economic growth, cultural and socio-economic aspects, policy, governance and institutional issues, and international influences have accelerated the municipal solid waste generation rate and complicated the SWM sector (Achankeng, 2003; Davies, 2015; Kubanza & Simatele, 2016; Minghua et al., 2009; Guerrero et al., 2013; Marshall and Farahbakhsh, 2013). On the one hand, the SWM sector is predominantly preoccupied, in most of the cases, with collection and removal services (Breheny, 1992). On the other hand, one notes the inefficiency of SWM strategies and lake of infrastructures, mainly waste treatment facilities and, as a consequence, the proliferation of uncontrolled landfills, causing environmental and human potential risks (Henri et al., 2006; Wilson, 2007). In developing countries, health and environmental implications associated with SWM are mounting in urgency (Marshall and Farahbakhsh, 2013). Development of sustainable SWM strategies with greatest environmental potential, meeting the needs of society and economy, as well as safeguarding the natural resources is one of the priorities, but also one of current challenges in developing countries. Thus, there are great needs for the implementation of efficient SWM strategies, including modern approaches of waste reduction, separation, recycling and reuse, as well as waste treatment as energy source and finally appropriate management of final waste.

Kinshasa is the capital and largest city of the Democratic Republic of the Congo (DRC) and has an estimated population of more than 12 million, with generated amount of MSW estimated at 0.5-1 kg per person per day depending on the living standard (Parau, 2015; Mavakala et al., 2016). According to a recent study (Simatele and Etambakonga, 2015), the annual generation of solid waste in the city of Kinshasa is estimated to 2 million m^3. Actually, RATPK (Régie d'Assainissement et des Travaux Publics de Kinshasa) collects less than 20 % in nine of the twenty-four municipalities and sends to disposal in a controlled municipal landfill in Mpasa, which has been in operation since 2010 (Mavakala et al., 2016, Mwanamoki et al., 2015; Tshibanda et al., 2014). The remaining fraction is eliminated in public spaces and urban rivers, which are customarily considered as possible landfill sites. Owing to rapid increases in urbanization and industrialization as well as population growth trend, the generation rate of MSW will continue to rise. Consequently, there will be an increase in number of uncontrolled landfills with great potential environmental impacts and high risk on human health (Moore et al., 2003; Mwanamoki et al., 2014). Therefore, there is a need for new strategies to manage solid wastes and new approaches to map and generate useful descriptions on solid waste disposals, selective collection and recycling of solid wastes, which will reduce the amount of solid waste disposal into customarily landfill sites and so their potential impacts.

Currently, no data virtually exist on solid waste landfills localization and description in the city

of Kinshasa (Mangenda et al., 2014, 2015).As results, , it is almost impossible for the authorities to efficiently manage solid wastes, as they are unable to qualitatively characterize and quantitatively measure them or to develop an effective waste management strategy. Due to this lack of information, alternative means to collect data on waste disposals is required (Etambakonga, 2012). In recent years, crowdsourcing has been coined as a promising alternative tool to gather data (Brabham, 2008; Brabham, 2009; Brabham, 2012; Brabham, 2013a,b;). Crowdsourcing can be defined as the collective wisdom of a crowd to find a solution to a problem that affects it (Baruch et al., 2011; Haklay, 2013). Therefore, crowdsourcing can be an interesting solution supporting waste management (Mclaren, 2011). Indeed, crowdsourcing is a new way of utilizing the power of the crowd in solving problems (Howe, 2006). While crowdsourcing was originally defined as a web based business model requiring voluntary open collaboration in the development of creative solutions (Howe, 2006), it is now being used increasingly in different domains of study. In fact, in computer science, crowdsourcing has been used in recommendation systems (Larson, 2013), software development (Mao, 2013), multimedia (Redi, 2013), database design (Franklin, 2011), and search engine evaluation (Kazai, 2011). Other domains have also utilized crowdsourcing for specific purposes. For example, crowdsourcing has been used in environmental sciences (Fraternali, 2012; Jarrod et al. 2017), medicine (Foncubierta, 2012), business and management (Seltzer, 2013), law and politics (Bader, 2013), sociology (Borch, 2012) and astronomy (http://events.asiaa.sinica.edu.tw/workshop/ 20140303/). Projects like Stardusthome, Galaxy Zoo, Wikipedia, Wikimapia, social mapping, peer to peer software, smartphone software, blogs, social bookmarking applications, and social networks…are typical examples of crowdsourcing tool. Thus, it can be a key element in addressing challenging urban sustainability issues such as waste management in a developing country, energy consumption, transport efficiency, water and sanitation, sewage. Consequently, organizational models for participatory and community-based waste management have been widely discussed in the recent years, but have rarely investigated technological solutions (Kironde and Yhdego, 1997; Mongkolnchaiarunya, 2005; and Scheinberg, 2010).

Recognizing the need to have alternative means to collect data on solid waste disposals, this paper proposes the use of crowdsourcing as a possible mechanism to involve different group of stakeholders in identifying, localizing and describing landfills. The objective of this study is to create a spatial and temporal database through a participatory process to support data collection and information generation on the greatest environmental problem that the city of Kinshasa is facing.

2. METHODOLOGY

2.1 Study site description

This research was performed in the City of Kinshasa, the capital and largest city of Democratic Republic of the Congo. Kinshasa is located between 3.9 degrees and 5.1 degrees' south latitude and 15.2 degrees and 16.6 degrees' east longitude, covering an area equivalent of 9965 km^2, with a mean altitude of 240 m above sea level. The estimated population rose from five thousand inhabitants in 1881 to more than twelve million at present with a density of 1211 inhabitants per square kilometer (Mavakala et al., 2016). The city of Kinshasa is a decentralized administrative entity and subdivided into 24 municipalities (Fig.1). Kimbanseke having around

one million inhabitants is the most populated commune while Gombe is less populated. Bumbu is the densest municipality with 62,120 inhabitants per square kilometer. The data collected for the research presented in this paper come from 23 municipalities (except from the municipality of Maluku considered as a rural), which 187 uncontrolled landfills were identified from October 29, 2015 to January 4, 2017.

Figure 1. Study site location, Africa, DRC, Kinshasa. a: Africa map, b: DR Congo map, c and d: Kinshasa municipalities map.

2.2 Citizen Science and Crowdsourcing approaches

In areas where local authorities do not have the necessary resources to locate solid waste disposals and characterize them, alternative means to generate such information are required. One of the new technologies for environmental monitoring that has emerged a decade ago and that has proven to be a valid alternative to complement existing datasets or generate new information is to involve individuals in a collaborative effort using internet to obtain needed information (Goodchild, 2007; Ho & Rajabifard, 2010; Tulloch, 2014, Hosseini et al., 2015). Crowdsourcing is a technique to outsource the work and divide it between participants to achieve a cumulative result (Verplanke, et al., 2016). When crowdsourcing is used to involve members of the public in collaborative scientific research projects to address real-world problems, the term Citizen Science is commonly used (Goodchild, 2007; Haklay, 2011). Consequently, using Citizen Science and Crowdsourcing approaches to map and generate useful descriptions on solid waste disposals in a city like Kinshasa appears to be a promising solution to investigate. To our knowledge, crowdsourcing as a tool for mapping and getting information regarding waste disposals has been rarely used. We found only two attempts to apply such approach and none of them actually have been published in scientific literature. The first experiment was made in 2013 to generate a crowd map where people could report in mapping an illegal waste dumping in Montenegro (http://europeandcis.undp.org/blog/2013/11/08/the-crowdmap-for-citizen-reporting-of-waste-

dumps-in-montenegro-6-months-later/). Unfortunately, this effort has been discontinued and the application is not anymore available. The second effort dates from 2014 and has involved more than thousand scientists around the world to analyze almost 60,000 documents and produce a crowd map that visualizes municipal solid waste management data in various counties around the World (https://handshake.pppknowledgelab.org/columns/crowd-sourcing-for-waste-management/). Despite the remarkable effort done to develop the Waste Atlas (www.atlas.d-waste.com), virtually no data is available from developing countries or cities including Kinshasa.

2.3 Data collection and validation

Citizen sensing of solid waste disposals consists of mapping and describing the spatial distribution of both controlled and uncontrolled landfills using a participatory approach involving local residents. Thanks to the large diffusion of Global Positioning System (GPS) and Smartphones it is now possible for virtually any citizen to capture information and knowing at the same time the exact location on Earth (IFAD, 2009; (Diaz et al., 2011). Several solutions exist to collect and map observations such as KoBoToolbox (http://www.kobotoolbox.org), Taarifa (http://taarifa.org), OpenDataKit (https://opendatakit.org), GeoODK (http://geoodk.com), or EpiCollect (http://www.epicollect.net).

In our case, we decided to use the Ushahidi platform (https://www.ushahidi.com). Ushahidi, which means “testimony” in Swahili, was first developed to map reports of violence in Kenya after the post-election violence in 2008. Since then, numerous crowdsourcing projects have used this tool for information collection, visualization, and interactive mapping (Riccardi, 2016). Ushahidi provides a robust suite and valuable open source tool that enable local observers to submit information or reports using their mobile phone or Internet, at the same time creating a spatio-temporal archive of observations. Ushahidi platform allows efficient data collection, management, and analysis. In particular, it offers features to collect data from multiple sources (e.g., SMS, email, Twitter, Custom surveys) and multiple platforms (e.g., iOS, Android, Web). It supports also data management, such as data validation, filtering, and workflows. Finally, it enables visualizing (e.g., maps, reports) and downloading data in various formats.

To collect meaningful data, an important aspect was to design a form, which would easily help capture essential information to characterize solid waste disposals. For this purpose, several expert advices were obtained to define the most relevant fields (Table 1). All the fields were translated in French as this is the main language used in the country.

Table 1. Fields of the form

Field Name	***Definition***
Name of the street or district	*This is the title of the report giving already an idea of the localization of the observed event.*
Description	*Describe what has been observed.*
Categories	*Select one or more categories describing the disposal (e.g., public disposal, wild dump, active or inactive).*
Dimensions	*Estimation of the width, height and volume of the disposal.*
Solid waste observed	*Estimation in percentage of the content (e.g., plastics, metals, glass, and organic matter).*
Description of the situations	*Describe the surroundings (e.g., close to a road, a river, a house)*

Observed nuisance	*Describe nuisance (e.g., smell, smoke, leachate)*
Geographical location	*Define the geographical location either on an interactive map or using GPS coordinates.*

Together with the report pictures, videos and links to other resources such as press articles can be jointly submitted. The preferred solution to submit reports is to use the dedicated web application (http://kinmap.grid.unep.ch/ushahidi/reports/submit) that allows filling the form (Fig. 2). Alternatively, users can also use: (1) the Ushahidi mobile phone app for iOS or Android, (2) send an email to a dedicated address (kinmap@unepgrid.ch), or (3) send a tweet with the hastag #kinmap. All reports are then collected and should be reviewed, validated, and approved before being considered for publication.

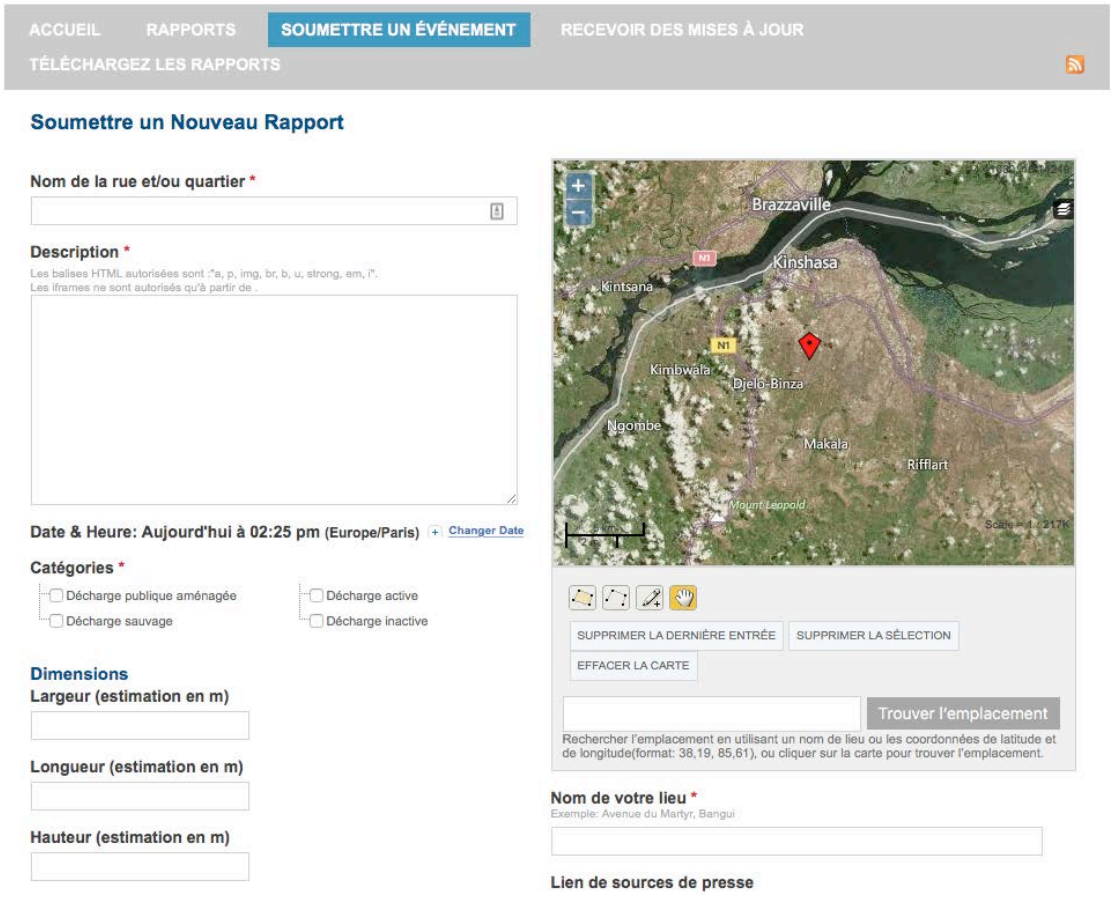

Figure 2. The form used to collect observations implemented in the web-based application.

Prior to data collection campaigns, it is important to develop the capacities of users to first use the tool to report an observation and then other people in turn (e.g. train the trainers). The targeted participant was a group of 30 students in environmental sciences from University of Kinshasa (UNIKIN) and Université Pédagogique Nationale (UPN) that already have some basic knowledge in geomatics. This choice was justified by the fact that the group was a quick win participants as they are already aware of the issue and they are familiar with the technology

used to build the provided tools. A series of capacity building resources were developed to train students and help them to disseminate afterwards those resources to develop new skills to other people. The training material was composed of (1) Tutorial: a three-page document explaining how to submit an observation and to fill accordingly the form; (2) Video: a twelve-minute recorded video explaining how to submit an observation, how to fill the form, review and validate data, and visualize and download reports; and finally (3) Webinars: two remote sessions were organized with students to demonstrate, discuss and obtain their feedbacks over the platform use.

Once students were comfortable with the tool, field campaigns were then organized and closely coordinated in order to collect observations and report them accordingly into the platform using the appropriate web form.

Once submitted, reports are not instantly and publicly available until they are validated. One of the key elements for an effective crowdsourcing is to make sure that data are of sufficient quality through a data validation process, which is a two steps procedure. In the *verification* step, data are verified in terms of completeness, accuracy, and consistency. If data successfully pass the first step, then they are reviewed by a second person (usually an expert) for *approval*. This procedure ensures that data are verified, quality controlled and are reliable to be available on the platform. Even after publication, users are still to be able to make comments on the observations and report any mistakes, changes or new information on an identified landfill.

3. RESULTS AND DISCUSSION

The crowdsourcing application implemented to collect, manage, visualize, and download data is available at: http://kinmap.grid.unep.ch (Fig. 3). It allowed to collectively produce a spatiotemporal database of observations of solid waste disposal across Kinshasa city.

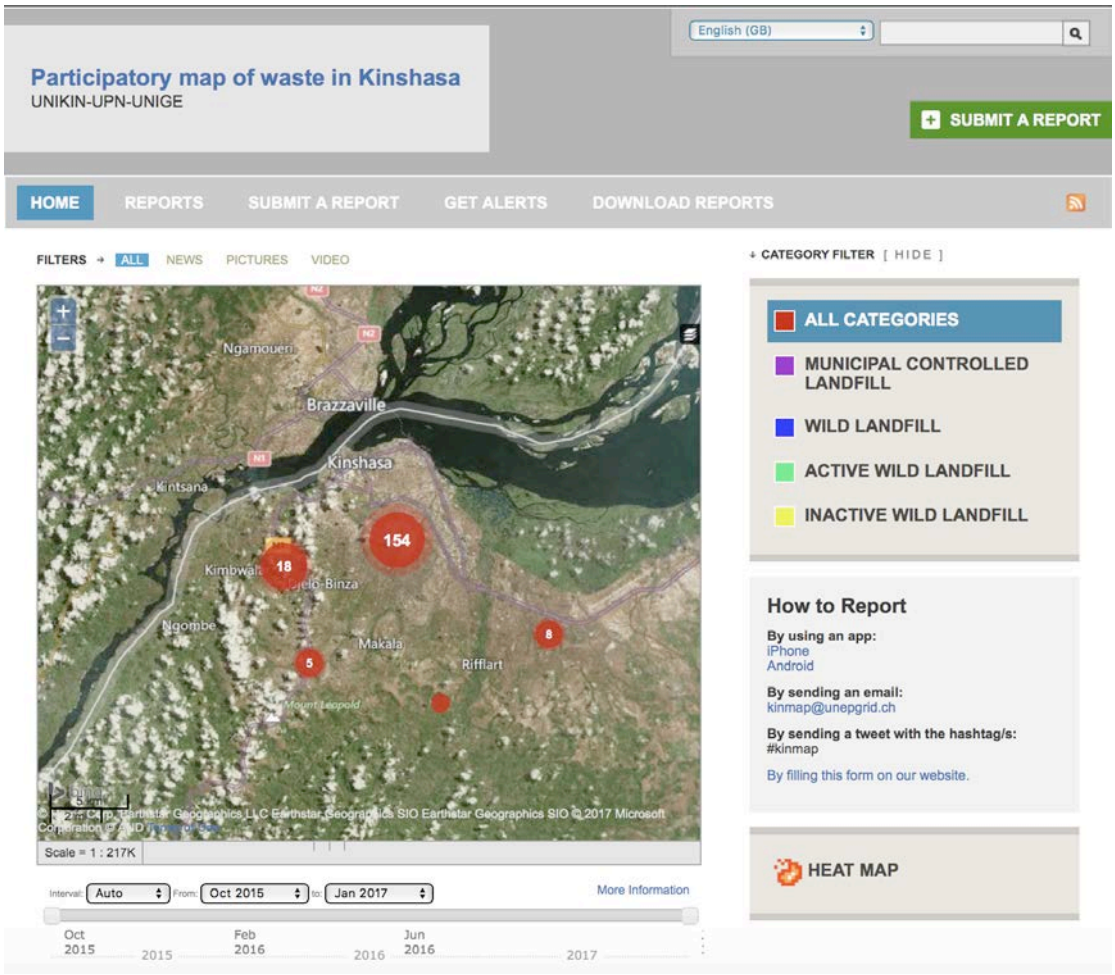

Figure 3. The landing page of the crowdsourcing platform. It allows users to access and visualize observations through an interactive map and to submit new observations using the green button on the top-right of the page.

The application has several features enabling users to visualize the spatial and temporal distribution of observations through an interactive map. Depending on the scale, the map aggregates reported observations (i.e., clusters) to enable an efficient visualization (Fig. 4).

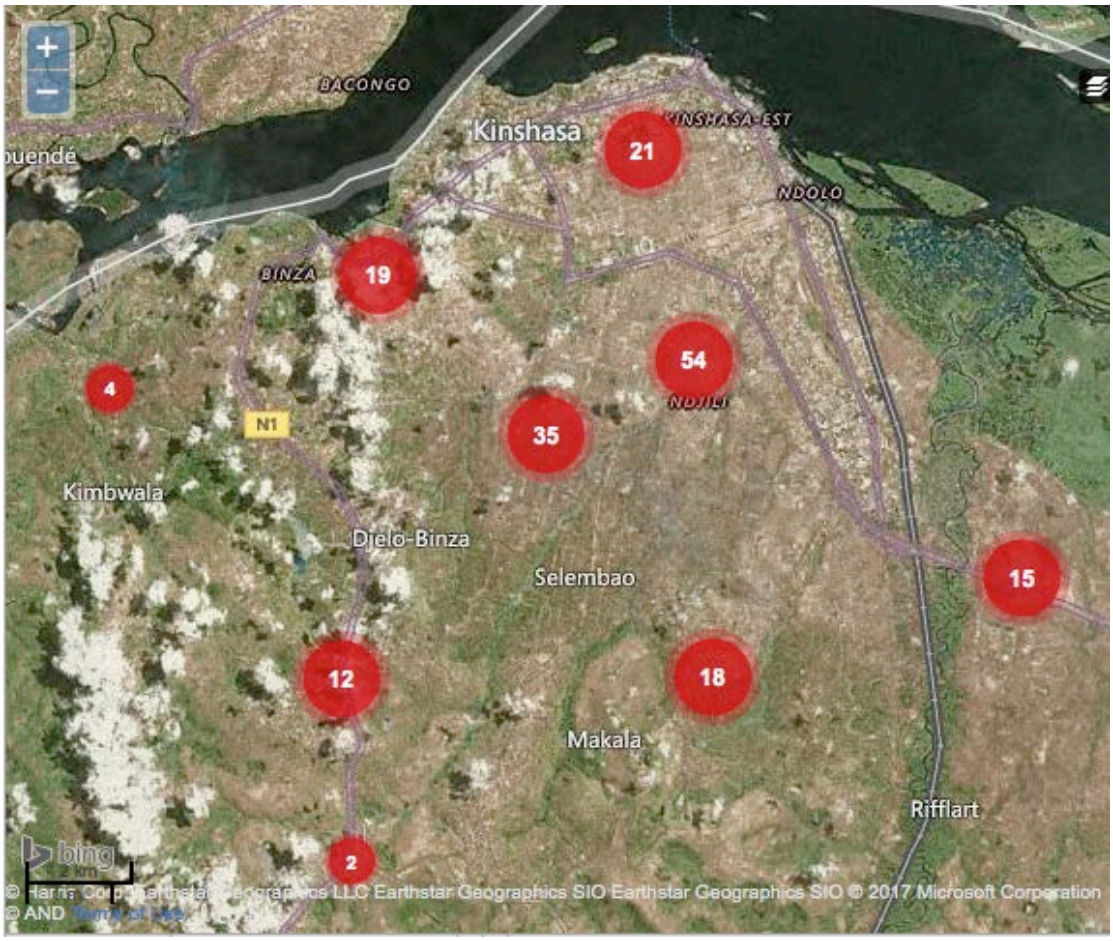

Figure 4. Spatial distribution of reported observations. This map is at a higher zoom level compared to the one depicted in Fig. 3.

Users can submit new observations by clicking on the green button “Submit an event”; they have also alternative means to report an observation via mobile phones, email or tweets; they can access reports through a dedicated listing (Fig. 5); and they are able to download reports in Comma Separated Values (CSV) or Keyhole Markup Language (KML) for further use or analysis in other applications such as Geographical Information Systems (GIS) or Statistical software (Fig. 6).

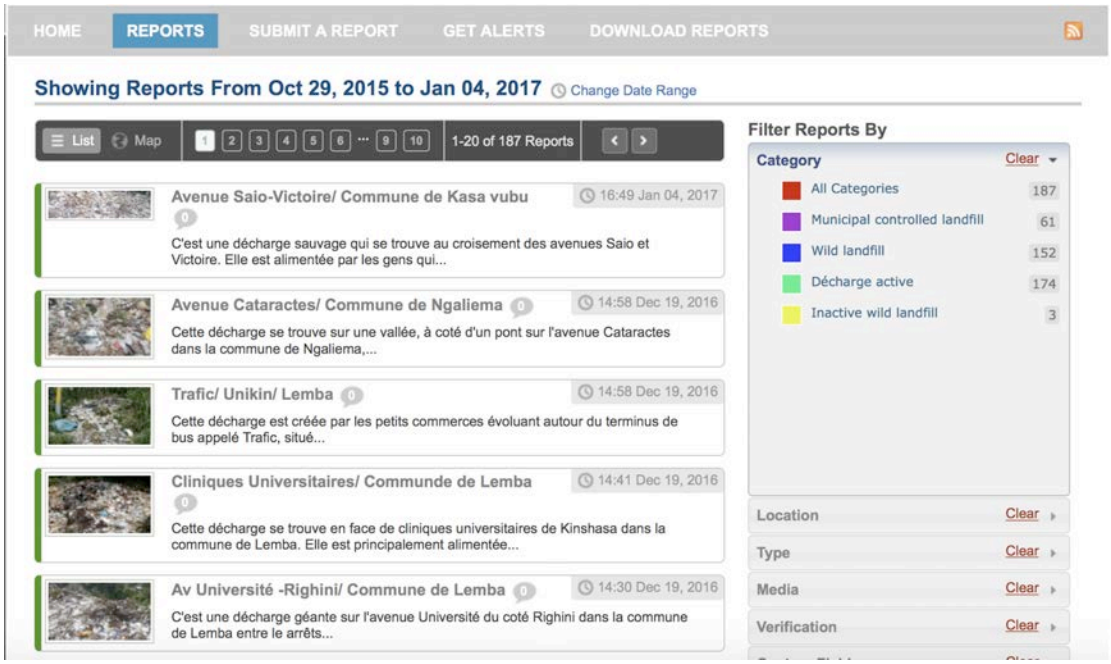

Figure 5. Listing of reports.

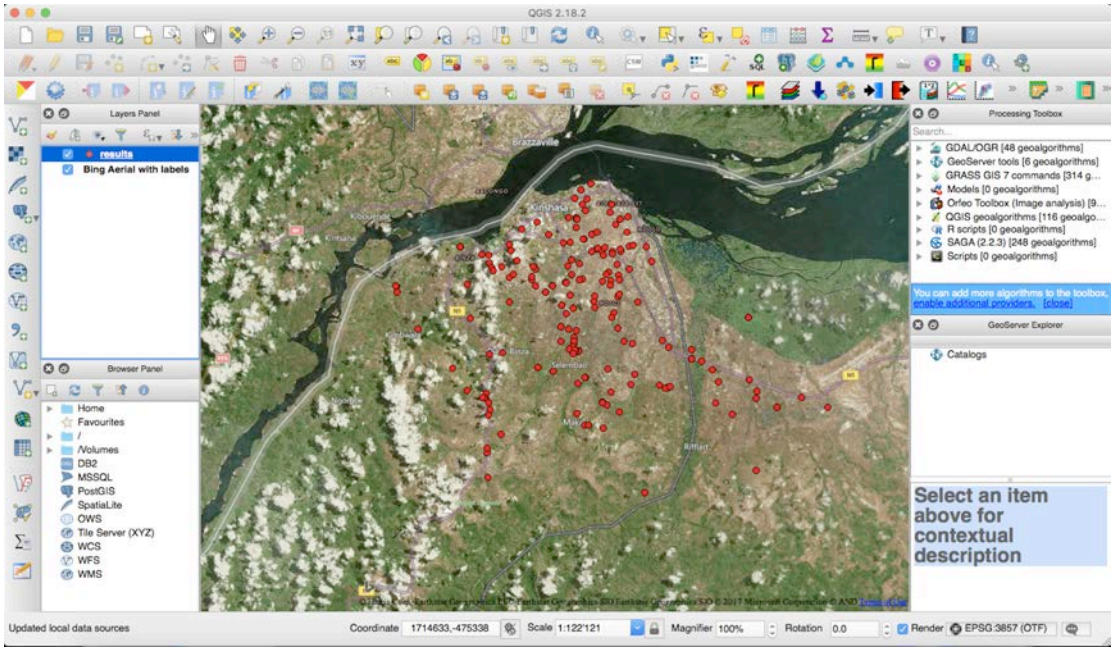

Figure 6. Visualization of download observations in the QGIS application.

The last feature implemented in the platform is a heatmap. Heatmap uses a Kernel Density Estimation to generate a density map from points. The density is computed from the number of

points in a given location. Larger numbers of clustered points will result in larger values. This allows easy identification of hotspots and clusters where there is a high concentration of the activity. In our case, this allowed us identifying hotspots of observed solid waste disposals (Fig. 7).

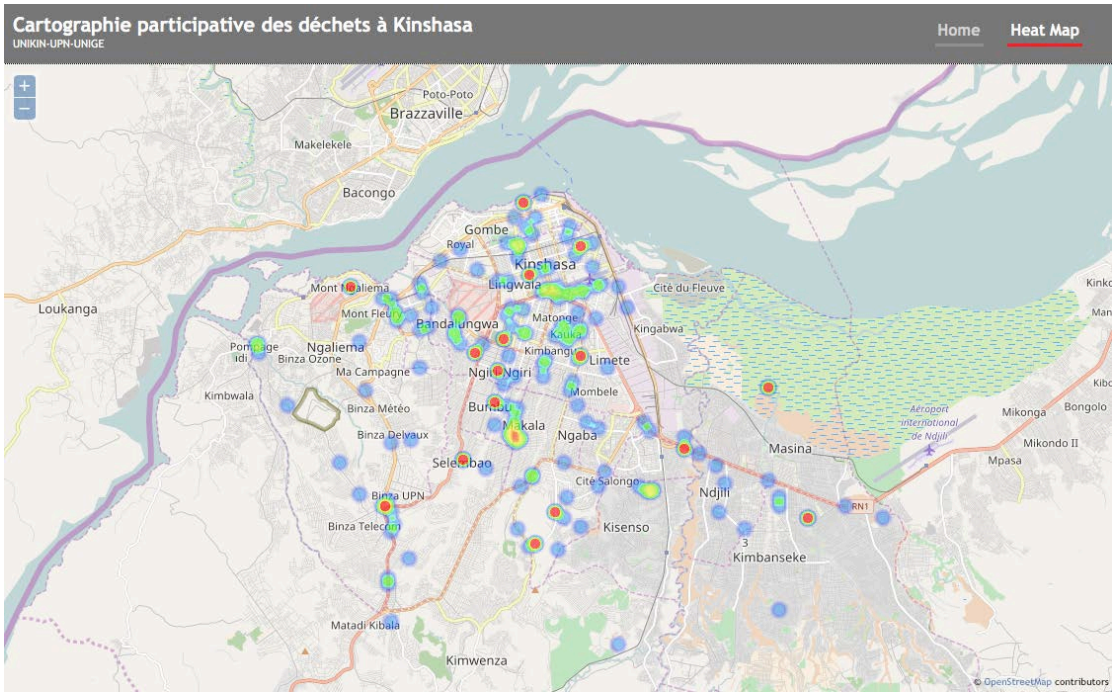

Figure 7. Heatmap module allowing to identify hotspots of solid waste disposals observations across the city of Kinshasa.

Currently, the database holds 187 observations of solid waste disposals across Kinshasa. These observations are divided in 61 public disposals (e.g., transit centre), 151 wild dumps, 174 active and 3 inactive disposals (Fig.8). The estimated volume of solid waste accounted for 587'920 m^3. Regarding the nature of the observed solid waste, it was mainly composed of plastic and organic matters followed by metals and glass. These disposals were generally located near public roads or houses. Also, they could be sometimes found close to a river and rarely in open fields. In terms of nuisance: they are mostly smelly and sometimes smoky or leachates that can hinder local people.

Figure 8. Picture illustrated the kind of observed of solid waste disposals across Kinshasa (photos taken by Bienvenu Mavakala). The observations are divided in A: public disposals (Mpasa in June 2016, municipality of Nsele), B: wild landfill (a river transformed to a wild landfill, neighborhoods of Bongolo bridge in January 2016, municipality of Kalamu), C: public disposal transformed in active wild uncontrolled landfill (in November 2016, municipality of Kitambo) and D: inactive wild landfill (in January 2016, municipality of Kimbaseke).

This work suggests that crowdsourcing can be a valuable mechanism to involve citizens in collecting data on solid waste landfills. To date, this approach has helped to create the most detailed database and map of landfills across the city of Kinshasa. This also contributes to fill in the information gap in identifying, localizing and describing landfills and therefore supporting authorities to gain knowledge about this major environmental problem. The proposed approach was developed as a proof-of-concept and the implementation was successful. The first results show that citizen-sensing of solid waste disposals can bring several benefits in terms of collecting data and generating useful information. Nevertheless, we have to be cautious because many challenges may arise that can hinder further progress in data collection and support to waste management strategies.

3.1 Benefits

The major benefit of this approach is that it has provided a new tool and mechanism to collect data and generate useful information regarding solid waste landfills that was not available before. Indeed, crowdsourcing can be an effective participatory method to map and also describe the geographical distribution of landfills across the city of Kinshasa. Several

studies have already demonstrated the benefits of crowdsourcing in environmental management for hydrologic measurements (Fienen & Lowry, 2012), describing cities (Hollenstein & Purves, 2010), natural disasters (Koswatte et al., 2014; McDougall, 2012), monitoring biodiversity (Chandler et al., n.d.), or weather monitoring (Gharesifard & Wehn, 2016). All these authors emphasize the fact that crowdsourcing offer new and promising opportunities for data collection, management, and analysis.

Using crowdsourcing helps overcoming the lack of human and financial resources to collect data. Indeed, creating and managing data can be a costly task (Bishop et al., 2000). Moreover, not all the necessary human capabilities are available due to lack of training and/or resources. Consequently, crowdsourcing and participatory processes allow involving individuals in a collaborative effort to acquire data. It is a mean to outsource the work and divide it between participants to achieve a cumulative result.

An essential aspect in crowdsourcing is to gain commitment to involve citizens in collaborating in a given specific task (Baruch et al., 2011). Key to obtain massive public participation is to point an issue on which citizens are regularly and largely affected and on which they can have a common sense of effect. Involving them in the process of collecting data on a specific issue allows empowering citizens in giving them the ability to communicate and deliver rich multimedia geo-referenced community knowledge to wide audience (Bani, 2012).

To gain commitment and participation of local communities, it is necessary to provide tools that are easy to use for non-specialist in document and present local spatial knowledge. The proposed approach using a simple web-based application is an effective mean to help involving citizens in data collection. Also, this helps communicating easily the information and conveying a sense of authority, and is often highly convincing.

By generating georeferenced data, they can be easily integrated in GIS or statistical software for further analysis. This allows associating them with other environmental or socio-economic data, helping new and innovative knowledge to emerge from relationships that were not envisioned previously. Consequently, such citizen-generated data can be potentially useful to inform future waste management and spatial planning strategies by helping, for example, localizing and identifying priority areas for action.

3.2 Challenges

Even though crowdsourcing can bring several benefits as an alternative mean to collect data regarding solid waste disposals, there are several challenges to overcome in order to reach wide adoption and commitment in using such approach.

An important challenge concerns data quality. Indeed, citizen-generated data are often criticized for their insufficient quality for scientific and decision-making purposes (Craglia et al., 2012; Flanagin & Metzger, 2008; Ostermann & Spinsanti, 2011). To tackle this issue, multi-step validation allow generating data that are of sufficient quality and that can be useful (Capineri et al., 2016). In our approach to collect meaningful and harmonized data, we decided to conceive in consultation with experts a simple form to easily capture essential information to characterize solid waste landfills. In addition, we developed a two-steps validation procedure to ensure that data are verified, quality controlled and reliable before their publication on the platform. Finally, we also developed a series of capacity building to train participants and help them to disseminate afterwards those resources to develop new skills in other people (i.e., train the trainers' spirit). All these components help reducing the risk of poor quality data.

Another essential element is to gain commitment of new citizens to participate and continue

the effort of collecting data. Indeed, even though the current database is available in detail for the city of Kinshasa, it is by no means complete. Different studies have shown that citizens are interested in participating in data collection if they have a certain feeling of the ownership and being part of a dedicated community (Capineri et al., 2016; Taylor & Broeders, 2015). They provide insights on how leverage the potential of the crowd to continue a collaborative effort. In our approach, we decided to target a specific audience (i.e., students in environmental sciences) that allow us to reach easy commitment and support to collect data, as they are aware of the environmental problem and they have enough knowledge. Together with the capacity building resources, our objective is that these students will be the able to raise awareness on this crowdsourcing tool and be able to train others such as their colleagues, friends families, etc. These people will be in turn able to collect data and to spread the word around them.

Finally, a relevant issue related to the acceptance of such tool by government to support waste management strategies. Even if driven by a positive approach and successful process to collect data and improve knowledge, inform and support local authorities to improve environmental conditions, enhance transparency and support the development of effective management strategies and decision-making processes (Chiu et al., 2014; Craglia & Shanley, 2015; Mclaren, 2011; Rinner et al., 2008), this can negatively perceived. Indeed, local authorities may have the feeling of being disposed of their mandate and consequently generate reluctance to use such information collected by citizens and not consider it as useful (Rak, Coleman, & Nichols, 2012). They can also feel pressure from citizens for their possible inactions. Therefore, this can be a very politically sensitive issue and building a trusted relationship is a necessity. It will help acknowledging the authorship, legitimating the ownership, strengthen local identity, enhancing empowerment, inclusiveness of voices in a community, and develop local capacity (Verplanke et al., 2016).

3.3 Perspectives

Based on our first promising results achieved and taking into account of the challenges mentioned above, we are aiming to continue this effort and further explore the potential of crowdsourcing for collecting data on solid waste landfills.

To increase the number of observations and improve the completion of the database, more citizens should be involved in the data collection process. A possible solution to reach wider commitment is to use the so-called “engaging communication”. This is a communication technique that allows engaging people in making a dedicated action or task and ultimately to change their behavior (Girandola & Joule, 2008). This approach is particularly interesting for waste management because engaging citizens through such a process can potentially support long-term commitment in participating in data collection and can also help them to change behavior by not disseminating waste. In other words, they can potentially become actors of the change.

Another opportunity is to test crowdsourcing techniques in different urban areas that are facing similar problems but in different socio-economic and cultural contexts. This can be a mechanism that allows rising awareness on this important environmental issue and at the same time make citizens actors of the change.

At the global scale, it is recognized that approximately 50% of the generated waste are not collected, treated or safely disposed (Lenkiewicz, 2016). Therefore, waste management should be recognized as a major environmental issue and vital for global sustainable development

(Lenkiewicz, 2016). The United Nations have agreed in 2015 on 17 Sustainable Development Goals (SDG) covering a broad range of sustainable development issues such as ending hunger and poverty, improving health and education, making cities more sustainable, fighting climate change, and protecting oceans and forests. To meet these goals waste management should be a priority as it affects nearly all SDG. To reach this objective, one possible contribution is to incorporate data crowd sourced by citizens into the monitoring process of SDG (Fluckiger & Seth, 2016). However, this will require governments to recognize crowdsourcing as a valuable approach for measuring progress towards SDG, to support projects that promote citizen participation in tracking the goals, and develop best practices for integrating crowdsourced data in official national statistics.

4. CONCLUSIONS

The proposed approach using crowdsourcing appears as a valuable, innovative and promising alternative for involving citizens in collecting data on solid waste landfills. The approach has been tested in the city of Kinshasa that is facing a major environmental issue owing to mismanagement of solid waste landfills and lack of data identifying, localizing and describing landfills across the city.

The major benefit of this approach is that it has allowed the involvement of citizens in the collection of data and generation of useful information. Collectively, they have created the most detailed database and map on in relation with landfills in Kinshasa, which could possibly support local authorities in developing efficient waste management strategies.

However, the main challenge is to ensure a sufficient quality of the collected data so that they are comprehensive and useful. To collect meaningful data, simple tools to capture essential characteristics of landfills and data validation procedures have been developed. This ensures that collected data are consistent, verified, traceable, quality controlled and reliable. Other challenges concern ensuring that data collection will continue and that local authorities will accept to use the information generated with the support of citizens.

In the wider context of globalization and urbanization, the importance of waste management should be recognized as a major environmental issue and necessary for meeting the Sustainable Development Goals. Data crowdsourced by citizens can be a possible contribution for supporting and measuring progress towards SDG, especially for those of which efficient and effective waste management strategies play an important role.

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The views expressed in the paper are those of the authors and do not necessarily reflect the views of the institutions they belong to.

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