Improving Knowledge and Practices of Mitigating Green House Gas Emission through Waste Recycling in a Community, Ibadan, Nigeria

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Abstract

Throughout the world, waste sector has been implicated in significant contribution to anthropogenic greenhouse gas (GHG) emissions. Involving communities in recycling their solid waste would ensure climate change effect mitigation and resilience. This study was carried out to improve waste management practices through a community-led intervention at Kube-Atenda community in Ibadan, Nigeria. The study adopted a quasi-experimental design, comprising mixed method of data collection such as semi-structured questionnaire and a life-cycle-based model for calculating greenhouse gas generation potentials of various waste management practices in the area. A systematic random sampling was used to select sixty (60) households for a survey on knowledge, attitude and practices of waste management through Recovery, Reduction, Reuse and Recycling (4Rs) before and after the training intervention. Data collected were summarised using descriptive statistics, chi-square test, t-test and ANOVA at $p = 0.05$. The mean age of the respondent was 49.7 ± 16.7 and 68.3 % were females. Respondents' knowledge scores before and after the intervention were significantly different: 7.07 ± 1.48 and 11.6 ± 1.6 while attitude scores were: 8.2 ± 2.3 and 13.5 ± 0.8. There were significant differences in the major waste disposal practices in the community before and after the intervention. All (100 %) the participants were willing to participate in waste recycling business and the model predicted that adoption of 4Rs strategy had a great potential in saving greenhouse gas emissions in the community. The behaviour of the community people has changed towards waste management that promote climate change mitigation and adaptation through waste reduction, reuse, and resource recovery.

Keywords: Greenhouse gas, Life-cycle-based model, Waste management practices, Behavioural change, Climate change mitigation, Community people

1.0 Introduction

In Nigeria, as well as other countries of the world, the health and environmental effects of municipal solid waste have been extensively explored [1-13]. According to Intergovernmental Panel on Climate Change (IPCC), waste sector significantly contributed to anthropogenic greenhouse gas (GHG) emissions, accounting for approximately 5% of the global greenhouse budget [14]. This 5% consists of methane (CH_4) emission from anaerobic decomposition and carbon dioxide (CO_2) from aerobic decomposition of solid waste. It has been reported that developing countries and emerging economies could reduce their national GHG emissions by 5% through adoption of municipal waste management systems that have focus on waste recycling [15]. Also, by establishing what is called "closed loop waste management", German waste management activities was able to reduce about 20% of the overall GHG over the period 1990 to 2005 [16]. The IPCC calculations take into account only end-of-pipe solid waste management strategies such as: landfill/waste dumping, composting, waste incineration and sewage disposal while the positive impacts of waste recovery, reduction, reuse and recycling (4R's) on GHG emission are directly accounted for in the GHG inventories reported to the United Nations Framework Convention on Climate Change (UNFCCC) under the Kyoto Protocol [15].

Accordingly, a number of studies have specifically focused on GHG emissions, their associated global warming potentials and climate change from waste management activities in Nigeria [17-20] and European countries [21-23]. However, a successful waste management approach for Nigeria and the African continent requires not only identifying solid waste related problems but providing practical solutions to the problems. This has to do with community-action-oriented projects on all aspects of waste management, including adoption of the 4Rs concept, changing people behaviour through sensitisation and awareness creation on the ill effects of poor waste management, identifying the most environmentally friendly and economically viable alternative to the current waste management practices, using life-cycle assessment (LCA) approach and building community people's capacity in resource and energy recovery from the waste. Lagos municipal authorities have failed to achieve proper practices of waste storage and segregation at source owing to lack of community participation [24]. Improving the public general knowledge and awareness creation in the form of education and technical training [25] is therefore important in making waste recycling a huge success. As demonstrated in a study conducted by Lilliana et al. [26], citizens that received information about the benefits of recycling were more likely to participate in recycling campaigns.

Life-cycle assessment of waste management practises has proven to be a suitable tool for providing a reliable comparison between waste management technologies and analysing the related benefits and drawbacks [21]. As such, several studies in the last years assessed the beneficial environmental aspects of waste management using LCA-based approach [27, 28]. Soares and Martins [29] identified socio-political-economic barriers to the process implementing alternative and complementary technologies for generating electricity from MSW in São Paulo, Brazil, using LCA. Ogundipe and Jimoh [19] used LCA methodology to determine municipal solid waste (MSW) management strategy for Minna, Niger State, Nigeria. Mohammad and Kenneth [30] utilised Solid Waste Management Greenhouse Gas (SWM-GHG) calculator to compare four scenarios representing the current and suggested technologies in Jordan and observed reduction of GHG emission of about 63 175 tonne CO_2-eq/year in a scenario where all the organic waste was recovered. However, it should be noted that a comprehensive LCA study should include other environmental impacts apart from climate change such as acidification potential, eutrophication potential and human toxicity [28].

The failure of the current end-of-pipe approach, based on solid waste collection and disposal, to mitigate climate change effects such as flooding in Nigeria is quite visible. This situation puts an urgent need for introducing an integrated and holistic approach that will not only protect the environment but build people’s capacity in wealth creation from waste for poverty reduction, climate change resilience, improved health and self-esteem. The current study was therefore aimed at assessing the effects of a community-led waste recycling sensitisation and training intervention on knowledge, attitude and practices of community people and a life-cycle- based environmental impacts of various waste management practices for reducing greenhouse gas emissions in the community.

2.0 Material and methods

2.1 Study area

Ibadan is located in the south-western part of Nigeria on Longitude 3^0 53' East of Greenwich meridian and Latitude 7^0 34' North of the Equator. The city is the second largest in Africa and fourth most populated in Nigeria with an estimated population of about four million people [31]. It is in 128 km northeast of Lagos and 345 km southwest of Abuja, the federal capital. The city comprises eleven contiguous local government areas with sub-division into five (5) urban areas- Ibadan North, Ibadan North-West, Ibadan South-West, Ibadan South-East and Ibadan North-East and six (6) peri-urban (Ibadan less city) consisting of Egbeda, Akinyele, Moniya, Ona-Ara, Lagelu, Oluyole and Ido. Like many other urban centers in Nigeria, Ibadan grew naturally without any form of master planning. Kube Atenda community (Figure 1) that was purposively selected for this study based on its location in high density area with poor waste management problem (Figure 2) is located in Ibadan Northeast local government area. The community is over populated (10,000 people) with low-income people due to its closeness to major commercial centres in the city which has impacted waste generation and management in the area.

FIGURE 1 HERE

FIGURE 2 HERE

2.2 Study design and sampling techniques

This study adopted community-based quasi-experimental study design and the sample size was calculated using a simplified form of comparison between two proportions (Eq. 1) thus:

$$n = \frac{(Z_{\propto} + Z_{\beta})^2\,[P_1(1-P_1)+P_2(1-P_2)]}{(P_1-P_2)^2} \quad \text{.................................... Eq. 1.}$$

Where n = minimum sample size, $Z\alpha = 1.96$ (95% level of confidence), $Z\beta = 0.84$ (80% power), $P_1 = 0.25$ (baseline prevalence- on assumption), $P_2 = 0.50$ (anticipated 25% increase). From equation 1, n = 55 ∞ 60. A systematic random sampling was used to select sixty (60) respondents (household heads) for the survey and training. However, 5 people were dropped out between pre- and post-intervention.

2.3 Procedures for data collection

Mixed method (quantitative and qualitative) approach was adopted for data collection. This included: interviewer- administered and semi-structured questionnaire, Focus Group Discussion (FGD) guide, observational checklist for waste characterisation and SWM-GHG calculator developed by Institute for Energy and Environmental Research (IFEU) for assessing GHG emission potentials of waste management practices in the community. The questionnaire was used to collect information on socioeconomic status, social environment/infrastructure status, ethnic relations, perceived health issues and knowledge attitude and practices of waste management before and after the intervention.

A total of 12 questions were used to assess respondents' knowledge and practices of the respondents were assessed with 14 questions. Correct response to each of these questions was given one score while a wrong response was given zero score. Half of the total correct scores, which is 6 (for knowledge) and 7 (for practices) were set as a cut-of mark so that respondents that scored the cut-of marks and above had good knowledge or good practice and those scored below the cut-of marks had poor knowledge or poor practices, as the case may be. Mean knowledge scores was calculated by finding the average of all the respondent's correct marks. That is, summation of individual correct scores divided by the total number of respondents.

. Two focus group discussion sessions were organised for male and female respondents separately in the community with eight members in each group. The information obtained was used to design the questionnaire. Physical characterisation of waste generated in the community was carried out for consecutive three weeks, using simplified tools such as picker, rake, weighing scale and refuse bags. Waste generation rate was computed thus (Eq. 2.):

$$\text{Waste generation rate}\left(\frac{\frac{\text{kg}}{\text{cap}}}{\text{yr}}\right) = \frac{MSW_T \times 365}{N} \qquad \text{.............................. Eq. 2.}$$

Where MSW_T = total waste generated per day in the community, N = total population (10,000) of the community and 365 = total of days in a year.

The calculation method used in the SWM-GHG calculator follows the life-cycle assessment method [15]. It was used to compare the different waste management strategies by calculating the GHG emissions of the different recyclables (typically glass, paper and cardboard, plastics, metals, organic waste in CO_2 equivalents) and waste fractions disposed of over their whole life cycle – from "cradle to grave". This method corresponds to the "Tier 1" approach described in IPCC [14]. The tool sums up the emissions of all residual waste or recycling streams and calculates the total GHG emissions in CO_2 equivalents. To achieve this, effects of waste management activities on greenhouse gas emissions at four situations were assessed with the calculator. The situations comprised pre- and post-intervention and two alternative waste management scenarios suggested for community (scenario 1 and scenario 2). In the situation at pre-intervention (base line), the waste management practices were characterised by mere disposal under difficult health conditions such as dumping on ground and stream, open burning and without regular waste collection services by the municipality. Under this situation, almost half of the scattered waste is burned in open fires to produce extreme air pollution in the community. The situation at post-intervention involved solid waste recycling and reuse to some extent, including composting of organic waste. The remaining residual waste that could not be recycled was disposed of to some designated dumpsites through registered private waste collectors in Ibadan. Small quantity of solid waste was still scattered, burned or dumped into the stream.

For the two alternative scenarios proposed for the future outlook of the waste management in the community, the scenario 1 assumed an increased efficiency in the separate collection of waste, high recycling rates for the recyclables and composting of organic waste. Similar to situation in post-intervention, some quantity of solid waste is still scattered but no longer burned or dumped into the stream. The scenario 2 represents the most advanced solid waste management strategy. Here the remaining residual waste is pre-treated before being discarded via mechanical-biological and/or mechanical-physical stabilisation producing a refuse derived fuel. It is the resulting fraction of impurity that will be sent to the dumpsites to minimise greenhouse gas emissions and waste scattering in the community no longer occurs.

In addition, there was a two month training intervention comprising a community sensitisation workshop and capacity building on composting operation at household level, smokeless charcoal production from dry agro-allied waste (Figure 3), biogas production form organic waste, and segregation of recyclables such as pet bottles, plastics, paper, glass, and metal for revenue generation through community sorting centres and buy-back arrangement (Figure 3). Attendants at the sorting centre, who are members of the community, would transport the recyclables into waste recycling industries in the city for sale and money accrued from this arrangement would be used to pay attendants' salaries and maintain the centre.The data collected at pre- and post- intervention were compared using chi-square test, analysis of variance (ANOVA) and t-test at 5% level of significance to establish the effect of the intervention in the community. Logistic regression model was also used to identify the strength of categorical variable association.

FIGURE 3 HERE

3.0 Results and Discussion

3.1 Questionnaire administration

Results of socio-demographic characteristics of the respondents are shown in Table1. The mean age of the respondents was 49.7 ± 16.7 years, 68.3 % were female and more than a third (31.7 %) had primary education. The mean number of households found in houses and people occupying households were 3.7 ± 2.0 and 5.6 ± 3.4, respectively. In addition, 51.7 % were owners and 48.3 %were tenants. Several respondents (36.7 %) had been living in the community between one and ten years while half of them (50.0 %) earned below 20, 000.0 naira (56.0 USD) per month.

TABLE 1 HERE

Table 2 and Figure 4 show the results of the respondents' knowledge of waste and waste management before and after the intervention. There was significant difference in the mean knowledge scores at pre-intervention (7.1 ± 1.5) and post- intervention (11.6 ± 1.6). Half of the respondents (50.0 %) were aware about waste recycling at pre-intervention against 100.0 % at post-intervention. None of them (0.0 %) knew anything about biogas and smokeless charcoal production from waste at pre-intervention against 100.0 % at post-intervention. Discussion at FGD sessions showed that many of the participants had heard about biogas before but could not understand the concept while almost all of them were hearing smokeless charcoal for the first time. The results of the respondents' attitude towards waste management in the community before and after the intervention are shown in Table 3 while Figure 5 depicts the category attitudinal scores. The mean knowledge scores - at post-intervention (13.5 ± 0.84) was significantly higher than that of pre- intervention (8.2 ± 2.3).

TABLE 2 HERE

FIGURE 4 HERE

TABLE 3 HERE

FIGURE 5 HERE

As shown in Table 4, majority of the respondents disposed their waste every day and very early in the morning, even at post-intervention. Women were more responsible for waste disposal than any other member of the family at pre-intervention (41.7 %) and post-intervention (43.6 %). None of the respondent (0.0 %) separated waste before disposal at the pre-intervention while more than half of them (67.3 %) carried out the separation at post- intervention. A previous study has revealed that the materials recycled could be increased by 33.5% if the waste separation was applied at the source of generation [28]. The reason for not separating waste majorly included: not knowing about it (73.3 %) and not having time to do so (88.9 %) at pre- and- post intervention respectively. Also, the responses on who separated waste in households were similar at both periods of data collection: children (16.2 %), my wife/my husband (35.1 %) or myself (48.6 %). The proportion obtained for those that separated their waste (0.0 %) in this study at the pre-intervention is close to that observed in a previous study [32] where 4.4% of respondent separated their waste. The higher proportion noticed at post intervention (67.3 %) is a clear indication that community members have started to realize value in waste as a result of the intervention. It also showed the effect of their capacity building in converting waste to wealth as willingness to separate their wastes at source for recycling would depend on their ability to gain financially from such exercise. Only very few respondents (11. 7 %) recycled their waste at pre-intervention against 63.6 % at post-intervention which is more than those that were practicing waste recycling in Lagos, Nigeria (37.8 %), in line with a finding by Tunmise [24].

TABLE 4 HERE

Waste disposal practices in the community are shown in Figure 6. Burning was more rampart at pre-intervention (35.0 %) while almost all respondents at post-intervention adopted private waste collectors (92.7 %). The proportion of respondents that dumped their waste indiscriminately at pre-intervention (30.0%) is lower than 66.3 % found by Nabegu [2]. Participants at the FGD sessions said that they disposed of waste through stream dumping and open burning. According to one of them, '*waste is also buried into pits, waste collectors have tried in the past and failed owing to our inability to pay their charges*'. The also said that it was very difficult to burn waste during rainy season and so, '*there is no challenge once there is rain fall which will carry the waste but once there is no more rain fall, the waste remains in the stream to create odour'* as put by another female discussant. However, there was sharp reduction in the proportion of respondents that practiced inappropriate waste disposal at post-intervention: burning (35.0 % Vs 1.8 %), open dumping (30.0 % Vs 5.5 %) and stream dumping (26.7 % Vs 0.0 %) at pre- and post-intervention, respectively. The reason for the improvement may be due to the impact of the intervention on the community people.

Almost all respondents (98.3 %) did not patronise private waste collector at pre-intervention as 55.9 % said that waste collectors had not come to meet them (while all (100 %) that patronised the private waste collectors rated their performances as being poor. At post-intervention, respondents' practices of waste disposal was shifted to private waste collectors (92.7 %) probably due to their increase in awareness of ill-effects associated with improper handling of waste and lack of recycling facilities. Reasons for choosing waste disposal method by the respondents were: convenience (46.7 % Vs 38.2 %), being the cheapest method (15.0 % Vs 9.1 %), environmentally friendliness (18.3 % Vs 27.3 %) and only available means (20.0 % Vs 25.5 %) at the pre- and post-intervention respectively. Plastics (57.1 % Vs 42.9%) and paper (42.9 % Vs 17.1 %) were major components of waste removed for recycling or reuse at pre- and post-intervention respectively (Figure 7). There was reduction in the quantities of plastics and paper removed for recycling at post-intervention due to the fact that the respondents have realised values in other waste components and started to focus on other components that can earn them more financially such as aluminium cans. That is, apart from plastic and paper components, respondents recycled and reused other components such as food and yard waste, metal, rubber and leather due to the new knowledge and skills acquired during the training intervention.

FIGURE 6 HERE

FIGURE 7 HERE

In terms of respondents' willingness of participating in waste recycling programmes in the community, all the respondents at post-intervention (55, 100.0) were ready to participate. The reasons for participation included: environmental protection (43.6 %), financial benefits (38.2 %) and personal interest (18.2 %). In addition, when the respondents were asked about their suggestions for promoting waste segregation and recycling activities in the community, the responses were: community people should be educated about waste recycling (40.0 %), community members should be encouraged financially (23.3 %), refuse bins should be given to members to segregate the waste for recycling and resource recovery (7, 11.7%), among others. Similarly, 63.6 % of the respondents at post-intervention said that they needed more training or seminar on waste segregation and recycling to sustain the waste recycling enterprises in the community. Participants at the FGD session also suggested more sensitisation and proper follow up of proper waste management activity in the community as well as provision of facilities to recycle their waste.

There was no correlation between monthly income and respondents' attitude score with all the variable on waste management practices such as: how often did they dispose their waste, where did they store their waste before disposal, which method of waste disposal did they adopt and so on. Meanwhile, there were positive correlations between respondents knowledge score and respondents attitude score (p= 0.026) and whether the respondents remove part of their waste components (p=0. 027). No correlations also existed between the monthly income, number of households in a house, number of people in each household and the quantity of waste generated. At post-intervention, positive correlations were found between respondents' monthly income and patronisation of private waste collectors in the community (p= 0.024); waste component removal for reuse as well as waste separation before disposal (Table 5). The respondents could patronized private waste collector at post intervention as they sold part of their waste to complement their monthly income. At the end of the follow-up, logistic regression model revealed that respondents with good knowledge were three times more likely to be willing to participate in waste recycling business (OR=3.4; C.I=2.0-6.7); five times more likely ready to segregate their waste at source (OR= 5.7; C.I= 1.6-9.8): six time more likely to remove part of your waste component for reuse and recycling (OR= 6.7; C.I= 1.2-9.1) than the respondents with poor knowledge. This is in agreement with findings of a study [33] which revealed that respondents with higher level of education possessed good knowledge of the impact of improper waste management on health than those with lower level of education. The result is however not in consonance with finding of Tunmise [24] who showed that educational levels of respondents had no significant effect on willingness to recycle their waste.

TABLE 5 HERE

3.2 Waste characterisation into different components

Figure 8 shows results of physical characterisation of waste in the community. Nylon accounted for 32.6 % of the total waste characterised. Organic contents in the form of food and yard waste accounted for 19.7 % while glass bottle and textiles were found in very small proportions. These results is not in agreement with the finding of Sha'Ato *et al.* [34] who assessed solid waste composition in a rapidly growing urban area in central Nigeria and observed more organic content (57.5 %) than the plastic content (6.10 %). The assessment revealed 675.77 kg for a total of waste generated per day in the community and a waste generation rate of 24.67 kg/cap/yr (or 0.068 kg/cap/day). The 0.068 kg/cap/day is lower than 1.2 kg/capita/day generated by world cities with about 1.3 billion tons of solid waste per year and an average of 1.1 kg/capita/day generated by the Middle East and North Africa region's urban population with 63 million tons of MSW annually as reported by the World Bank [35]. It was also lower than 0.5–1.0 kg reported for inhabitants of Kano, Nigeria, metropolitan area [7] and 0.5- 0.9 kg/cap/day calculated for middle income earner and 0.4- 0.6 kg/cap/day for low income earner in Ilorin city, Nigeria [17]. The very low waste generation rate may not necessarily be an indication that inhabitants of the study area were majorly low in-come earners, but that majority of residents did not stay at home during the day due to various business activities. This explains why many of the respondents could only be met at home very early in the morning for the questionnaire administration.

FIGURE 8 HERE

3.3 Greenhouse emission potential of waste management practices in the community

The GHG emission balance comparison for different waste management options in the community are shown in Figures 9- 17. These include: the quantity of waste removed for recycling or reuse and waste disposal activities, GHG emission balance for waste management activities and the waste mass flows, and the GHG emissions for recycling activities at pre- and post-intervention situations (Figure 9-14). The figures show the results separately for recycling and for disposal activities and also as the sum of both components "Total MSW" (Figures 10 and 13). The first bars in these figures indicate the GHG emissions caused by recycling (Debits as positive values). The second bars represent the emission savings by recycling (Credits as negative values). The third bars show the net effects, that is the differences between debits and credits (Net). Figures 15-17 depict all four situations assessed when taking pre-and post-intervention situations in comparison with other alternative scenarios (scenario 1 and 2). The first four bars show the debits from recycling in the four situations and the second four bars the credits from recycling in the four situations. The next section shows the same for disposal of waste. In the final section, debits, credits and net results are shown for the total MSW treatment in each case for the four situations.

Generally, it can be seen that more GHS emissions are saved in order of pre-intervention to the more advanced scenario 2. In similar studies [8, 36], it was concluded that a ‘‘recycling society’’ still needs thermo-chemical treatments of waste, which would provide a sustainable recovery of energy and materials as an added advantage to waste management. As open burning is prominent in the pre-intervention, other situations are characterised by controlled sanitary landfill**.** Results of a study conducted by Mahdi et al. [28] showed that improving the current SWM with 72% of sanitary landfills with energy recovery and 28% of dry recyclable materials was the best scenario in terms of environmental impacts and economic cost. From Figure 17, the debits incurred in the post-intervention situation is more than that of pre-intervention. The resident has stopped dumping organic waste in the stream again but rather kept it for the private waste collector. Anaerobic decomposition of the organic waste into methane during the storage might have accounted for the higher debits. However, it is good to note that the far higher credits in the post-intervention placed it in vantage position comparing to the pre-intervention situation. Also in her study, Kofoworola [20] observed that material recycling and energy recovery had reductions in GHG emissions of between 22.0 – 67.0 %.

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FIGURE 16 HERE

FIGURE 17 HERE

Conclusion

The training intervention including waste management sensitisation workshop and capacity building on energy and resource recovery from waste has significantly improved knowledge, attitude and practices of waste management in the community. Community members have started to separate their waste at source for recycling, reuse and sale at the community buy-back centre, realising values in waste and ability to gain financially from its recycling. Knowledge is a predictor of community willingness to segregate their waste at source and participate in waste recycling business. The community people are now willing to participate in waste recycling programmes in the community so as to avoid open burning, stream dumping and other waste management practices that can aggravate climate change effects. Also, inhabitants are low in-come earners that need community development programmes such as entrepreneurship in waste recycling for their good livelihood and well-being. Women were at the forefront of managing waste at household level as they were more responsible for waste disposal than any other member of the family. The adoption of waste recovery, reduction reuse and recycling strategy has a great potential in saving greenhouse gas emissions in the community. Continuing education and training on energy and resource recovery from waste is therefore recommended, especially for men, to maintain and sustain proper waste management practices in the community.

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