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SOLID WASTE GENERATION, PLANNING, AND PROJECTION IN WA, GHANA

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Abstract
The search for cutting-edge policy intervention for sustainable solid waste management (SWM) continues to generate thoughts, interest and research in Ghana. This is evidenced from the speed, scale, scope and complexity of countless government efforts at exploring innovative actions aimed at achieving perfectly formed SWM strategies. Nonetheless, the efforts are being hampered by limited forecast data regarded as the backbone for proper SWM planning. The objective of this article was to forecast the quantity of annual solid generation in Wa between 2016 and 2026. The study adopted the Autoregressive Integrated Moving Average model in estimating the predictions. The results indicate that without structural interruptions of the current solid waste generation trends, by 2026, the quantity of solid waste that will be generated in Wa may be six times more than that of 2016. Given the fact that the negative externalities of poor SWM are increasingly reaching crisis point and that existing protocols are unable to ameliorate the problem, we suggest a shift in paradigm if Wa is to be counted among the league of world class filth-free cities in the near future.

Keywords: Autoregressive Moving Average, Forecast, Urbanization, Solid waste, Wa

Introduction

The world is experiencing the most spectacular change in its history as countries are urbanizing at an unprecedented rate with more than 50 percent of the current population living in cities (UN Habitat, 2010; Ahmed and Dinye, 2011; Oteng-Ababio, 2014). Statistics from the UN Habitat (2010) indicate that the world's population increased from three billion in 1950 to seven billion in 2011. Projections are that by 2050, seven out of ten persons will live in urban centers (Montgomery, 2009). The greatest impact of the urban revolution will be felt in sub-Sahara Africa (SSA). According to the UN in 2011, 414 million Africans lived in cities and that by 2050 urban Africans will be 662 million (UN Habitat, 2010). It is however important to state that this assumption will only be a reality if the current urban revolution continues. The high concentration of people in the cities of SSA has implications for solid waste generation whose management is becoming an increasingly arduous challenge for residents and governments (Oteng-Ababio, 2014), even though researchers (Annez et al., 2010; Owusu-Sekyere, 2014; Oteng-Ababio, 2014) have made a strong case that when properly handled, it may become a valuable resource. For instance, in Accra and Kumasi–the two largest cities in Ghana, and in many other cities and towns, scavengers and waste pickers are increasingly seen scavenging for solid waste (plastics, scrap metals and e-waste) as a 'new' source of raw material for the plastic and steel industries.

Available data from the Ghana Statistical Service (GSS) indicates that the deficiencies in solid waste management (SWM) are most visible in and around the three prominent urban areas of Accra, Tema and

Kumasi (GSS, 2012; Oteng-Ababio, 2011). This situation is largely blamed on weak operational capacities of the metropolitan authorities; limited financial resources due to unreliable revenue sources (Oteng-Ababio et al.,2012); implementation of imported policies without recourse to local conditions (Ali, 2010); limited community participation in strategic planning; and poorly designed collection, transport and disposal systems (GSS, 2012). While the three metropolitan areas have always drawn the headlines, the deficiencies in SWM services are even more acute in other emerging cities including Wa, where getting the right policy mix for effective interventions is being hampered by lack of appropriate data resulting from inadequate waste auditing systems. The lack of accurate data on quantity of solid waste generation does not only limit the ability of stakeholders to plan to meet current demands, it also limits their ability to make future projections. Meanwhile, waste projection informs efficient and sustainable waste policy making as well as an indispensable process in SWM planning. To this end, Chung suggests that of all the processes in SWM, waste projection is the single most important (Chung, 2010).

Although there have been extensive discussions on the poor state of SWM in Wa in terms of the increasing human vulnerability to the problem; inadequate access to collection service; improper dumping; street littering and burning (see, Akaateba and Yakubu, 2013; Abdul-Kadri and Owusu-Sekyere, 2012; Amoah and Kosoe, 2014), no attention has been paid to forecasting future scenarios in order to develop effective and corrective policies towards sustainable SWM. This situation creates a knowledge gap which this article attempts to fill. In this article, we project the quantity of solid waste that will be generated annually in Wa between 2016 to 2026 using the Autoregressive Integrated Moving Average (ARIMA 2, 1, 1) which is a time series model. The literature is replete with different methodologies for solid waste forecasting. Younes et al. (2015), used modified ANFIS model for solid waste forecasting taking into consideration the economic and demographic factors that affect solid waste generation. Similarly, Intharathirat et al. (2015) also used multivariate grey models which is a mathematical approach to forecast municipal waste collection in Thailand. Their choice of the mathematical model was due to limited data. Time series which is another forecasting methodology is a chronological sequence of observations of a particular variable (DTREG, undated). Usually, the observations are taken at regular intervals such as days, weeks, months and years. Our waste projection analysis as reported in this study consists of two steps; first, we build the time series model. Second, we used the model for waste data forecasting.

We hope that the findings from the study could be a guide for sustainable SWM policy formulation in Wa in particular and Ghana in general. This paper is based on the premise that waste managers in Ghana in general and Wa in particular do not have the accurate forecast data to aid efficient waste management planning, in the meantime accurate forecast data is a *sine qua non* for any effective SWM system. We believe that such data limitation has the tendency of obscuring the reality of the current waste stream and does not help in future projections. Our paper is structured in five sections; after the introduction, the subsequent section looks at Wa's status as an emerging city with special emphasis on current approaches to SWM. The third section concentrates on our sources of data and the development of the ARRIMA model. The results is presented in the fourth section while section five comprehensively discusses the results and offers some suggestions for policy direction.

Theoretical Perspective of the Study

In theory, SWM is a function of population growth and economic development (Hoornweg & Bhada-Tata, 2012). From this perspective, the coming years will witness an increase in the quantity of solid waste generation due to the expected increase in population, urbanization rate, overall economic growth, increase in production and consumption, and changes in consumption pattern. Correspondingly, the World Bank predicts that the cost of annual global SWM will increase from USD 205.4 billion to about USD 375.5 billion by 2025 (Hoornweg & Bhada-Tata 2012). The UNEP (2011), indicates that as of 2011 about 11.2 billion tonnes of solid waste were collected annually. Such quantity of waste has huge economic value due to its recyclability. For instance, UNEP (2011) estimates that the world waste market, from collection to recycling, is hovering at USD 410 billion a year, not including the sizable informal segment in developing countries. At the same time, such quantities of solid waste present a dilemma to countries classified as developing due to its negative externalities. Expressively, the objective of any legislation on solid waste is to protect the environment and public health. To abate the problem of poor SWM, the waste management hierarchy (WMH) approach has been adopted by most local authorities and their donor agencies. The WMH is a concept that promotes waste avoidance ahead of recycling and disposal. It includes a 5-staged process, involving waste reduction, re-use, recycle, incineration and safe disposal of the residual at landfills with most preferred method at the apex (Forbes et al. 2001) as shown in figure 1.

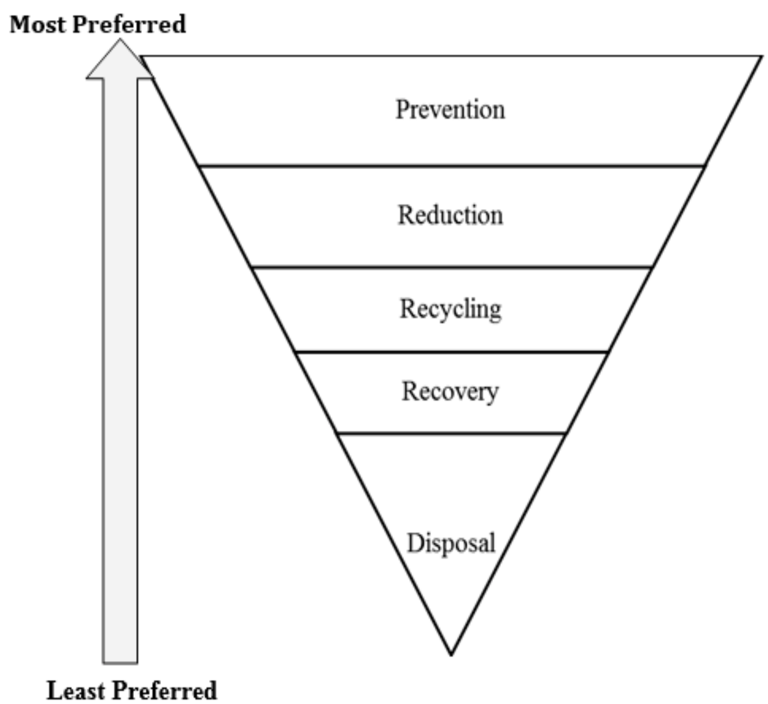

Figure 1: Waste management hierarchy

Source: UNEP (2011)

The WMH concept can be traced back to the 1970s, when environmental Non-Governmental Organizations (NGOs) started to critique the practice of disposal-based SWM (Schall, 1992). They argued that rather than regarding ‘rubbish’ as a homogenous mass that should be buried, waste should be seen as consisting of different materials that should be treated differently. They contend that certain type of waste should not be produced at all; others should be reused; some should be recycled or composted; some should be burnt while others can be buried (Schall, 1992). WMH is also a framework used in the approach of Integrated Solid Waste Management. The concept is used for managing all sources of waste: prioritizing waste avoidance and minimization; practicing segregation; promoting the 3Rs (Reduce, Re-use and Recycle); implementing safe waste transportation; and treatment and disposal in an integrated manner with an emphasis on maximizing resource-use efficiency (UNEP 2011).

The most preferred option for SWM is waste prevention or avoidance (U.S. EPA 2012). Waste prevention involves measures taken before a substance, material or product becomes waste. This can be achieved through the re-use of products or the extension of the life span of products and also a reduction of the content of harmful substances in materials and products (European Commission 2010). The U.S. EPA (2012) also stresses such waste prevention techniques as donating items, buying in bulk and reducing packaging. Waste prevention is important because it leads to resource conservation (WRAP 2012) and eliminates the need to dispose something that is not produced. Source reduction is the next preferred method. It reduces waste generation in the first place. Waste prevention involves the design, manufacture, purchase or use of materials to reduce their quantity or toxicity before they reach the waste stream (O'Leary & Walsh, 1995). It includes minimizing the production of wastes during any step in the creation or use of a product. It may include backyard composting of yard trimmings and food scraps because this method of management keeps these wastes out of the waste stream.

Recycling includes all activities that involve collecting recyclable materials that otherwise would have been considered waste. It also involves sorting and reprocessing including composting waste materials into products, materials or substances for the original or other purpose (EC, 2008). The greatest advantage with recycling is that it prolongs the lifespan of landfills. It saves energy, natural resources, provides raw materials and above all adds to a country's economic fortunes. The fourth level is recovery which Filho & Kovaleva (2015), define as "any operation the principal result of which is waste serving a useful purpose by replacing other materials which would otherwise have been used to fulfil a particular function, or waste being prepared to fulfil that function, in the plant or in the wider economy". Recovery operations may also include recycling/reclamation of metals and metal compounds, regeneration of acids or bases, oil re-refining or other reuses of oil, land treatment resulting in benefit to agriculture or ecological improvement and so on (European Commission 2010).

In Ghana, waste management officials have attempted to implement the WMH which is a prescription from the global North being facilitated through what is termed as "sister city" initiatives. The impression is always created that the historical forces and mechanisms that have driven the evolution of SWM in high-income countries can provide insight into how to move forward in developing country contexts (Wilson et al., 2006). In such countries, efficient SWM is driven by proper planning through reliable data. Reliable data for sustainable SWM is however not readily available or patchy to some extent and therefore SWM policies even fail at birth in most cities in the global South. The seemingly limited solid waste data also affects solid waste forecasting which is regarded as indispensable process in SWM planning (Chung, 2010). This study is premised on a broader scale that the WMH framework can be achieved only when reliable data is available.

Spatial Setting and Methodology

The study was conducted in Wa which is the regional and municipal capital of the Upper West Region of Ghana and Wa Municipality respectively. The city lies within latitude 9º50' N to 10º20' N and 1º40'W to 2º45' W and covers land surface area of 234.74 km^2 constituting about 6.4% of the Upper West Region (Aduah & Aabeyir, 2012; Wa Municipal Assembly [WMA], 2012).

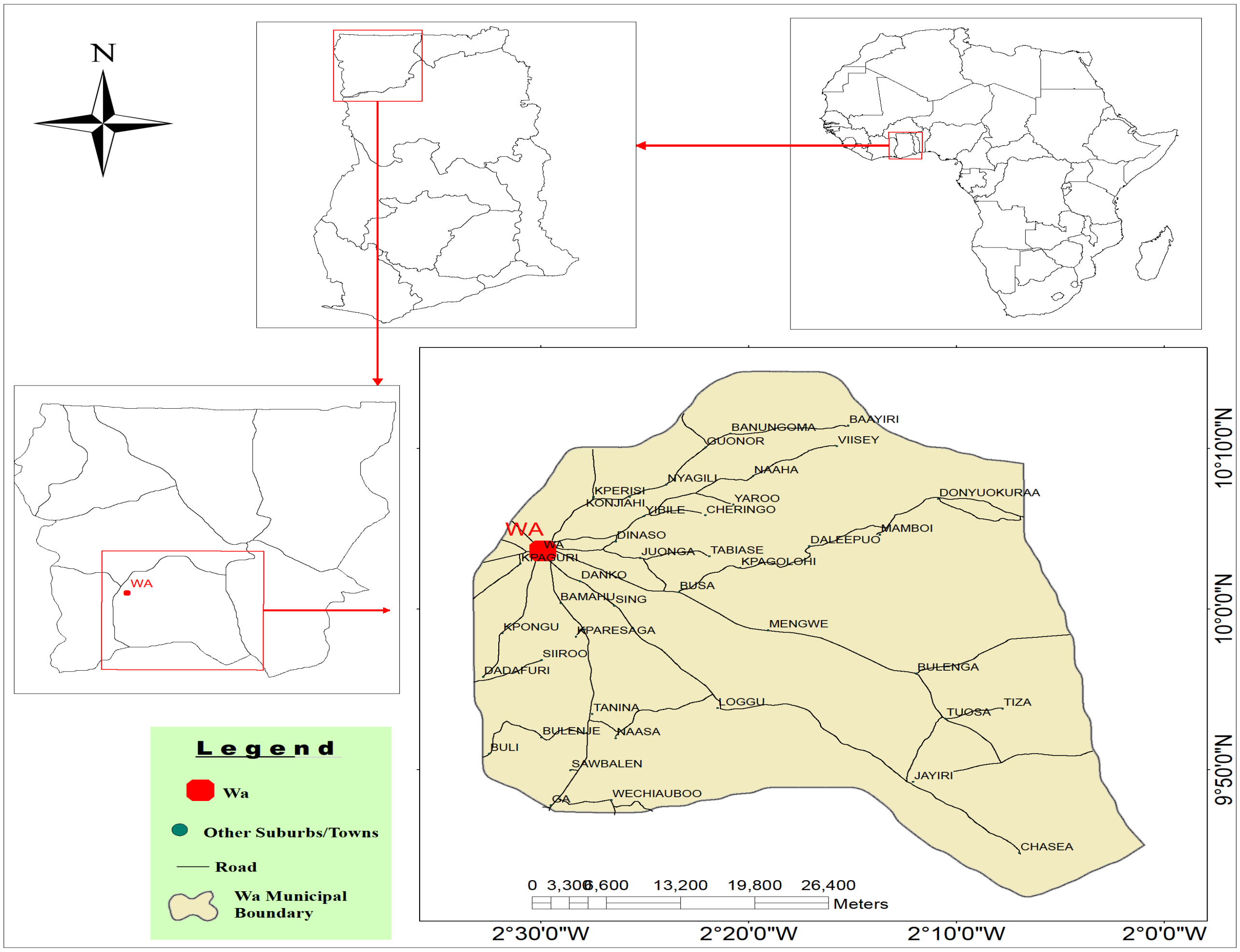

Figure 2: Map Showing the Study Area

Source: Owusu-Sekyere (2016)

A significant feature of the city is that it links Ghana to Burkina Faso and therefore has become an important centre of trade in the north-western corridor of the country (see figure 2). With a total population of 13,740 in 1970 and 36,067 in 1984, the city's population as of 2012 was about 71,083 with a growth rate of 4% per annum (GSS, 2012). While most urbanization trends in other parts of Ghana were facilitated by trade, political power and the discovery of natural resources (gold, bauxite, diamond and cocoa), resulting in the creation of job opportunities (Yankson, 2007), the Wa situation marks a departure from the known status quo.

The urban growth and development of the city have been influenced by the establishment of two tertiary institutions; Wa Polytechnic and the University for Development Studies (UDS) respectively (Amoah, 2012). The establishment of the two institutions have resulted in the influx of thousands of students and workers who have dramatically transformed and expanded a hitherto district capital to a municipality. This has accordingly increased the quantity of solid waste generated by the increasing population. Regrettably enough, there has not been substantial investment in environmental services to ensure that the solid waste generated is efficiently and sustainably managed. At the same time, the waste so generated is also becoming so diverse in its origin and forms and so pervasive in its impacts, through terrestrial, aquatic, and atmospheric pathways that it has the potential to adversely affect both the inhabited and uninhabited parts of the city.

Data Sources

To achieve the set goals of the study, we conducted a deep search for secondary data on the annual tonnage of solid waste generated in the city of Wa. This was obtained from the waste management department of the WMA and Zoomlion Ghana Limited (ZGL). The data was modelled using ARIMA 2,1,1 to forecast the yearly quantity of solid waste that will be generated between 2016 and 2026. Secondly, we conducted twenty-eight key informant interviews using unstructured interview format. The key informants included two staff each from the waste management department, the environmental sanitation department, the public health department of the Ghana Health Service, ten workers from ZGL and other stakeholders involved in the management of sanitation in Wa. The reason for choosing relatively unstructured interviews was to allow flexibility as well as adjust the questions to each of the key informants. In addition, we also wanted to be 'open' so as to obtain other information from the respondents that could be of interest to the study. Each key informant gave their perspective, on the solid waste management problem and what could be done to ameliorate the situation in the city. We were particularly concerned about their constraints to proper service delivery and their proposed policy intervention for the future. Their responses are aptly captured in the form of narratives in the subsequent sections of this paper.

Modelling the Quantity of Solid Waste

The yearly quantity of solid waste generated over a ten year period (2004-2014) which was obtained from the WMA and ZGL was used for our forecast. The reason for using yearly data is in sync with the works of Younes et al. (2015), who observed that there is paucity of data in developing countries on daily basis and that "annual solid waste prediction is essential for sustainable municipal solid waste management planning". The same reason (limited data) was adduced by Intharathirat et al. (2015), for their study in Thailand. We could not have used data for 2015 because as of the time of this research, statistics from official sources were not available as the year (2015) had not ended. The rates were modelled using ARIMA, a stochastic model popularized by Box and Jenkins in 1976. The ARIMA (*p,d,q*) is a modified form of the Autoregressive Moving Average Model (ARMA). ARMA (*p,q*) model is where the times series variable is non-stationary. An ARMA (*p,q*) model is the combination of an Autoregressive process and a Moving Average process into a compact form in order to reduce the number of parameters. For an ARMA (*p,q*) model, *p* is the order of the Autoregressive process and *q* is the order of the Moving average process. An ARIMA is used only if a time series variable is weakly stationary. If the times variable is non-stationary (that is has a unit root), the ARMA (*p,q*) model is extended to an ARIMA (*p,d,q*) model where *(d)* is the order of integration of the series (number of times the series is differenced to make it stationary). ARIMA (*p,d,q*) model is thus expressed as:

$$\left(1-\sum_{i=1}^{p}\emptyset_i L^i\right)(1\text{-}L)^d X_t = \left(1+\sum_{i=1}^{q}\theta_i L^i\right)\varepsilon_t$$

Where;

p and ***q*** are positive integers.

$\boldsymbol{L^i}$ is the lag operator

$\boldsymbol{\Theta_i}$ are the parameters of the moving average

$\boldsymbol{\mathcal{E}_t}$ are error terms

t is an integer index

$\boldsymbol{X_t}$ are real numbers

Ø is the i^{th} autoregressive parameter

Model Identification and Estimation of Parameters

In order to select the most appropriate model for the data, there was a comparison of all competing models and the one with the minimum Akaike Information Criterion value (AIC), Bayesian Information Criterion (BIC) and Residual Variance was selected. Other statistical tests like Root Mean Squared Error (RMSE), Mean Absolute Percent Error (MAPE), Bias Proportion or Mean Forecast Error (MFE) and Mean Absolute Scaled Error (MESE) were also used in testing the accuracy of the forecast fitted models, (Table 2). The best model will be the one that achieves a compromise between the various information criterion values.

Table 2. Competing Models with Information Crterion Values

Model	**Akaike Information Criterion (AIC)**	**Residual Variance**	**BIC**	**MASE**
ARIMA(2,1,1)	1544.7	135,737,828	1556.01	0.8125169
ARIMA(1,1,2)	1544.54	135,322,947	1555.86	0.8209374
ARIMA(1,1,1)	1542.79	136,055,977	1551.84	0.8108

ARIMA (2, 1, 1) model was the best model for the forecasting since its values were better than that of the other competing models. We selected the best model among all candidate models by the Akaike Information Criterion (AIC), Normalized Bayesian Information Criterion (BIC) and the Log-likelihood values. The best model was the model with the maximum Log-likelihood value and least AIC and BIC values. The chosen model for the solid waste data series is therefore in the form:

$$Y_t\text{-}Y_{t-1} = \propto_1 (Y_{t-1}\text{-}Y_{t-2})\text{-}\theta_1 e_{t-1} + \mu + e_t \quad (2$$

$$Y_t\text{-}Y_{t-1} = 0.3449\ (Y_{t-1}\text{-}Y_{t-2}) + e_{t-1} + 265.5104 + e_t \quad (3$$

OR

$$Y_t = (1 + \propto_1)Y_{t-1}\text{-} \propto_1 Y_{t-2}\text{-}\theta_1 e_{t-1} + \mu + e_t \quad (4$$

$$Y_t = 1.3449Y_{t-1}\text{-}0.3449Y_{t-2} + e_{t-1} + 265.5104 + e_t$$

Where;

y_t is time series stationary

θ_t is The moving average parameter

e_t is white noise series

This indicates that the fitted model is a linear combination of a previous solid waste value, previous forecast error and a constant.

Results and Discussion

Solid Waste Generation in Wa

Statistics from the WMA (2014), indicate that the quantity of solid waste generated in Wa has been increasing from year to year since 2004 (see figure 3).

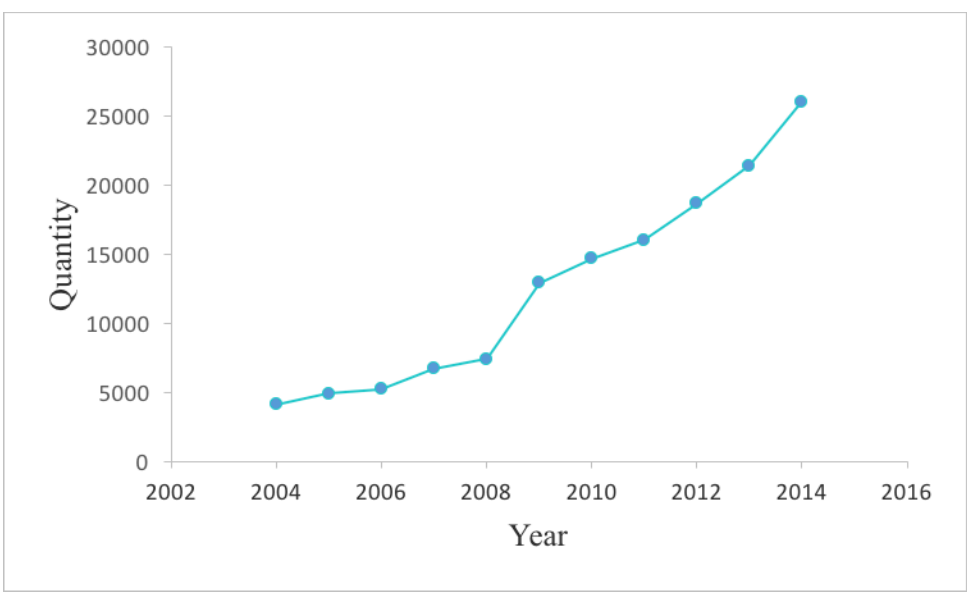

Figure 3: Quantity of Solid Waste Generated in Wa since 2004 (in tonnes)

Source: WMA (2014)

Our research showed that over 90% of solid waste generated was disposed at the crude dumping site at Siriyiri – a fringe community located about 5km away from the city centre. The dumpsite is located in an ecologically sensitive area without proper leachate or gas recovery systems. Like the quantity, the waste composition of any society is influenced by its level of socio-economic development, geographic location, cultural norms and sources of energy. As countries urbanize and income level increases, inorganic waste materials (plastics, paper, and aluminium) typically increases (UNEP 2011). In the case of Wa, we observed that the organic fraction which were composed of kitchen wastes including food leftovers, vegetables, leaves, animal excreta, rotten fruits and bones formed over 60% of vwaste while plastic, glass, metal and paper account for less than 20% of the total waste. The high percentage of organic material is synonymous with many countries that thrive largely on agricultural products for economic development. The high percentage of food and plant waste can be explained based on the fact that Wa's economy thrives largely on agricultural products for domestic consumption. Apart from the food leftovers and waste from food processing, lack of storage facilities and ready market for the farm products lead to high percentage of food and plant waste (MLGRD, 2002). The high composition of organic waste further implies a high rate of putrefaction and hence a potential odour nuisance. One critical resource that remains untapped is that the high quantity of organic waste presents an opportunity for the production of compost which is much needed by the ailing agricultural sector that is failing to absorb the teaming youth. Organic waste can also be decomposed anaerobically to produce biogas, which can be used as an energy source. Anaerobic decomposition also produces valuable fertilizers.

Projecting Solid Waste Generation in Wa

The diagnostic checking of the ARIMA (2, 1, 1) model revealed that the model was adequate for the series. The ARCH-LM test showed that there was no ARCH effect; hence the residuals had a constant variance. The Ljung-Box *p*–values (> 0.05) also showed that there was no serial correlation in the residuals of the model, (see table 3).

Table 3. Diagnostic Test Statistics

Test	Statistic	p-value
ARCH LM	11.0797	0.522105
Ljung-Box	6.0	0.737

The p-values were determined by using Autocorrelation function (ACF) and Partial Autocorrelation function (PACF). For any ARIMA (*p, q, p*) process, the theoretical PACF must have non-zero partial autocorrelations at lags 1, 2,..., *p* and must have a zero partial autocorrelations at all lags, while the theoretical ACF must have non zero autocorrelation at lags 1, 2,…, *q* and zero autocorrelations at all lags. The non-zero lags of the sample PACF and ACF were tentatively accepted as the *(p)* and *(q)* parameters. For a non-stationary series, the data was differenced to make the series stationary. The number of times the series was differenced determined the order of *(d)*. The ACF and PACF plot of the residuals also showed that the residuals were white noise series, (Figure 4).

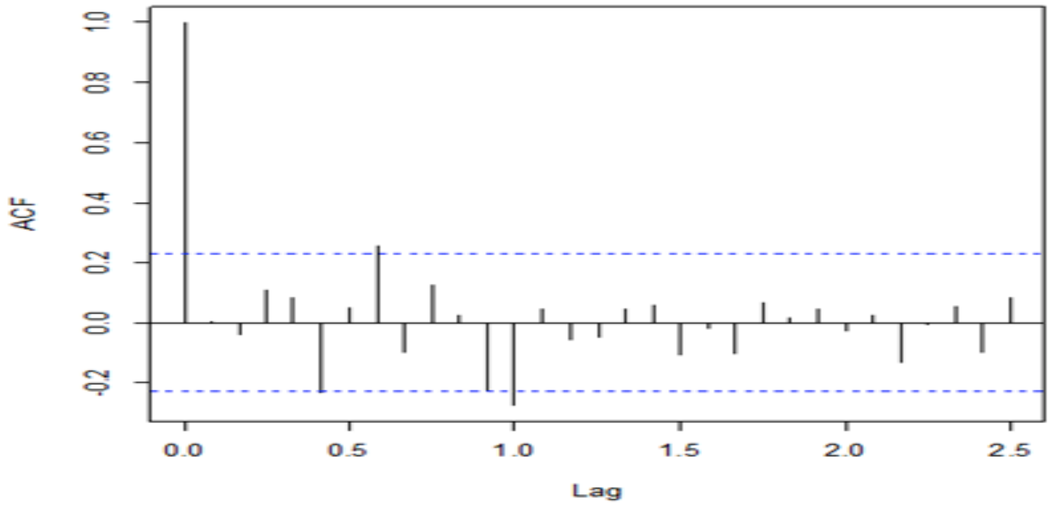

Figure 4: ACF of ARIMA (2, 1, 1) Residuals
(Box-Ljung test: model1residuals; X-squared = 34.7176, df = 30, p-value = 0.2531)

Again, in order to check whether the residuals were normally distributed with mean zero and constant variance, the normality quantile-quantile plot (*q-q* plot) and a histogram were used, (see Figure 4). If the residuals were normally distributed, the points on the normal quantile-quantile plot should have been approximately linear, with residual mean as the intercept and residual standard deviation as the slope whilst the shape of the histogram shows "a bell-like" shape. From figure 4, the ACF of residuals show that only 3 out of the 30 lags of the sample autocorrelations exceed the significant bounds, with two other lags just touching the bounds. These lags were ignored since the probability of a spike being significant by chance was about one in thirty. The ACF died down after lag 12 with most lags getting close enough to zero. This simply gave an indication of non-significant autocorrelation, since one would have expected that at most 3 out of 30 sample autocorrelations to exceed the 95% significance bounds. Similarly, from the Box-Ljung test, the computed p-value (i.e. 0.2531) was also greater than α (alpha) at 5% level of significance. Hence, from these deductions, we failed to accept the null hypothesis that the series of residuals exhibited no autocorrelation and therefore, the conclusion was that there was very little evidence for non-zero autocorrelations in the residuals at all lags (i.e. the residuals are independently distributed).

The histogram of the residuals displayed provided an indication of a plausible symmetric distribution (figure 5). The QQ-normal plot for the residuals also shed more light on this since most of its residuals did not deviate considerably from the line of best fit and its distribution looked approximately linear.

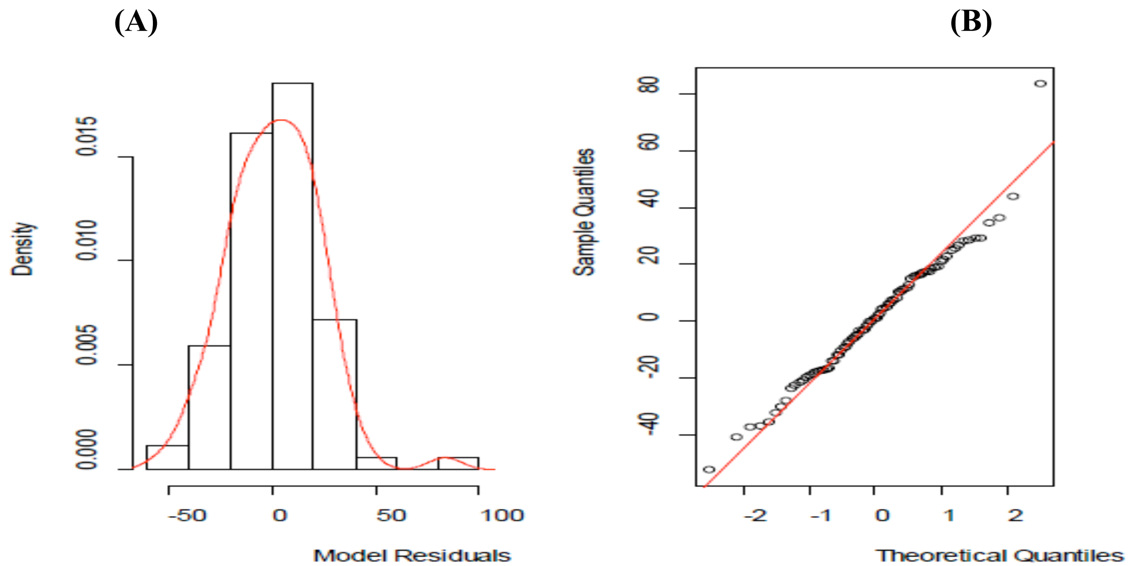

Figure 5: Histogram (A) and QQ-Normality Plot (B) for Residuals of ARIMA (2, 1, 1)

The time series plot of the quantity of solid waste collected (figure 6), gives an indication of non-stationary in the series. Figure 6 showed a sampled ACF with lag 1 and the other lags lying within the significant bounds, hence showing no significant peaks.

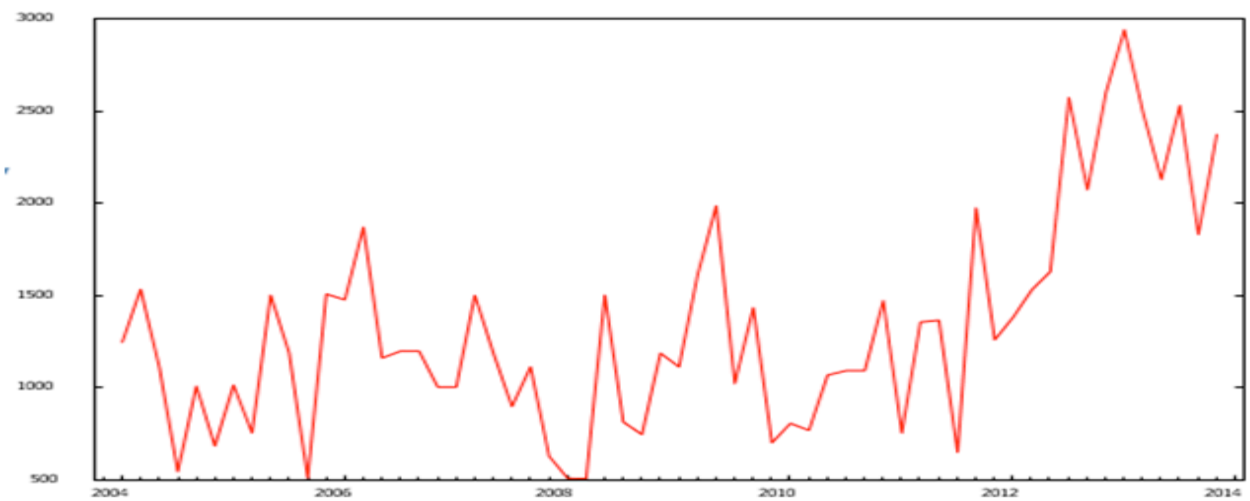

Figure 6: Time Series Plot of Quantity of Waste Collected

The non-stationary of the series can also be seen from the ACF plot of the series which showed a slow decay and also from the PACF plot which had a very significant spike at lag 1, (figure 7). In order to select the appropriate model and also make more accurate forecasts, several feasible ARIMA models were fitted to the observed data by making reference to the sampled ACF and sampled PACF (figure 7) of the differenced data. Since the data was differenced, the fitted ARIMA models would be in the order of (p, d=1, q). From the correlogram in figure 7, the sampled ACF died down for three (3) successive lags after the first significant lag i.e. lag 1, and thereafter, cuts inconsistently at lag 5 and lag 7. Lags 5 and 7 were however considered not significant, because they could be caused by the irregular component of the series.

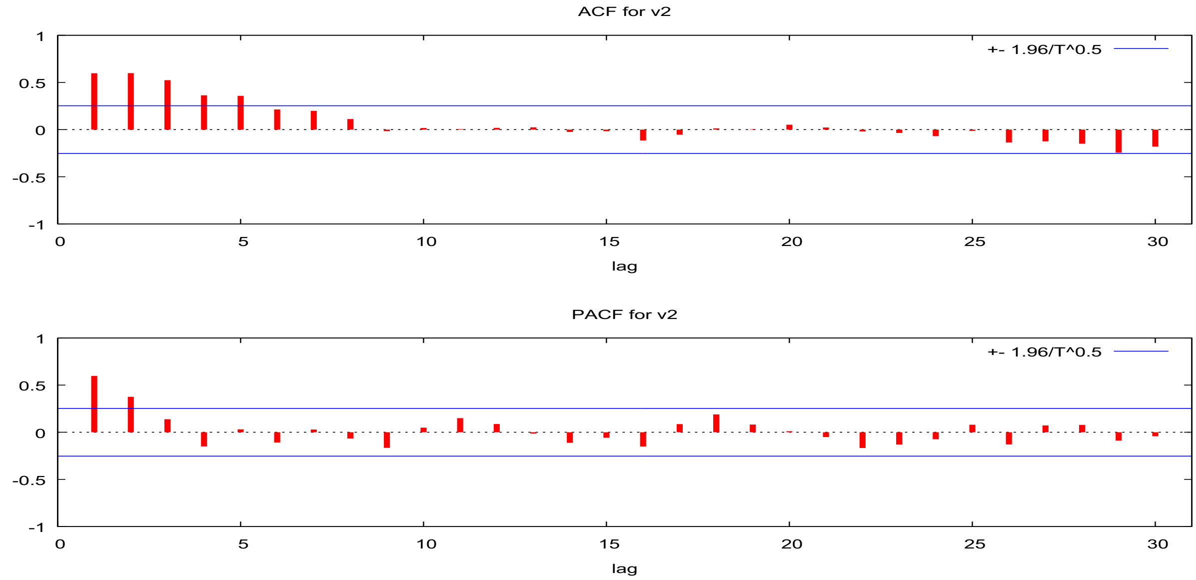

Figure 7: ACF and PACF of Indifference Quantity of Solid Waste Collected

The Augmented Dickey-fuller test further confirmed this assertion. The test was insignificant at the 0.05 significance level showing that the series had a unit root and hence not stationary. The series was therefore first differenced and tested for stationary with the Augmented Dickey-fuller test, (see table 4).

Table 4. Augumented Dickey-Fuller Test

Order	Test Statistics	p-value
0	0.082482	0.709
1	-8.36537	0.000

The first difference was enough to make the series stationary as shown by the test. Also, the partial correlogram revealed that the partial autocorrelations at lags 1, 2, 5 and 6 exceeded the significance bounds, and were negative as well. The partial autocorrelations died down after lag 6. Lag 26 was however, considered not significant since it could be due to chance, considering the fact that lag 25, which came right before it was significantly not far from zero. Based on the selection of the most fitted ARIMA model, a ten year forecast of solid generation is presented in figure 8. We project that by 2026, Wa will be generating 70,983 tons of solid waste, that is if current trends stay the same, a figure almost six times higher than the 2016 figure. Given the fact that the health and environmental implications of improper solid waste management is increasingly reaching a crisis point with regular outbreaks of cholera and other environmentally related diseases, there is the need for city authorities and planners to have a re-orientation of national policies and programmes that can cater for today's needs and still be relevant for the future.

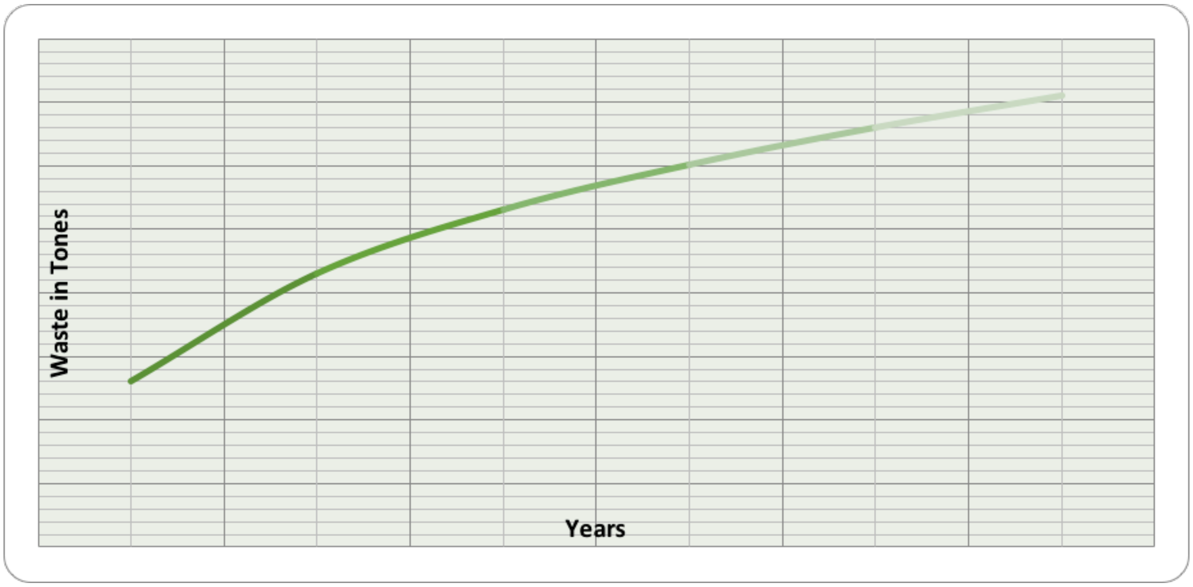

Figure 8: 10 Years Forecast Plot of Solid Waste Generation in Wa (2016-2026)

In order to appreciate the extent of the problem and the conditions that can work well in urban Wa, it is important to provide an understanding of the existing SWM regime in the study area. Our belief is that this will provide the context for balancing the argument on the search for sustainable SWM in Ghana in general. Until 2006 when ZGL – a private waste management company, was contracted by the WMA as a partner, the Assembly was the sole agency providing SWM services in the Municipality. Under the arrangement, ZLG is expected to collect and dispose 80% of the solid waste generated and the remaining 20% is the responsibility of the Assembly. The existing partnership arrangement between WMA and ZLG is in the form of service contract. With this form of privatization, ZLG has been given a particular zone to manage. The total cost is not pushed to the beneficiaries, but rather government subsidizes the cost, and allows beneficiaries to pay between 10 and 20% of the total cost. The company takes responsibility of the cost of billing and collecting user charges. As explained by the Municipal planning officer:

> *"The choice of this form of privatization was based on the limited polluter pay principle. It was to caution people to try as much as possible to reduce the volume of solid waste that they generate. It was also to help the government reduce the colossal amount of money that is expended on the management of solid waste",* he concluded.

In terms of service delivery, two levels of services were identified in Wa: house-to-house (HtH) collection system and central communal collection (CCC) system. The communal collection system operated largely in the densely populated and low income communities within the municipality where solid waste is dumped. Unlike in other parts of the country where households using the communal services paid as they dumped their refuse (Owusu-Sekyere, 2016), Wa had a contrary situation; no fees were paid for dumping refuse in the central communal containers, rather, the fees were paid by the Municipal Assembly through deductions from the District Assembly Common Fund. The house-to-house collection service was mostly delivered largely in high and middle income residential areas with accessible routes. Households utilizing the service were charged between GH¢15.00 (US$4.00) and GH¢10.00 ($3.50) per month, depending on the size of the litter bin. The bins were provided by the private company at no cost to the households. These institutional arrangements made households important actors within the SWM system because they were in a position to provide feedback to enhance service improvements. Though the salutary effects of the private sector participation cannot be taken for granted, the empirical proof that the privatization was actually working was still rather weak.

From all indications, Wa's population has grown in terms of size and density (GSS, 2010) and this growth has not taken place alongside the expansion in social and economic infrastructure. The administrative area designed as the official metropolis has severely been blighted with haphazard developments and congestion of small retail shops. These dynamics have further increased the quantity of solid waste being generated within the Metropolis. Our research showed that it was becoming increasingly difficult for city authorities to spatially define local arrangements for service provisions, patterns of economic development, exercise political control and allocate scarce resources for development.

Our projections even present a serious dilemma as the existing waste management policies already discussed are even not enough to deal with the problem. As noted by a ZLG official in an interview:

> *"for the past five months, the government has not paid the company for the services we have rendered. What is more, our operational areas have also been expanded to include Bamahu which was not initially part of the Municiplaity. If this practice of non-payment continues, we have no option than to leave. I tell you my brother, the future is bleak"*.

The concerns so expressed exemplifies the apparent weak SWM regimes there is in Wa. We argue therefore that it will require a new and invigorated approach to deal with the projected solid waste generation. It is also clear that the blanket adoption of the SWM hierarchy framework cannot work in the context of Wa. As a first step towards abating the problem we suggest that city authorities need to adopt adequate anti-sprawl policies so that the city can efficiently be managed. Furthermore, waste managers need to plan for future scenarios. We argue for a multi-scalar, "pluralistic" solid waste management system for Wa, or what Scheinberg et al. (2006) refer to as "modernized mixtures" (the integration of formal and informal waste management structures that are compatible with each other rather than competing against each other). This inclusive or integrated approach explains how a greater number of stakeholders who are involved in the organization of waste management should be given a serious consideration. This includes not only local governments and the private sector, but also, the often unrecognized stakeholders, including informal workers - scavengers as well as waste generators (i.e. households, businesses, and institutions). Overall, an integrated waste management system which emphasizes the 3Rs (reduce, reuse and recycle) as well as composting (recover) should be considered. Integrated waste management not only reduces the quantity of solid waste that ends up at the dumpsites but also utilizes the full potential of waste as a resource. The Municipal Director of Waste Management said in an interview:

> "*what we are looking at in the near future is composting. You know the major occupation here is agriculture and therefore if we are able to turn the waste into compost not only will it increase the yield of farmers, it will also save the nation huge sums of money that are used in importing fertilizer. The compost plant will also serve as a source of employment, but all this will depend on the availability of funds",* he concluded with optimism.

The effectiveness of policies in managing waste is strongly influenced by factors such as efficient and sustained public education and the maintenance of waste recovery facilities. Additionally, a very important factor behind the success of such programmes is government's political will to promote waste recycling and reduction. The projections will be valid if the current status quo remains the same. Already, there has been widespread concern among policy makers in Ghana about the fast pace of the demographic shift towards urban centers in recent years and the fact that this demographic shift is accompanied by anticipated industrial development and changes in consumption patterns.

Conclusion and Recommendations

From its broadest contours, this study contributes to the dynamic body of geographical research on solid waste forecasting in a developing city. In Ghana, this study adds to the growing literature on solid waste management in areas outside of major metropolitan areas such as Kumasi and Accra. It re-affirms the position that clearly, there is a compelling need to develop a sustainable solid waste management strategy that can withstand the unfolding urban revolution. The situation in Wa may not be an isolated case, as most cities in Ghana lag behind in terms of policy and best practice. Given the fact that city authorities struggle to generate enough revenue both locally and internationally, they cannot afford to implement waste management techniques that may be incompatible with their environmental, social and economic contexts. Rigorous evaluation of waste management options, comprehensive projections and planning should inform the best way to safeguard against ill-fated investments toward a meaningful and sound solid waste management in the long-term. These findings can, with further elaboration, provide the basis for re-thinking Ghana's current waste disposal policies.

Overall, the evidence suggests that in order to pursue a more sustainable municipal SWM, local government policies may have to be rebalanced towards assigning appropriate priorities and support to waste prevention activities, priorities and support that have so far received lip-service rhetoric within Ghanaian environmental policy principles but are never effectively implemented. In addition, the authorities may need to adopt measures either through adaptive local resource management or through adjustment in existing human systems. Situations where land is allowed to be wantonly degraded (e.g. through sand winning) to justify future landfilling are unsustainable and must be discouraged.

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References

Abdul-Kadri Y. & Owusu- Sekyere E. (2012). Challenges of Privatizing Waste Management in the in Wa Municipality Of Ghana: A Case of Zoomlion Ghana Limited *Journal of Environment and Earth Science* Vol 2, No.11, 2012

Acquah, I. (1958). Accra Survey: A Social Survey of the Capital of Ghana, formerly called the Gold Coast, undertaken for the West African Institute of Social and Economic Research, 1953-1956, Warwick Square, London: University of London Press

Ali, A. (2010). Wasting time on solid waste in developing countries. *Waste Management,* 30, 1437-1438.

Akaateba, A. M. & Yakubu, I. (2013). Householders' Satisfaction towards Solid Waste Collection Services Of Zoomlion Ghana Ltd in Wa, Ghana. *European Scientific Journal,* November 2013 edition vol.9, No.32 ISSN: 1857 – 7881 (Print) e - ISSN 1857- 7431

Amoah, T.S. (2012). Gentrification and Urbanization in Ghana: The Case of The Central Business District of Wa in the Upper West Region. *LAP Lambert Academic*

Publishing, Germany. ISBN: 978-3-659-21568-1.

Amoah, S. T & Kosoe, E. A. (2014). Solid Waste Management in Urban Areas of Ghana: Issues and Experiences from Wa. *Journal of Environment Pollution and Human Health*, vol. 2, no. 5 (2014): 110-117. doi: 10.12691/jephh-2-5-3.

Ahmed, A. & Dinye, R.D. (2011). 'Urbanization and the challenges of development controls in Ghana, a case study of Wa Township'. Journal of Sustainable Development in Africa, Vol. 13 (7), pp. 210-235.

Annez, P., Buckley, R., Kalarickal, J. (2010). 'African urbanization as flight? Some policy implications of Geography'. Urban Forum 21:221-234

Awortwi, N. (2004). Getting the fundamentals wrong: woes of public-private partnerships in solid waste collection in three Ghanaian cities. Public Administration and Development, 24(3), 213-224. http://dx.doi.org/10.1002/pad.301.

Awunyo-Vitor, D., Shaibu, . I., Seidu, J.G. (2013). Urban Households' Willingness to Pay for Improved Solid Waste Disposal Services in Kumasi Metropolis, Ghana. *Urban Studies Research* Volume 2013,http://dx.doi.org/10.1155/2013/659425.

Box, G.E. & Jenkins, G.M. (1976). Time Series Analysis: Forecasting and Control. Wiley Series in Probability and Statistics.

Chung, S. S. (201). Projecting municipal solid waste: The case of Hong Kong SAR Resources, *Conservation and Recycling* 54.11 (2010): 759-768.

Cointreau-Levine, S. (1994). Private Sector Participation in Municipal Waste Services in Developing Countries. Vol. 2. The Formal Sector Urban Management Programme Discussion Paper 13. UNDP/UNCHS/ World Bank Urban Management Programme. Urban Management and the Environment.

Cointreau-Levine, S., Coad, A. (2000). Guidance Pack: 'Private sector participation in municipal solid waste management'. Available at: http://www.sanicon.net/titles/ (accessed 28 February 2006).

Daily Graphic, Saturday 26 April, 2005, Accra, Ghana, pp. 21–28. Daily Graphic, (2005). Daily Graphic, 3th November, 2005, Accra, Ghana, pp 14.

Daskalopoulous, U., Mayes, D., Harris, C., Lansbury, M. (2008). Status of institutional reforms for integrated water resources management in Asia: Indications from policy reviews in five Countries. Working Paper 108, International Water ManagementInstitute, Sri Lanka.

DETREG (undated). Software for Predictive Modelling and Forcasting. www.dtreg.com/index

EEA (2013). Municipal waste generation. Retrieved from http://www.eea. europa.eu/.

European Commission (2010). Being wise with waste: The EU 's approach to waste management, pp. 1–16. Retrieved from http://ec.europa.eu/environment/waste.

Forbes, D., L., McLean, R., F., Tsyban, A., Burkett, V., Codignott, J., O., Mimura, N., Ittekkot, V. (2001). Coastal Zones and Marine Ecosystems. 264 Geography Reader. In: James J, Canziani MOF, Leary NA, Dokken DJ, White KS (eds) Climate Change 2001: Impacts, Adaptation, and Vulnerability. Cambridge University Press, UK, pp 343–379

GSS, (2012). Final Report on Population and Housing Census, Accra: Sakoa Press Limited. Ghana Statistical Service.

Hoornweg, D., Bhada-Tata, P. (2012). What a waste a global review of solid waste management, Washington, DC.

Intharathirat, R., Abdul Salam, P., Kumar, S., Untong, A. (2015). Forecasting of municipal solid waste quantity in a developing country using multivariate grey models, *Waste Management,* 39. 3-14

ISSER. (2012). Institute of Statistical, Social and Economic Research). Ghana Social development outlook, 2012, University of Ghana. Accra.

Katusiimeh, M.W., Burger, K., Mol, A. P. J. (2013). Informal waste collection and its co-existence with the formal waste sector: the case of Kampala, Uganda. Habitat International, 38(C), 1-9.

Kapepula, K. M., Colson, G., Sabri, K., Thonart, P. (2007). A multiple criteria analysis for household solid waste management in the urban community of Dakar, *Waste Management*, 27(11), 1690e1705. http://dx.doi.org/10.1016 j.wasman.2006.07.009.

Kumasi Metropolitan Assembly Waste Management Department (KMA) (2011). Data for purposes of planning waste management intervention programmes. Kumasi Waste Management Department. Kumasi, Ghana.

Leal F., W., Kovaleva, M. (2015). Food Waste and Sustainable Food Waste Management in the Baltic Sea Region, Environmental Science and Engineering, DOI 10.1007/978-3-319-10906-0_2

Ministry of Local Government and Rural Development (MLGRD) (2005). Kwabenya Landfill Development.Technical Advisory Committee, Final report. Ministry of Local Government and Rural Development (MLGRD).

MLGRD (2001). Government and Rural Development (MLGRD). Ghana: The Local government system. Accra: Ministry of Local Government and Rural Development.

MLGRD, (1999). National Environmental sanitation policy, Accra, Ministry of Local Government and Rural Development. Ministry of Local Government and Rural Development (MLGRD) Accra, Ghana.

Montgomery, R.M. (2009). Urban Poverty and Health in Developing Countries, ***Population Bulletin*** 64, no. 2

Oduro-Kwarteng, S. & van Dijk, M., P. (2013). The effect of increased private sector involvement in solid waste collection in five cities in Ghana. In: ***Waste management & research*** 31(10): 810–93

Okot-Okumu, J. & Nyenje, R. (2011). Municipal solid waste management under decentralisation in Uganda ***Habitat International,*** 35(4), 537e543. http:// dx.doi.org/10.1016/j.habitatint.2011.03.003.

Oteng-Ababio, M. (2010). Private sector involvement in solid waste management in Ghana: the case of the Greater Accra Metropolitan Area (GAMA). ***Waste Management and Research*** 28: 322-329.

Oteng-Ababio, M. (2011). Beyond technical details: The stalled Kwabenya Engineered Sanitary Landfill Project in Accra, Ghana. ***Danish Journal of Geography***, 111(2)

Oteng-Ababio, M., Melara, J. E., Gabbay, O. (2012). Solid waste management in African cities: Sorting the facts from the fads in Accra, Ghana, ***Habitat International***, 1-9http://dx.doi.org/10.1016/j.habitatint.2012.10.010.

Oteng-Ababio, M. (2013). Unscripted (in) justice: unequal exposure to ecological hazards in Metropolitan Accra**. *Journal of Environment and Planning A*, *45.*** doi: 10.1068/a45256.

Oteng-Ababio, M. (2014). Rethinking waste as a resource: insights from a low-income community in Accra, Ghana, *City,* ***Territory and Architecture*** 1:10.

Owusu-Sekyere, E. (2014). Scavenging For Wealth Or Death? Exploring The Health Risk Associated With Waste Scavenging In Kumasi, ***Ghana Journal of Geography*** 6: 63 – 80

Owusu-Sekyere, E., Bagah, A., D., Dwamena Y., J., Q. (2015). The Urban Solid Waste Management Conundrum in Ghana: Will It

Ever End? ***World Environment*** 5(2):52-62 DOI: 10.5923/j.env.20150502.02

Owusu-Sekyere, E. (2016). Re-thinking Landfills as Asset: Empirical Evidence from Urban Ghana. In V. Fletcher (Ed.), ***urban and rural development, perspectives, strategies and challenges*** (1: 115-132). New York, ST: Nova Science Publishers Inc.

Post, J., Broekema, J., Obirih-Opareh, N. (2003). Trial and error in privatisation: experiences in urban solid waste collection in Accra and Hyderabad. ***Urban Studies*** 40: 837–854.

Rotich, H. K., Yongsheng, Z., Jun, D. (2006). Municipal solid waste management challenges in developing countries the Kenyan case study. ***Waste Management*,** 26 (1), 92-100. http://dx.doi.org/10.1016/j.wasman.2005.03.007.

Scott, C.A. & Raschid-Sally, L. 2012. The global commodification of wastewater. ***Water International*** 37(2): 147-155.

Schall, J. (1992). Does the Solid Waste management Hierarchy Make Sense? A Technical, Economic and Environmental Justification for the Priority of Source Reduction and Recycling. Working paper #1, Program on Solid Waste Policy, Yale University.

Scheinberg, A., Justine A., Arnold van de K., (2006) Waste pickers: poor victims or waste management professionals. Paper No. 56 presented at the CWG- WASH Workshop, 1-5 February, 2006. Kolkoba, India.

Skanska-Shimmck-Herzog, (2012). Safety, health and environmental management systems (SHEMS). Silicon valley Benyassa extension project.

UNEP (2011). Waste: Investing in energy and resource efficiency. In Towards a green economy: Pathways to sustainable development and poverty eradication (pp. 286–329). Retrieved from http://www.unep.org/greeneconomy/Portals

UN Habitat (2010). Collection of Municipal Solid Waste in Developing Countries. 10-37 United Nations Centre for Human Settlements.

UN-HABITAT (2008). Ghana: Country Programme Document 2008–2009. 1039 UN-Habitat, Nairobi.

U.S. EPA (2012). Solid waste management hierarchy. Wastes-non-hazardous waste-municipal solid waste, available at http://www.epa.gov/wastes/nonhaz/municipal

van Dijk, M., P. (2010) Incorporating Informality: 35 years of research and policies on the urban informal sector. In: Fransen J, et al. (eds) Maastricht: Shaker, pp. 1–15.

Wilson, D.C., (2007). Development drivers for waste management. ***Waste Management & Research*** 25 (3), 198–207.

Wa Municipal Assembly (2012). "The Composite Budget of The Wa Municipal Assembly For The 2012 Fiscal Year". Wa Municipal Assembly.

Wa Municipal Assembly (2014). The Composite Budget of The Wa Municipal Assembly For The 2013 Fiscal Year, Wa Municipal Assembly.

World Bank (1996). Urban Environmental Sanitation Project Staff Appraisal Report.

Yankson, P. W. K. (2007). Street Trading and Environmental Management in Central Accra: Decentralization and Metropolitan Governance in Ghana. ***Research Review*** 23(1): 37-55.

World Bank (1999). International Bank for Reconstruction and Development, What a Waste, Solid: Waste Management in Asia.

Wilson, D.C, Velis, C., Cheeseman, C. (2006). Role of informal sector recycling in waste management in developing countries. ***Habitat International*** 30: 797–808

WRAP (2012). Decoupling of waste and economic indicators, Retrieved from http://www.wrap.org.uk/sites/files/wrap/

Yin, A. A. (2004). Landfills in Jiangsu province, China, and Potential Threats for Public Health: Leachate Appraisal and Spatial Analysis Using Geographic Information System and Remote Sensing. ***Waste Management****,* 28: 2750–2757.

Younes, M.K., Nopiah, Z.M., Basri, N.E.A., Abushammala, M.F.M., K.N.A, M. (2015). Solid waste forecasting using modified ANFIS modelling, ***Journal of the Air and Waste Management Association*** (10):1229-38, doi10.1080