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Full Length Review Article

Social-engineering systems thinking approach to waste management in developing countries - A Review

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Abstract

Municipal waste management has been part of the global environmental protection challenge confronting science and society at large. Studies on sustainable waste management approach often entails prioritizing economic aspects and see the environment as an entirely separate entity from humans. Technological and economic tools and solutions are indeed important, but sustainable developments require inclusion of human actions as part of interconnected web imparting on the world. This study critical reviewed existing documents on the municipal solid waste management systems from both the developed and developing nations, and postulated the "Socio-Engineering Systems" approach for sustainable waste management in the developing world.

Key words: Sociocultural, Systems, Waste, Integrated, Society, Policy.

INTRODUCTION

Waste handling in spite of the numerous technological advances that have been documented is one of the greatest challenges facing the global community. The severity of these challenges is perhaps best described in the level of attention given to it in one of the eight United Nation's Millennium Development Goals (MDGs): ensure environmental sustainability by integrating the principles of sustainable development into country policies and programs and reverse the loss of environmental resources. In achieving sustainable development, the management of environmental pollution, waste production and its management are among the key issues that need to be seriously considered. According to Kwawe (1995) and Oteng-Ababio (2010), waste management systems (WMS) and policies in developing countries like Ghana have relied on foreign technologies and have marginalized the potential of local society and indigenous systems in managing waste thereby making their applicability and acceptability unsustainable. Several failures cases have been reported due to failure to consider waste characteristics, climate, availability of operational skills and finance in the local context. More so, the impacts of the imported technologies are not evaluated in the local context hence its integration has become a challenge. So, just importing advanced technology is not a panacea and poses other technical challenges. Morrissey and Browne (2004) also stated that prior to 2000 solid waste management systems in most developing countries were developed using models that focused on the economical and environmental spheres with limited attention to the social aspects. To date, most models in use in the developing countries are centered on isolated problems within the system making them of little relevance to decision makers (Chang *et al*., 2011). Fig.1 below as reported by Marshal and Farahbakhsh (2013) describes the solid waste management system in the developing world like Ghana, and the subsystems at play and challenges in managing solid waste. These authors also reported that WMS that ignore social components and priorities are doomed to failure. Carabias *et al*. (1999) also condemned WMSs modeled around foreign technologies by reiterating that the issues of public acceptance, changing value systems, public participation in planning and implementation stages, and consumer behavior are equally significant as the technical and economic aspect of waste management. Therefore, effective WMS must be fully embraced by local authorities and the public at large. But, implementing best practices would require a balance between several factors like geographical location, climate, nature and quantity of waste generated and the social factors in addition to the lack of equipment, infrastructure, skill and financing. There is a need to work towards an integrated sustainable solid waste management that is locally appropriate to specific developing world country. This review begins with the examination of the aspects and dimensions of the integrated solid waste management system. It then explores the interconnectivity of these aspects in the developing world where the local context; socio economic structures, values and beliefs are given lesser attention in the solid waste management decision making.

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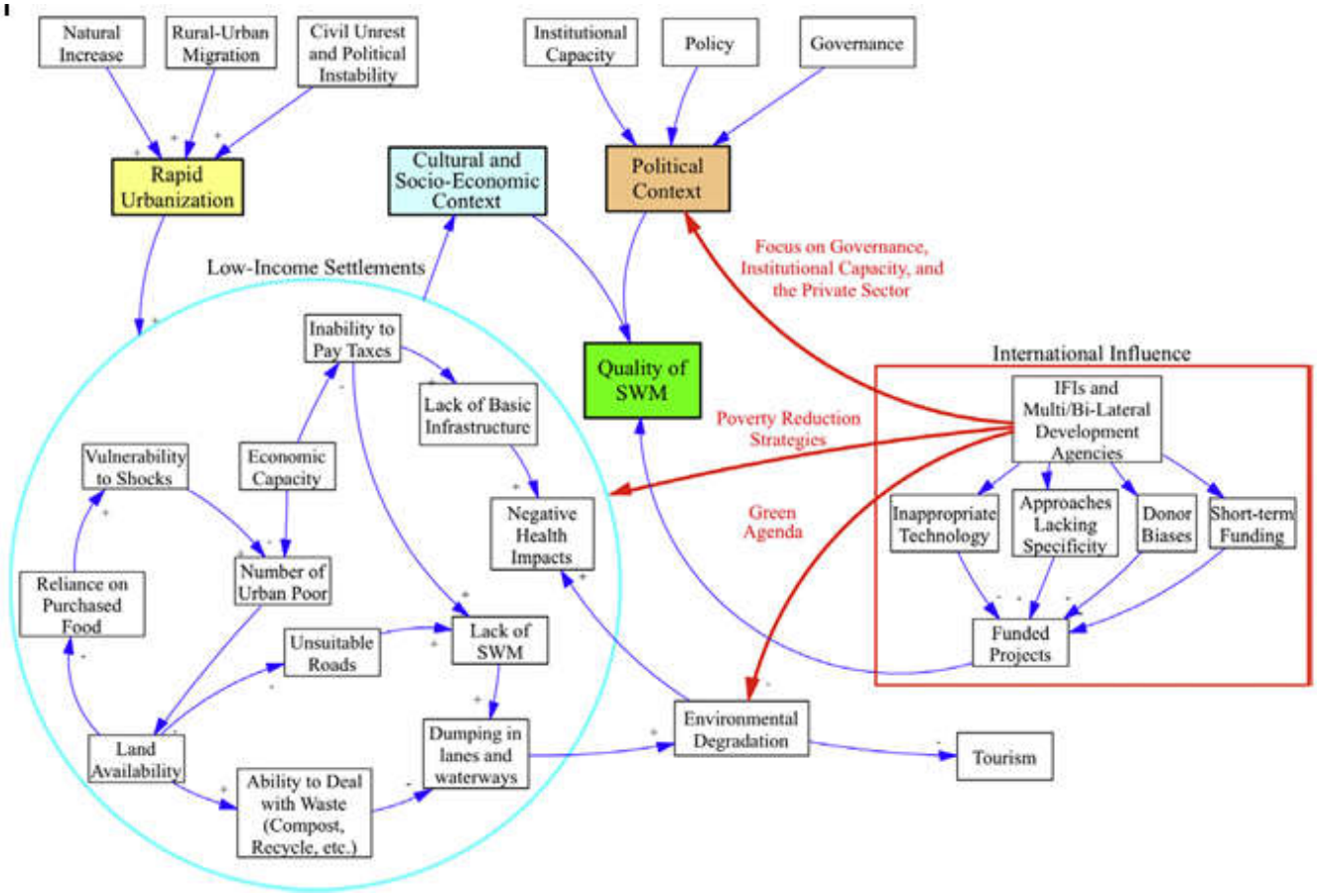

Fig. 1. Solid Waste Management System for developing countries (adapted from: Marshall and Farahbakhsh, 2013)

Integrated Solid Waste Management System (ISWM)

There are a plethora of frameworks that define the variables to be measured in studies involving sustainable waste management systems development. A system for municipal waste management varies between regions and sectors, as there is no one-size-fits all approach to waste management stemming from differences in economic, technical, environmental and social conditions. Although it is difficult to create a unified all inclusive approach, the Integrated Sustainable Waste Management (ISWM) framework can provide an overarching legislation, institutions and a conceptual outline. Integrated Sustainable Waste Management is essentially a waste management system (WMS) that best suits the society, economy and environment in a given location, a city in most cases (Klundert van de, 2000). This framework is considered appropriate for this study because the concept of ISWM according to McDougal *et al*. (2001), combines a wide variety of appropriate and applicable methods, technologies and management approaches in relation to the achievement of specific goals; in the case of this study to reduce the amount of waste sent to landfills through improved reuse, recycle and resource recovery. The preceding section outlines the dimensions of the ISWM, the Socio-engineering and System Thinking concepts and their applicability to waste management in developing countries.

Dimensions of ISWM

The framework originated in the growing awareness and recognition that WMS are not made up of single separate systems but is made up of many systems intertwining (McDougall *et al.,* 2001). Thus, sustainable waste management systems in most cases are not one but many different process. Furthermore, these processes are also related to each other and hence it makes sense to create a WMS that takes on a holistic approach. There is no single definite approach in which to approach ISWM. Each system of WM developed under the framework of ISWM requires its own specialized approach. The concept of ISWM consists of the three pillars of sustainability which must be integrated into any effective waste management system: stakeholders, system elements and aspects. As illustrated by Klundert van de (2000) in Figure 2, sustainability can be looked at from six dimensions, i.e. from technical, environmental, social, economic/ financial, institutional, and political perspective. The time factor was included since sustainable waste management from the ISWM perspective is a long-term strategic approach that involves planning and development issues which needs time. The last section of the ISWM framework as outlined in Figure 2 by Klundert van de (2000) is the strategic aspects of solid waste management. The aspects of solid waste management as explained by Schubeler (1996) are as follows:

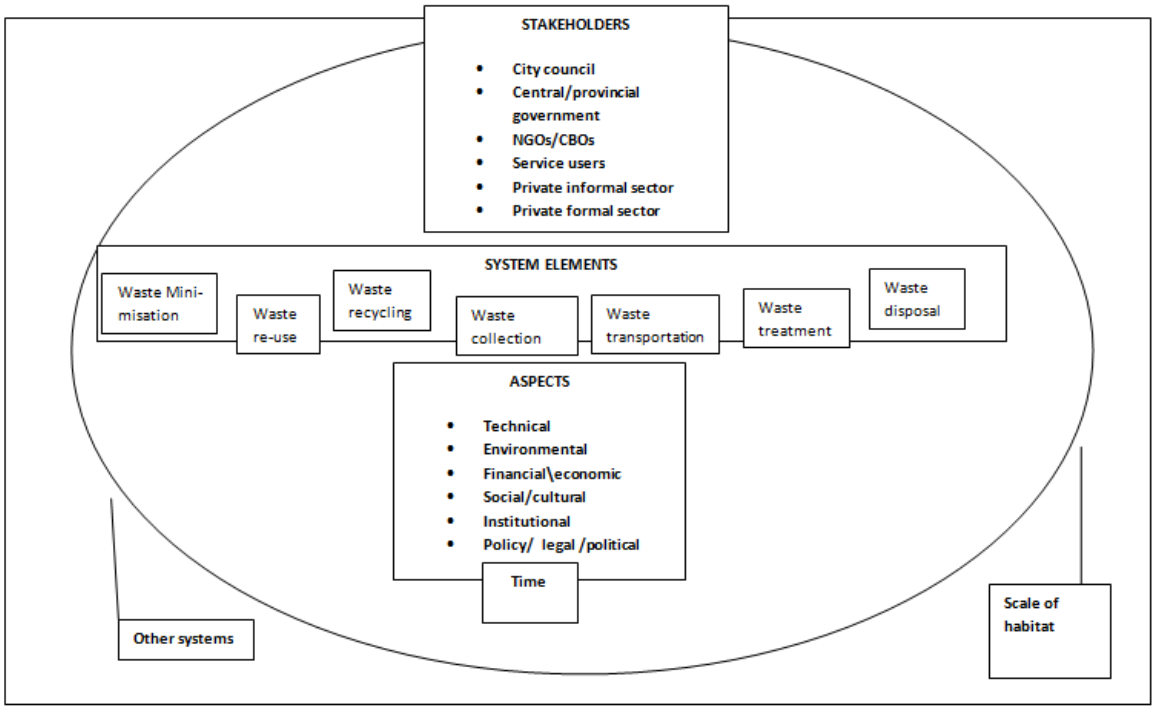

Fig.2. Integrated Solid Waste Management framework (Source: Klundert van de (2000)

- Political aspects is concentrated with the formulation of goals and priorities, determination of roles and jurisdiction, and the legal and regulatory framework,
- Institutional aspects deal with the distribution of functions and responsibilities and correspond to organizational structures, procedures, methods, institutional capacities and private sector partnership,
- Social aspects is concerned with the patterns of waste generation and handling of household and other users, community-based waste management and the social conditions of waste workers. The volumes of waste generated by individuals are reflective of their attitudes as well as their socio-economic characteristics. Attitudes towards waste may be positively influenced by awareness-building campaigns and educational awareness.
- Financial aspects concern budgeting and cost accounting, capital investment, cost recovery and cost reduction.
- Economic aspects focused on the impact of services on economic activities, cost-effectiveness of MSWM systems, macro-economic dimensions of resource use and conservation, and income generation.
- Technical aspects are concerned with the planning and implementation and maintenance of collection and transfer systems, waste recovery, final disposal, and hazardous waste management.

Studies on sustainable waste management approach often entails prioritizing economic aspects and see the environment as an entirely separate entity from humans. In relating to MSWM, it also necessary to introduce a shift in paradigm that technology and society are separate.

Today's increased environmental awareness within society make people wonder where their consumed products comes from and ends after their "end of life". Technological and economic tools and solutions are indeed important, but sustainable developments require inclusion of human actions as part of interconnected web imparting on the world. Therefore, in order to develop a sustainable waste management system as this study aimed to achieve, it will require more than changes in technology but the need to begin recognizing these systems one way or another and how they are connected (i.e. technology and society).

Socio- Engineering

The term "Social Engineering" as documented in literature has been associated with negative behavioral and societal programs such as Cyber Fraud, and the totalitarian social control of the former Soviet Russia, Nazi Germany, and the Maoist China (McMahon, 2001; Thompson and Parson, 2009; Kennedy and Parsons, 2012). Notwithstanding, the negative literature and horrific experiences of those who were subjected to the "black social engineering", this research is focused on the very positive, less intrusive interventions aspects of social engineering that have amounted in the positive societal change at the community level (McMahon, 2001; Thompson and Parson, 2009;Kennedy and Parsons, 2012). The earliest record of the term social engineering was reported by Pound in 1922 in his book titled "The Philosophy of Law". Twenty-five years later, Popper (1945) also reported on the philosophical foundation of social engineering discipline in the "The Open Society and its Enemies". Thereafter, the term prevailed until 1966, when Podgo' recki in a bid to annul the negative perception associated with it

changed the name social engineering to "Sociotechnics" (Podgorecki, 1990; Kennedy and Parsons, 2012).

A plethora of definitions of social engineering exist, and across all these definitions, certain characteristics of the term social engineering are agreed upon. Social Engineering is agreed to be:

- Using practically scientific findings from empirically tested theories especially from the social sciences (Podgorecki, 1990; Alexander and Schimdt, 1996; Turner, 2001), and
- Using these findings to identify methods and create designs for social change in the very long term (Podgorecki, 1990; Alexander and Schimdt, 1996; Duff, 2005; Kennedy and Parsons, 2012; Scott, 1998).

The term social engineering for the purpose of this study has been defined as the application of the knowledge and principles of science and technology in solving the municipal solid waste menace using local data. This two agreed characteristic definition of social engineering fit well into the context of this study. Knowles (2005) also reported that strategies aimed at promoting health, economic and environmental benefits must involve an innovative resource recovery system that considers local needs followed by local productions systems which will employ wastes as inputs rather than as output. Recent years has witnessed researches, practices and expertise centered either on technological and scientific advances that focuses on social change couched in terms of behavior, economic, or governance shifts (Williams, 2010). But these two spheres of action i.e. technical and social are seen to be separate and opposite. The lack of local participation in the initial design of engineering and scientific solutions always pose how their technologies fit well into urban policy and are taken up by end-user.

This calls for the need to interrogate our understanding of technical and social change, and research centered on the "intersections" of social and technical knowledge and practice (Williams, 2010). The understanding of the social context and practices will help develop and advances use of sustainable technologies and how these technologies can shape and inform society (behaviors) in issues like municipal solid waste management. This requires a partnership and coalitions between scientists, social scientists, politicians and the public. This multi-faceted or inter phase conceptualization of the urban waste management menace will help place our activities and programs in attempting to bring urban change in a sustainable manner. Finally, Social engineering, according to Kennedy and Parsons (2012) is also the "*arranging and channeling of environmental and social forces to create a high probability that effective social change will occur"*. This definition best fits well into this context, since the municipal solid waste management issue have shifted from been a technological problem to a social one. This co-ordinated approach to social change takes a systems perspective.

Systems Analysis and Thinking

In the face of rapid urbanization, many municipalities are lacking the fiscal and institutional resources need for the sustenance of urban residents due to the lack of maintenance of obsolete existing infrastructure **(**Silva *et al*., 2012). In many aspects of urban development's and redevelopments requirements i.e. rapid transit in our cities, medical care, education systems, air traffic control, de-pollution of the air and water ways, crime prevention, are all attributable to the rapid changes in society brought on by technological advancements. Municipal waste management has been part of the global environmental protection challenge confronting science and society at large. Modern times have witness the emergence of an approach that is considered as an intellectual discipline for mobilizing science and technology to solve large scale problems in an objective, logical, complete and in a professional manner.

This approach which is the Systems Approach uses *sophiscated techniques in solving problems by assembling and processing the necessary data, comparing alternative approaches as to the relative benefits and short comings, making sensible compromises, producing qualitative analysis and predictions where appropriate, seeking out judgments from experiences of the past and introducing creative innovations where they are indicated (*Ramo and Clair, 1998). This systems approach although existed years back, the broadening of the concept in recent times has raised doubts and controversies about the usefulness of this approach for tackling the bigger problems confronting society today which is more "social" than "technological" in nature. For instance, systems engineers and experts trained in the more unpredictable behavior of man have questioned the suitability of this approach in solving complex social engineering problems of our civilization. But, such views have been considered to limit the scope of ("in the small") applicability of the systems approach (Ramo and Clair, 1998). "In the large" this approach is hailed to be a powerful tool that can demolish any problem either engineering and/or human. Systems approach uses controlling qualitative factors that are not quantifiable for judgment and intuition i.e. it tackles social-engineering problems by seeking through both technological and social solutions with all the intellectual disciplines that can be mustered. It is seen to use experts' knowledge in deciding on the better options to choose in designing our cities, transportation systems, communication networks, educational and medical facilities, waste disposal techniques, crime prevention methods, the use of resources and others (Ramo and Clair, 1998). The concept of System Thinking and Analysis is prevalent in the field of sustainable development, waste management and hence also this research. Defining this approach has being difficult to find in literature but Ramo and Clair, (1998) summarizes the features of system as follows:

- The complexity of environmental problems and thus waste management often requires a systemic approach. A system is made of a number of components(sub-systems) and the connections between these components,
- The components complement each other and together function as a complete system'
- It should be possible to tell components apart from the whole, however, the system must be seen as completely closed.

Municipal waste management consists of different components and the connections between them and thus could be considered as a system. In order to be able to examine the municipal waste management menace to optimize change or adapt it for the better, the field of study that harness the knowledge of the people and the workings of social systems in addition to technology is useful is the System Analysis. System Analysis approach does not disregard the human elements ("technology- pure") in solving complex social-engineering problem. But rather uses a unifying integrating mechanism (social science and technology) to tackle social problems *(*Ramo and Clair, 1998) such as the waste management problems in our urban centers which are more of a social problem than technology. The cities are adaptive socio-technical systems made up of intertwined sub-elements having unique combined qualities than the individual elements. Due to the cities' systemic nature, changes in one element induce changes in another element. Considering the social behavioral function at play in our municipal waste management system, the systemic behavior can be effectively analyzed by looking at the entire waste management system and not its elements in isolation- hence the Social Engineering Technology Systems Analysis perspective to take into account enabling conditions, precipitating circumstances, societal behavior and specific actions for social change in our municipal waste handling processes. According to Duhame *et al.,* (1985) the aspects of the enabling conditions in society that are relatively inflexible are the political, economic, technological, social and cultural. They indicated that behavioral changes are often possible and compatible with society. In order to design interventions strategies to maintain or change a particular behavior towards solid waste in our society, a useful theory to serve as a guide is the Theory of Reasoned Action.

Theory of Reasoned action (TRA)

Management of Municipal solid waste has present environmental, social, and economic problems. Despite the highly developed infrastructure and economy in the developed world, studies into waste behaviors and attitudes have indicated similarities between the industrialized and the developing nations (O'Connell, 2011). Although, waste diversion practice like recycling is well-known, other waste minimization behavior remain unknown and unpracticed by many; voluntarily practiced in certain homes in developed nations. In order to reduce the amount of waste sent to landfills. There is the need to analyze public opinion in order to establish the facts that encourage people to participate in and maintain pro-environmental behaviors (Schultz *et al*., 1995; Barr, 2003). Furthermore, waste and recycling has been one of the area's most programs to advance sustainability in waste management is seeking improvements. In achieving these improvements, important factors needed to be considered are human characteristics, behavior and performance and human interactions with technology (Haslam and Waterson, 2013). Tudor *et al*. (2011) also stated that in achieving sustainability in human consumption and waste management, three challenges that need to be addressed are the development of policies to encourage sustainability, effecting behavioral change and the promotion of localism.

Public education for people to understand the connection between their behavior and environmental harm and to engage in pro-environmental behaviors (Babcock, 2009) has proven to be a difficult task in many cultures and economies (O'Connell, 2011). A spectrum of reasons is assigned to the individual choice to engage in waste reduction through recycling, composting, diversions, reuse and responsible consumption (Kennedy *et al*., 2009). Recent research works indicate the education, income, and age levels are the shared differing characteristics of the individual that helps to explain what prevents and motivate waste minimization and diversion behaviors (De Feo and De Gisi, 2010). The bulk of waste behavioral research has concentrated on recycling neglecting and marginalizing waste minimization strategies such as reuse, reduced consumption and manufacture 'take-back programs' which have less environmental impact than recycling (O'Connell, 2011).

The Theory of Reason Action will provide the overarching framework for improving social characteristics, behavior and performance and interaction with technology. The theory is based on the assumption that individual behavioral intentions are directly associated with their attitudes. An individual's intention to perform or not to perform an immediate action, according to the theory, is contingent on two determinants; 1) attitude towards the behavior, and 2) the subjective norms (Fishbein and Ajzen, 1975). These two determinants act independently to shape an individuals' behavioral intention. Personal factors are the basis for the attitudinal component, while normative determinant is based on perceived social pressures. They argue that both the attitudinal and normative factors are influenced by beliefs associated with the behavior in question. Thus individuals' beliefs constitute the fundamental determinants of his/her behavioral intentions (Fishbein and Ajzen, 1975; Addo-Yobo *et al*., 2006).

Algebraically the TRA model can be expressed as:

$B\ \ BI = (A)wi+(Sn)w_2;\ A\ \alpha\ \sum biei;$ and $Sn\ \alpha\ \sum Nb_iMc_i$ *……(Eqn.1)*

where B = the behavior in question
BI = behavioral intention
A = attitude towards the behaviour
Sn = subjective norm relating to the behaviour
wr, w2, = empirical weights indicating the relative importance of A and Sn
Nbi= the jth normative belief
Mc_i = the jth motivation to comply
b, = the ith behavioral belief
e, = the ith outcome evaluation
n,m = the number of behavioral beliefs and referent groups, respectively.

It can be seen from above equation that changes in the strength of beliefs will influence the change in behavior. In order to bring about changes in societal behavior in solid waste minimization practices, which participation decisions are voluntary and under individual control there is the need to first establish these components, how they contribute towards behavior and quantify their level of influence (Addo-Yobo *et al*., 2006). The theory of reasoned action has been used to investigate relationship between attitudes and households recycling and composting, and practical social or institutional constraints that prevents people from participating in pro-environmental actions. Previous studies of attitude and behavior towards both waste and environmental in general in the social context have been done using international environmental attitude and behaviors. For effective implementation of waste management systems there is the need to consider issues of public acceptance, changing value systems, public participation in planning and implementation as well as consumer behavior. However, a waste management system modeled around the local values and attitudes in the developing world is yet to be developed.

Conclusion

Municipal waste management consists of different components and the connections between them and thus could be considered as a system. In order to be able to examine the municipal waste management menace to optimize change or adapt it for the better, the field of study that harness the knowledge of the people and the workings of social systems in addition to technology is the Socio-Engineering System Thinking and Analysis. It is an approach that will tackle all aspects of the integrated waste management system in tandem for a locally developed low cost, effective technologies and practices in the developing world.

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