A Future Prospect for Domestic Waste Management in Qatar

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Abstract—Sustainable Waste Management is one of the major challenges that face developing nations, with the mandate to balance between their economic & social development while keeping environmental performance. Qatar, for example, is generating a total of 28,000 tons per day of solid waste, of which only 3% is recycled. 4% is incinerated while the remaining is disposed into landfills. One of the targets of Qatar National Development Strategy, NDS is to raise the recycle share to 38% of solid waste, reducing landfill to 53% and converting waste to energy. Hence, this paper presents a potential view for managing and optimizing domestic waste management that is about 25% of the total generated waste in the country from system prospective. Hence, a detailed methodology for Socio-Technological System, STS, development and operation was presented. The STS is a robust modular system that dynamically changes in response to social activities and deals with the problem from micro and macro details levels. In the proposed STS development methodology, several controllable parameters need to be considered, such as future construction plans, population development, waste collection method possibilities, generation and recycling business development, strategies for materials use and reuse and so on. Moreover, the STS modularity to deal with the emerging technologies of converting waste to final products as significant fragments was taken care of to be able to adapt new technologies introduced in the future.

Keywords—Qatar, Socio-Technological Systems, Strategies, Waste Management

I. INTRODUCTION

Waste Management is one of the biggest challenges that nations need to deal with in a sustainable manner. The challenge becomes greater for developing nations as there should be a balance between economic & social development and environmental performance. Therefore, it is vital to optimize domestic waste management processes and improve their enactments. In Qatar as well as other Gulf Cooperation Council (GCC) member states the sustainable waste management is one of the hot areas addressed by some governments [1]. Nonetheless, the availability of large areas of deserts makes landfilling the most economic option to treat waste and keeps the other management programs infeasible [2]. This may explain the lack in research work related to waste management in the GCC area, both in technology and control sides. Table 1 shows a summary of the research works published in international journals carried out in the GCC states related to waste management. As seen in Table 1, the research done so far has concentrated on individual processes within the waste management system. None of those regional researches has tackled the issue of waste management from system and decision making view point.

<table>
<thead>
<tr>
<th>Research Topic</th>
<th>Country</th>
<th>Reference</th>
<th>Year</th>
</tr>
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<tbody>
<tr>
<td>Bio-products</td>
<td>Qatar, UAE</td>
<td>[3, 4]</td>
<td>2010</td>
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<tr>
<td>Collection and transportation cost</td>
<td>Kuwait</td>
<td>[7]</td>
<td>2004</td>
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<tr>
<td>Waste-to-energy</td>
<td>Saudi Arabia, UAE</td>
<td>[8, 4, 9]</td>
<td>2013</td>
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Internationally, the waste management research area is very active. However, most of the literatures published in the area are dealing with one face of the problem either it be economic, environmental or technological [13]. Very few studies have tackled the problem of waste management from its entirety to overcome such social and technological burdens. For example, a recent two studies on socio-technical analysis of biogas production and transitions towards sustainability were carried out [14, 15]. The studies took the system analysis part of the system development by identifying the characteristics that can improve biogas production in a local area. They didn’t consider providing models or tools to support policy makers to respond to technological and social changes. A more sophisticated system called general Bioenergy Decision System (gBEDS) for bioenergy production planning and implementation was presented by

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Ayoub et al [13]. The gBEDS relied on a robust information base that includes basic and detailed decision information, such as geographical information database, the waste materials’ database, the logistics database and the conversion database and was applied to a Japanese case. In section two, the current state of managing wastes in Qatar is presented. Section three shows or prospects on dealing with waste management issue via Socio-Technological systems development. The system development methodology is presented in Section four followed by conclusions and future challenges in Section five.

II. CURRENT STATE OF WASTE MANAGEMENT IN QATAR

Qatar is generating a total of 28,000 Tons per day of solid waste, of which only 3% is recycled, 4% is incinerated while the remaining is disposed into landfills. The current recycling portion of household waste and commercial waste are 3% and 1% respectively. The construction & demolition waste generated is about 20,000 tons of which a portion of 4% is recycled. The total domestic waste generated in 2032, excluding the C&D waste, is expected to be about 19,000 tons/day with an annual growth of 4.2% [16]. This comes as a result of the unsustainable growth of the GDP and population of Qatar since year 2000. This trend of increase is expected to continue growing rapidly towards 2022. This extremely upsurge in population number and economic development increases the impact on Qatar’s environment that requires plans and policies to address new and emerging national development priorities. One of the targets of the National Development Strategy, NDS, to be achieved by 2016, is to establish a solid waste management plan that strongly emphasizes recycling. The plan aims at raising the recycle share from 8% to 38% of solid waste, reducing landfill to 53% and converting waste to energy. Another target is to contain domestic waste generation at 1.6 kilograms per capita per day [17]. Raising awareness of Qatar’s population, on the importance of reducing waste and increasing recycling to the environment sustainable and preserve high quality of life, is another recommendation [17]. In other words, it is a plan to reduce waste, enforce more recycling and encourage more efficient use. The first step taken by Qatar government, to achieve such targets, is the establishment of the Domestic Solid Waste Management Centre (DSWMC) to deal with wastes in a sustainable manner (separation, recycle, bio-energy products). The total cost of the DSWMC is 3.9 Billion QQR for design, construction, and operation for 20 years [18]. The DSWMC has 6 main components for incoming waste management, waste to energy, anaerobic digestion & composting plant, energy recovery, engineered solid waste landfill and incinerated bottom ash treatment, and plant facilities. The center is served by five waste transfer stations distributed around the state with a total projected capacity of 4450 tons per day [18]. The current daily capacity of the DSWMC (1557 ton) is less than the domestic waste generated (2500) and the recycled portion is about 1.3% of the total [17]. The Qatar Development Bank has estimated the revenue potential for all solid waste value chains to be about 2.42 BQR. The household waste is accounted for 982 MQR and C&D recycling for 378 MQR based on pricing benchmarks in best in class [16] that shows the high potential of waste management as an emerging market. To meet these challenges a comprehensive environmental management system that aligns the national growth, social changes with environmental limitations to sustain the country’s development is required.

III. FUTURE PROSPECTS

There are many forms of potential approaches can be followed to deal with domestic waste such as reducing the amount of waste production through consumption reduction, waste separation from source in addition to waste processing. However, the effect of these methods will remain limited until they are integrated in a complete waste management system. We believe that a robust modular Socio-Technological system, STS, that is altering gradually in response to social activities of people is an ideal solution for this problem as it deals with the problem from micro and macro details levels. For example, when planning for domestic waste management, STS planners have to consider future construction plans, population development, how to collect the wastes (separated or mixed), how many companies are in generation and recycling business, what is the reuse strategy for all types of materials, where are they reused at home or abroad, what kinds of reduction methods, what is the response of the society to system change, and so on. In addition, the planners also consider what kinds of product specifications have to be controlled by the recycle companies. On the other hand, technologies of converting waste to final products continue progressing and as a result several parts of the STS should be modular enough to adapt new technologies introduced in the future. What we mean by the Socio-technological System is explained in details in the next subsection.

A. What is Socio-technological System

Socio-technological systems in the context of this work are the systems that comprise technological, human and managerial mechanisms [21] that interact together and lead to desired or unwanted impacts. The domestic waste management system is a typical socio-technological system that have technological mechanisms (treatment technologies), social (households), and managerial (local laws and regulations). These contrivances need to be harnessed into one robust and sustainable Socio-Technological Systems. Yet, Socio-Technological Systems development is problematic in nature due to its complex and multi-faceted interactions [19]. That results in several environmental, economic, social, and regulatory effects on waste management practices, which complicate local policy analysis as well as global sustainable development [20].
of Geographical Information System in Qatar. These waste collection points are further clustered to find the feasible locations of possible waste treatment facilities that need to be established within the waste management system in a specific area depending on production and processing capacities. Once treatment facilities locations are identified, the total costs of management scenarios are evaluated. The scenarios, identified based on social acceptance, should include; the number of collection days, type of waste collection (separation at source or in the central treatment facilities), costs, and technologies used in waste treatment. The evaluation criteria for the scenarios can also include the environmental impacts of applying a specific scenario.

IV. THE STS DEVELOPMENT METHODOLOGY

To achieve the desired outputs from the STS it should be designed to include several modules to support decision making such as simulation module with graph interface and genetic algorithms (GAs) model for optimal decisions. It also included a location allocation module built on data mining methods to calculate the location of storage and conversion plants. The proposed STS architecture is as Fig. 2. The environmental performance is considered in the STS via calculating CO2 emissions over the predefined material supply chains. The STS should consider a multi-input and multi-output waste treatment system. Hence, a superclass model for domestic waste need to be built to relate waste resources to their products, available processes, and possible future processes of utilization, then the optimization models are used to find the optimal treatment option from the viewpoint of cost and environment. The system presented by Ayoub et al, can be extended to Qatar waste management case while taking into account the clear difference in social, economic and technological aspects of the waste management system between Qatar and Japan.

Fig. 2 Socio-technological system architecture

The methodology of the socio-technological waste management system development presented here has three key phases. These research phases are explained in the following subsections.

Phase 1: Data collection about the current waste management situation in a representative area to identify its controllable factors, weak points and possible improvement.
Review the related literature about the possible systems that can be applied. The current waste management system and its practices should be outlined. Hence, the AS-Is model to project the current should be built in this phase. The following steps have to be carried out to complete this phase:

- Identifying the waste collection method in the target area (controllable factor).
- Defining the different contents of the domestic waste produced by the citizens in the area under study and their potential quantities (controllable factor).
- Pinpointing the current waste treatment methods.
- Finding the current waste management regulations (controllable factor).
- Identifying the current waste collection method in the target area.
- Future residential houses construction plans and population development in the area understudy.
- Reviewing related work in the international literature as well as market development.
- Identifying the waste collection methods possibilities in the country.
- Revising the national business development prospective and plans for materials use and reuse
- Build the As-Is Model for the current waste management system in the target area.

**Phase 2:** The main task here is analyzing the collected data and building the To Be Models for the future household waste management systems. Hence, more representative and suitable systems is identified through applying the following steps:

- Explain the current system’s strengths and weakness based on evaluation criteria (Economic, Environmental, social etc.)
- Build questionnaires and use them in data collection.
- Analyze the questionnaires to identify the social aspects of the current and future systems (Satisfaction, willingness to follow new rules, suggestions, etc.)
- Build the To-Be Model for potential system(s) and explain its merits and possible demerits.
- Plan the possible application scenarios and the number of required collection, separation, and treatment (recycling, biological processing, etc.) facilities.

**Phase 3:** This is the final part of the system design cycle (data collection, data analysis, system proposal and system application). Fig. 3 shows a schematic representation of the optimization techniques carried out in this research work and applied as follows:

- The addresses data points are associated to the quantities of waste produced in the four zones produced.
- The selected clustering method is applied to identify the locations of the collection and separation units if an intermediate processing is suggested in the As-Is Model. If this is not the case the spatial data is clustered to the predefined number of treatment facilities. The clustering methods used in this research optimize the location based on distances between current location of the waste and the cluster center.
- Using the resulted locations, proposed management scenarios, processing technologies, the economic and environmental performance of the waste management system is optimized.
- The optimal locations, costs and emissions are mapped and visualized using zones map on the Geographical Information System software.

![Fig. 3 The optimization Modules in the proposed system](image)

**V. CONCLUSIONS**

Sustainable domestic waste management encompasses complicated and multidimensional interaction among large number of technological choices, economic mechanisms, and control frameworks. To deal with this issue in Qatar, the current state of waste management and future prospects for the country is presented in this paper. A small portion of the generated waste is recycled or incinerated. The annual growth rate of domestic waste generation is growing in an unsustainable manner in the last 15 years an expected to continue in the same trend towards 2022. A robust modular Socio-Technological System is presented. An analysis of intrinsic relations between waste management schemes as well as with social and technological dimension is made to clarify the uncertain relations and, hence, deal with them. The GIS is used to relate the waste quantities data to their generation location and building a location allocation model using the Qatari addressing system using data mining methods to calculate the location of storage and conversion plants. In addition, STS includes several modules support decision making such as simulation module with graph interface and genetic algorithms (GAs) model for optimal decisions. The environmental performance is considered in the STS via calculating CO2 emissions over the predefined material supply chains. The STS development also contains building a multi-input and multi-output superclass model for domestic waste treatment processes. The model relate waste resources to their products, available processes, and possible future processes of utilization, then the optimization models are used to find the optimal treatment option from the...
viewpoint of cost and environment. This shows the significance of the proposed research that, we think, will set the ground for future advancement in management of all waste types.

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REFERENCES


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