The zero-waste design for the municipal solid waste management in Baghdad city

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Abstract. Zero-waste is ideological for facing waste difficulties in our community. The purpose is to start developing and performed in different areas including waste management and treatment, mining, construction, and city development. The zero-waste idea has been welcomed by policymakers because it animates sustainable production and consumption, best recycling, and resource improvement. Experts in waste management systems, however, understand and implement it in different ways. The present study aims to imagine a zero-waste strategy within Baghdad city based on the available data and published in the literature to get an optimum resource recovery from generated waste, by assuming a recycling factory working at a capacity of 7500 tons/day, in three basic units (composting unit 5000 ton/day, composting unit 1500, ton/day, and inert materials unit 1000 ton/day), theses expected capacities of each unit built on Baghdad municipality percentages of each type of waste (57% organic materials, 23% energy sources materials, and 20% for inert materials such as construction waste). From the findings can be concluded that Baghdad city can reach the desired goal (zero-waste) by recycling its waste and implementing a comprehensive management system that includes education, sustainable production, and consumption. Very few investigations have been observed in the fields of zero-waste design, this study shows that the field of zero-waste knowledge is various, and a zero-waste concept is continually growing through different strategies, plans, procedures, and policies. The judgments of this study propose that zero-waste programs are applied in many countries without any holistic zero-waste strategy. The study indicates that countries might be ready to reach zero-waste purposes of explaining general zero-waste plans and by uniting and promoting zero-waste actions (in cities and manufacturers).

1. Introduction

The Baghdad city witnessed rapid growth in economic and social fields [1], accompanied by an increase in land use and large urbanization and construction of informal areas at the expense of the green lands estimated at 255 areas [2], that has caused great pressure on the city's infrastructure, like transport sector, plants of sewage treatment, safe drinking water and the service of collection and waste management [3]. Baghdad is the administrative and economic capital of Iraq and the larger cities with a population of more than 8 million inhabit an area not exceeding 1000 km2 [4]. Daily about 6000-10000 tons of waste generated in Baghdad city at a rate reach to 1.3 kg/capita/day [5], actually this percentage can be increased due to the higher rate income of the Iraqi family and the lack of public environmental awareness [6-8]. The inclusive municipal solid waste management system consists of several steps, beginning from waste generation, collection, transporting, separation, treatment, or disposing of [9]. Waste generation is expressed in terms of kilogram/capita/day, so it is easy to calculate the total generated waste by calculating the per capita generation rate multiplied by the total population [10]. Unfortunately, there is no real treatment of municipal solid waste [11], the disposal of these huge quantities of waste is summarized by collection from residential neighborhoods and then transported to irregular landfills without any type of treatment like recycle, reuse, recover or separated ingredients that can be recycled such as paper, wood, glass, plastic and other materials that can be recycled and used as a natural resource, this behavior led to the accumulation of large quantities of solid waste in the environment, causing real problems because of unscientific disposal of MSW led to adverse effects on
all components of the environment and human health. Many countries have developed a strategy (Zero-waste) aimed to fully recycle solid waste according to the effective rules for solid waste management, this concept may be supplied a real solution for solid waste management and the challenges may be faced by the implementing authorities, Cole assumes in his study that zero waste can be reached when controlling the production of household waste and that preventing the generation of waste is better than recycling it, increasing education and behavior change programs for householders [12]. The study was carried out by Romano et al. 2019 in Tuscany, Italy, the first municipality in Europe that assumed a zero-waste policy in 2007, the findings show that municipal waste generation is higher when urban waste services are run by privately-owned firms, also when the taxable revenue of people per capita is lower [13, 14]. In New York City, which is one of the leading cities in accessing zero waste through the activation of the reuse strategy, and achieves an annual reduction of 45X106 kg of greenhouse gas emissions [15], Zotos et al, 2009, found that cooperation between local authorities and municipal service providers refer an acceptable and effective solution in waste management while the decentralization of waste management problems to local authorities without a parallel real budgetary and capacity support, thus following in local activity remaining disoriented and separated from national aims, therefore producing notable planning and implementation problems and obstructions against pressing issues at hand as well as the loss of available funds [16]. The progress to “zero waste” and circular economics has recently increased tracion as a choice to the dominant “take-make-waste” model of production and as a viable approach to discussing climate change, but that firms’ efforts presently are inadequate to sustain such a transformation; because there are no efficient sustainability indicators to estimate improvement, identify opportunities, so most of these measure products versus the impacts of source reduction, reuse, and remanufacturing [17]. So this study will explain the reality of solid waste in Baghdad city and how to reach zero garbage by studying the process of waste management and life cycle assessment of MSW and propose a plan to reach the desired goal [18-20].

2. Experimental Work

2.1. Description of Study area
The current study carried out within Baghdad city, that located in the center of Iraq country with coordinates (33.312805, 44.361488), Tigris River divided the city into two sites, west side (Al-Karkh) and east side (Al-Rusafa), about 131district separated in both sides of Baghdad each one subdivided into more neighbourhoods Table (1) shows the Baghdad districts with population and waste generation.

2.2. Methodology
Several steps have been adopted to draw a realistic picture of the problem of municipal solid waste management in Baghdad city summarized by.

1. Collect the required data and information from the Baghdad municipality on the volume of waste and a daily generated, Population size, Number of municipalities, Type of services provided, Volume of the daily output of municipal waste and Waste components.
2. Investigation of the current status of municipal solid waste management in Baghdad.
3. Drawing out the future features of integrated solid waste management according to available data, to reach the desired goal (zero-waste), by proposing a hypothetical recycling plant that converts all generated waste into usable products, such as hummus, energy materials, and inert materials that are included in construction and road paving operations.
4. Introducing the concept of zero waste and the possibilities of applying it to a city like Baghdad. Zero waste is the designing and managing of products and methods to regularly avoid and reduce the waste of materials and to preserve and recover all resources.
3. Results and Discussions

3.1. Current status of MSWM

Solid waste is collected manually by municipal workers from regions twice daily, morning and evening, then, the collected waste is put into waste compactor. After that, all waste transported to a temporary storage site called transformation stations, then waste is transferred to illegal waste dumping sites that are located in Al- Nahrwan region and Abu- Graib region. After that, the transformed waste separated as layers and covered with multi-layers of dust with will press to reduce the volume of the waste and reduce the impacts of scavengers looking for potentially profitable waste components, sort the waste Figure 1. In the fact these methods are insufficient to prevent the environmental effects of these huge amounts of waste, naturally, these dumping sides will be source for many health and environmental problems, Table 1 shows Baghdad districts with their area and population density as well as, waste generation rate according to Baghdad municipality 2017.

![Figure 1: Current status of municipal solid waste management (Baghdad municipality 2017)](image)

**Table 1: Waste Generation Rate Calculation for Baghdad (Baghdad municipality 2017)**

| District               | Population \(10^3\) | Area (Km2) | No. of Neighborhoods | Waste Generation Rate (Kg/Capita/Day) | Total Waste Generation (Ton/Day) |
|------------------------|----------------------|------------|----------------------|---------------------------------------|----------------------------------|
| Al-Rusafa              |                      |            |                      |                                       |                                  |
| Rusafa (Center)        | 455                  | 24         | 46                   | 1.1                                   | 500.5                            |
| Sadar                  | 1277                 | 54         | 62                   | 0.6                                   | 766.2                            |
| Shaab                  | 450                  | 98         | 33                   | 0.6                                   | 270                              |
| Ghader                 | 633                  | 45         | 41                   | 0.7                                   | 325                              |
| Baghdad Al-Jadida      | 765                  | 66         | 42                   | 0.7                                   | 535.5                            |
| Karada                 | 650                  | 68         | 45                   | 0.8                                   | 520                              |
| Adhamiyah              | 480                  | 27         | 28                   | 0.8                                   | 384                              |
| Al-Karkh               |                      |            |                      |                                       |                                  |
| Al-Karkh (Center)      | 560                  | 24         | 33                   | 0.9                                   | 504                              |
| Kadhimiyah             | 850                  | 56         | 24                   | 0.7                                   | 595                              |
| Shuala                 | 760                  | 89         | 40                   | ...                                   | 532                              |
| Mansour                | 435                  | 126        | 58                   | 1.2                                   | 510                              |
| Rasheed                | 350                  | 130        | 53                   | 0.8                                   | 400                              |
| Doura                  | 380                  | 78         | 31                   | 0.8                                   | 260                              |
| Total                  | 8245                 | 885        | 536                  |                                       | 5565                             |
3.2. Proposed of the zero municipal waste city
Zero-waste is an aim that is economical, ethical, and efficient and visionary, to know people in altering their lifestyles and practices for sustainable natural cycles, and disposed materials are designed to become resources for others to use [21-24]. The zero-waste city can’t be achieved by simply changing waste management practices [25]; these changes mean designing and managing products and processes to avoid any eliminate of toxic materials and conserve and recover all resources without burning them [26]. In the case of Bagdad city, the zero-waste goal is difficult, but not impossible, many cities around the world have set zero-waste goals, like New York, Buenos Aires, Paris, Milan, London, Singapore and Tokyo, most of them have more population density and less budget of Baghdad, in addition to more generation rate of the waste. The implementation plans differ from one city to others but have the same goal is to stop the transformation of natural resources into garbage. In the present study, we proposed a virtual factory that can be converted all receiving waste into other shapes of resources that can be reused in many fields such as agriculture, transporting, energy generation and construction, this proposed factory was designed depending on the information of solid waste that generated from Baghdad city and composition of these waste of compostable materials and energy generation materials as well as inert materials as it provided from Baghdad municipality, from Table (2) can be observed that maximum fraction wet organic material is (57 %) and contains about (23 %) of plastic, metals, textile, rugs, woods, and rubber, these materials can be transformed to energy within the second units of the proposed factory. The remaining waste contains inert materials like brick, sands, silt, stones, and gravel, which are used as building components. Table (3) and Figure (3) explain the main units of this factory and the job of each one with the maximum designed capacity. The virtual factory contains four main units, the first one called (pre-separation unit) dealt with raw wet waste, which passes through trammel screen, the waste less than 10cm goes to composting pad, these type of waste have a high N/C ratio so, it is very good for the compostable unit from the chemical analysis of waste samples it was found that pH value was 7.82, while organic matter percent reached to 51.13% with C/N ratio 35.57and the values of the heavy metals were Pb 81.4mg/Kg, Cd 0.26 mg/Kg, Cu 225.6mg/Kg, Cr 61mg/Kg, Zn 234mg/Kg, and Ni 13.26mg/Kg these values are expected to decrease by half or disappear in biological treatment because it will be consumed by bacteria and fungi to produce biomass (Table 4, Figure 5 and 6). On the other hand, waste with length, more than 1 cm goes to the third unit called combusting unit (Figure7), and the other inert materials like stones, bricks, gravels, and sands traveled to the fourth unit inert plant to convert to construction material or use in landfilling (Figure8). Waste is the indicator of the
inadequacy of society and a symbol of misallocated resources. An important development has been obtained in demoting waste but it differs from city to city.

**Table 2**: Raw Municipal Solid Waste Components (Baghdad municipality 2017)

| Compositions                        | *Percentage (%) | Standard Percentage (%) |
|-------------------------------------|-----------------|-------------------------|
| Organic matter (Compostable Material) | 57.0            | 55-65                   |
| Energy generated Material (textile, Plastic types, rags, rubber, wood, paper) | 23.0            | 25-35                   |
| Inert matter (construction waste, glass, stones) | 20.0            | 15-20                   |

* Values are on wet weight basis

**Table 3**: Units of the proposed solid waste factory within Baghdad city

| Pre-separation unit | Amount TPD | Composting plant | Amount TPD | Combustible Plant | Amount TPD | Inert Plant | Amount TPD |
|---------------------|------------|------------------|------------|-------------------|------------|-------------|------------|
| No. of units        | 3          | No. of units     | 3          | No. of units      | 3          | No. of units | 2          |
| Unit Capacity       | 2500       | Unit Capacity    | 1500       | Unit Capacity     | 500        | Unit Capacity | 500        |
| Total Capacity      | 7500       | Total capacity   | 4500       | Total capacity    | 1500       | Total Capacity | 1000       |
| Compostable material| 5000       | Total (compostable material) | 5400 | Total input material (Combustible material) | 1500 | Stones, sands and Bricks | 300-500 |
| Combustible Material| 1500       | Quantity of rejects | 500 | Total output material (expected) | 1000 | Reject Material | 200-300 |
| Inert               | 1000       | Recyclables      | 3000       | Quantity of Rejects (brick and stone) | 500 | Lifespan of landfill (Years) | 20-25 |

*TPD mean ton per day

**Figure 3**: A virtual factory of solid waste treatment units, Baghdad

**Figure 4**: Receiving and Preparation of waste (7500 TPD)
### Table 4: Chemical analysis of the waste and expected compost

| Parameters              | Waste Values | Compost Expected Values | Standard |
|-------------------------|--------------|--------------------------|----------|
| pH                      | 7.82         | 7.25                     | 5.5-8.5  |
| Organic Matter (%)      | 51.13        | 25.65                    |          |
| C (%)                   | 31.66        | 15.3                     |          |
| N (%)                   | 0.89         | 0.93                     |          |
| C/N ratio               | 35.57        | 16.45                    |          |
| Moisture (%)            | 47.55        | 21.65                    |          |
| Lead (Pb) mg/kg         | 81.4         | 20.35                    | 100.0    |
| Cadmium (Cd) mg/kg      | 0.26         | ND                       | 5.0      |
| Copper (Cu) mg/kg       | 225.6        | 56.4                     | 300.0    |
| Chromium (Cr) mg/kg     | 61.0         | 15.25                    | 50.0     |
| Zinc (Zn) mg/kg         | 234          | 29.25                    | 1000.0   |
| Nickel (Ni) mg/kg       | 13.26        | ND                       | 50.0     |

**Figure 5:** Processing of Compostable Material

**Figure 6:** Diagram of large scale compost processing

**Figure 7:** Energy generation processing

**Figure 8:** Inert Material Processing
3.3. Benefits of zero-waste strategy

3.3.1. Environmental and climate change. The environmental risks of waste on ecosystems and human health are not hidden from anyone, as many studies suggested that landfills are an important source of the very toxic carcinogen, dioxins, especially within air distribution and the result of landfill fires [27]. A variety of epidemiological investigations observed elevated incidences of cancer, birth defects, and low birth weights in families living near landfills. As well as the landfill's an important source of methane, one of the greenhouse gases, that provides 20% of global warming. In the EU, as a whole, was 32% of the methane produced from the process of degradation of organic waste in landfills carries with it the local dangers of contamination and explosion in addition to its contribution to climate change. The countries with limited areas like Japan, Iraq, Singapore opening new landfills is difficult because it is a major source of pollution. In their case, the problem has not been with organic waste but with materials that give off toxic emissions when burnt like dioxins and furans. Very zero waste strategy will contribute to reducing the emissions of carbon dioxide and methane from landfills and nitrogen oxides from the incineration of solid waste, by the recycling and reuse of secondary materials and wasted products without depending on new raw materials, this process will be saving of 0.8 metric tonnes of carbon equivalent for each tonne of waste. The recycling and reuse of 80% of the Iraq municipal waste would lead to a profit of 15 million metric tonnes of carbon equivalent, that have an identical impact to taking 5 million cars off the service [28].

3.3.2. Economic. Waste management can be an important source for the community economy. From marketing the used commodities, recycling organic materials into compost. The economy of Baghdad city can grow in the participation of the waste sector, although, the waste management in Baghdad has not become an economic resource for many people to look at [29]. Many items of waste yet have selling value. The deal with the used things can achieve great substitution livelihood. From our question to a sample of people about their desire to own second-hand goods within Baghdad city, results show that 55.6% of households little possess used goods, 34% of households never possess used things, 6.2% of households usually collect used things and the rest often get used things. This survey reveals that the habit of getting “waste” to achieve financial profits is still very limited and not fixed on the same flow. Scavengers in Baghdad city are still conventional in conducting their job, working individually, there are no responsible parties to run their business to achieve consistent amounts of used things. So far, the scavengers in Baghdad still get no guidance from the appropriate companies. The most common kind of waste is plastic, and its price depends on the global market and the value of crude oil. To defeat price changes is to improve the value of goods by treating the them before their resold. There are already contractors in Baghdad who can sell plastics or cut plastic into higher-value plastic ore [30].

4. Conclusions
We are aware the virtual factory step of recycling is insufficient, community pre-awareness and reconsidering production and consumption patterns are the backbones to achieve the desired goal. Baghdad city could be converted into a zero-waste by short and long-term implementation policies. Awareness, learning, behavior modification and systems considering are long-term policies, while legislation, innovative industrial design, besides 100% recycling are the short-term policies to perform in a city. Through the study, it can be concluded that recycling factories are an essential step towards sustainable cities that impose on the consumer a modern concept that waste is a resource of economic value that cannot be wasted and lenient in dealing with it, and that the application of screening and recycling plants will reduce the negative impacts on the environment and make it safer for living and use.

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