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Comparative Analysis of Landfill Sites in Baghdad: A Case Study of Al-Nubai and Al-Nahrawan Sites

Ghufran F. Jumaah[1], *Nuralhuda* A. Jasim[2*] *and Ayat* H. Mahdi[1]

[1] College of Civil Engineering, University of Technology-Iraq, Alsinaa St., 10066 Baghdad, Iraq.
[2]Civil Engineering Department, Wasit University, Wasit, Iraq.

Abstract. The aim of this study is to make a statistical and time series analysis of the inflow of waste at two landfill sites (Al-Nubai & Al-Nahrawan) in Baghdad at a comparative basis. There is a significant difference in the amount of waste collected at the two sites over a 12-month period. The results indicated that the waste volume of Al-Nahrawan is greater than that of Al-Nubai and the average waste volume of Al-Nahrawan is 12% higher than that of Al-Nubai throughout the year. Al-Nahrawan reported the greatest amount of waste inflow in December, and Al-Nubai reported a significant increase in February.The time series analysis depicts the fluctuation of the growth rate throughout the year: Al-Nahrawan had a 20% increase in waste while Al-Nubai had a 15% increase. Waste at both places was reduced during March with Al-Nubai reduced by 5% and Al-Nahrawan by 3%. However, these changes were not seen to be statistically significant as the t-statistic for this is -1.045 and the p-value is 0.306 for statistical significance (t-test). In addition, waste predicted trends reveal a consistent rise in waste in both locations, requiring adaptive waste management. The two sites will see higher volume of waste; Al-Nahrawan will likely need additional resources because of the higher amount of waste at this site. This analysis can be used to enhance waste management systems, ensure efficient use of resources and to respond to variations in waste volume throughout the year at the landfills.

1 Introduction

Municipal Solid Waste Management (MSWM) is one of the most critical environmental and logistical problems in the 21st century, especially in developing countries as urbanization has been accelerated in developing countries [1], [2].In Iraq, the increase in population and consumption rates, in addition to the absence of integrated institutional systems, has resulted in a waste disposal crisis [3], [4]. The capital city of Baghdad, with the Tigris River flowing through it and dividing the city into Al-Karkh and Al-Rusafa banks, has 13 administrative districts to manage its waste [3], [4]. But its current facilities are mostly inadequate to cope with the increasing amount of waste produced by its inhabitants.

* Corresponding author: njasim@uowasit.edu.iq

The per capita waste generation in Baghdad is currently in the range of 0.6 – 1.0 kg/day, as shown by the empirical data [10]. The city is expected to generate 6,427,773 tons of solid waste annually in 2030 because of the high rate of population growth (2.4%) [5]. Although all these challenges have been mounting up, most of the waste is disposed of from locations that are not scientifically designed sanitary landfills but they are open dumps or "uncontrolled landfills" [6], [7]. Such sites do not have necessary protection barriers, including liners and leachate collection systems, which causes high environmental degradation [8]. The most important disposal end points in this network are the Al-Nubai site and the Al-Nahrawan site. The purpose of this study is to facilitate a comprehensive and objective comparison of the two facilities with regard to their efficiency, environmental compliance and sustainability.

1.2 Problem Statement

The main issue addressed in this study is the lack of compliance with international standards in environmental and engineering aspects of sanitary waste disposal in the main landfills in Baghdad, Al-Nubai and Al-Nahrawan [9]. Legacy quarries or temporary pits are the typical disposal sites in Iraq and have a lack of geological and technical barriers that would prevent migration of contaminants [10]. The Al-Nahrawan site, which is close to the site, has recently been investigated and revealed the presence of high concentrations of Chemical Oxygen Demand, ammonia and heavy metals that have changed the mechanical and environmental characteristics of the lithology around the site [11]. At the same time, the Al-Nubai disposal site, the biggest one in the region, is suffering from problems with methane gas emissions and logistical over-extending as well [12]. In particular, Al-Nubai is a source of heterogeneous waste, which is made up of 46.04% organic matter, 21.66% plastic, and 18.42% paper, resulting in a high potential of methane production of 72.49 m^3/Mg [13]. In the absence of a comparative assessment of these sites, policy makers do not have any empirical ground to mitigate pollution from groundwater, reduce greenhouse gas emission and optimise the transport pathway that now causes unnecessary high operational costs and air pollution [14], [15].

1.3 Research Objectives

The main purpose of this study is to make a comparative study of the Al-Nubai landfill and Al-Nahrawan landfill to assess the environmental and operational possibilities of the two landfills. This encompasses characterising the composition and quantity of waste treated at each site and their different environmental impacts according to site-specific conditions. In addition, the study will investigate both landfills compliance with local Iraqi regulations and internationally accepted sanitary landfills criteria and will provide a comprehensive picture of the environmental performance and standards of both landfills.

2. Literature Review

One of the most important environmental and operational problems in Iraq is municipal solid waste management. The pressure on municipalities has been strengthened by the rapid urban growth, population growth, inadequate recycling facilities, and poorly designed landfills. Waste collection and transport remains largely to landfill sites and there is little sorting, recovery, treatment or methane capture in many Iraqi cities. This practice causes soil and groundwater pollution, greenhouse gas emissions, poor transport efficiency and public health risks, especially for the informal waste collectors operating in the landfills who are collecting recyclable waste directly. It is clear from the literature that a more comprehensive and holistic approach to landfill performance assessment is needed with an emphasis on environmental, geological, logistical and regulatory aspects.

Numerous studies have been conducted to identify the gap between the growth rate of cities and the capacity of municipal waste collection and disposal systems in Iraq.A large number of studies have been conducted to identify the gap between the growth rate of urban areas and the capacity of the municipal waste collection and disposal systems in Iraq. According to Ayad et al. [1], the disposal of solid waste in Baghdad was a serious issue since 2003, when the infrastructure was not able to cope with the growing amount of waste produced. The estimates they made projected that the residents of Baghdad would produce around 6.4 million tons of waste per year by 2030, adding to the already scarce disposal facilities. The same problem has been observed in other cities of Iraq such as Erbil, Najaf, etc., in which the municipal departments have some irregularity in the disposal schedules and they do not have effective systems for the process of separation, and they are burying recyclable materials such as paper, glass, plastic, etc. in large quantities without being recovered [2], [3]. The significant findings showed that the problem of waste disposal in Iraq is not only in terms of capacity, but is related to the absence of systematic waste recycling and recovery mechanisms.

One of the latest studies is the application of Geographic Information Systems (GIS) and Multi-Criteria Decision Analysis (MCDA) for the site selection of landfills. Studies in Babylon and Al-Hashimyah have revealed that many of the existing landfills were improperly located, which failed to take into account scientific and environmental factors such as groundwater level, urbanization, distance from agricultural lands, soil parameters, and accessibility [5]. Chabuk et al. [9] showed how suitable landfill sites were identified by integrating various environmental, geologic, social and economic aspects using weighted spatial analysis. In Baghdad, Najim [12] found that there are no appropriate landfills on land that fully meets the modern requirements for landfills on the outskirts of the governorate, while there are high waste production areas, especially Al-Zuhur, where there is inadequate infrastructure for waste disposal. The studies show that it is not only the amount of land that is available that can be used to determine the performance of a landfill; it may be necessary to use a comprehensive spatial and environmental approach to assess site suitability.

Another main issue in the literature that has been considered is the environmental and geological effects, especially on the production of leachate. The researchers conducted a study on the Al-Nahrawan landfill site by Ibraheem et al. [10] and observed that the leachate from the landfill was causing soil salinity levels to rise and levels of heavy metals to increase, which would be of concern in the long term since it would affect the groundwater. The same was observed in Erbil, where Jalal and Darwesh [11] found that the wells in the area around the landfill had deteriorated physicochemical properties in both the dry and rainy seasons using WQI. The studies suggest that contamination from landfills can be found beyond just the surface and could be present in groundwater systems, particularly in areas where landfills are not well lined, leachate is not collected nor monitored.

Iraq is now facing contamination of land and water and the pollution by landfills gas. Methane and carbon dioxide are the products of anaerobic decomposition of organic waste in landfills. The importance of methane is particularly worth noting due to its high contribution to climate change when it's not captured or treated. Tayyeeh and Fadhullah (2026) used LandGEM model for Al-Nubai landfill site and projected that the emissions of landfill gas could be maximum in 2028. Their results indicate that methane formation at the sites are consistent with the conditions expected in arid-region landfills, but the lack of gas capture technology restricts the potential for mitigation. This emphasises the importance of landfill gas management in the environmental evaluation of all Iraqi landfill sites.

It has also been found from literature that it is important to take into consideration the logistical aspect of landfill performance. Sadoon et al. [13] investigated the waste transportation system in Baghdad and stated that the Al-Nubai landfill receives significant quantities of waste from different districts, such as Al-Sadder 1 district which provides 520 tons/day and Al-Rasheed district provides 404 tons/day of waste to Al-Nubai landfill. The long distances from collection points to landfill sites result in greater fuel consumption, higher operational costs, heavier traffic and higher vehicle emissions. Hence, the assessment of contamination/emissions in landfills like Al-Nubai and Al-Nahrawan is not enough. Also, their practical sustainability should be assessed in terms of transport efficiency, routing and the cost to the municipal waste collection system.

The reviewed literature also reveals that poor waste management is one of the factors that affect broader issues of climate and sustainability in Iraq. Iraq is one of the countries most at risk from climate change and unsustainable development pressures, and they are continuing to face growing environmental risks as a direct result of their continued dependence on landfills for waste disposal. There is no proper system in place for recycling, and recyclable and organic waste wind up in landfill sites together. Organic waste represents methane emissions and recycling of recyclable materials is often done informally by people in unsafe conditions. Informal recovery puts workers at risk of exposure to dangerous environments, biological hazards and toxic substances. Thus, beyond the technical aspect of assessing the landfills in Iraq, there is a need to enhance the recycling systems, better recovery systems, and enforcement of regulations.

In general, it can be inferred from the literature that Iraq's landfill management is hampered by interrelated environmental, geological, logistical and institutional deficiencies. There are previous studies that have investigated the trends of waste generation, site selection for landfills using GIS, contamination from leachate, degradation of ground water, emissions of landfill gas and transport inefficiencies. But there is a need for comparative site-specific evaluation that combines all these aspects in an integrated evaluation framework. An evaluation of the landfill sites of Al-Nubai and Al-Nahrawan can be valuable evidence in this context for their environmental and operational suitability, their suitability with sanitary landfill standards, and the need for better recycling, monitoring and waste management in Iraq.

3. Methodology

The present study is of quantitative comparative research design to assess and compare the condition of operational and environmental status of Al-Nubai and Al-Nahrawan landfills in Baghdad. It is based on the statistical analysis of primary data gathered from site staff and municipal stakeholders to determine significant differences in management practices and environmental risk between the two sites.

3.1 Research Design

A comparative quantitative research design was used in this study to compare Al-Nubai landfill site with Al-Nahrawan landfill site in terms of their environmental and operational differences. Design was designed according to numerical data available on the quantities of waste generated daily, waste composition, and selected operational indicators. Simple statistics were used to compare the two sites and the differences in volume, waste compositions and total load on the landfill were identified. The study used descriptive statistical methods with the averages, percentages, and comparative tabulation as the main methods used. These methods were employed to present the differences between the two landfill sites in a clear and measurable form, while summarizing the collected data. This was deemed appropriate due to the study's objectives, which did not involve testing an elaborate predictive model, but rather making a comparison that was practical based on the quantifiable indicators that could be observed in the landfills. The study covers, in this design, an evidence-based overview of the relative burden that each landfill site suffers and the implications that the environmental and operational effects of the distribution of waste in Baghdad.

3.2 Study Area and Site Selection

The study is conducted in two main waste disposal sites in the Baghdad Governorate, namely:The research investigates two main waste disposal sites in the Baghdad Governorate, which are:
Al-Nubai Site is the most important disposal site in the Al-Karkh sector located in the northern outskirts of Baghdad and several major districts such as Al-Sadder 1 and Al-Rasheed. It has a high daily intake rate and high content of organic wastes (Tayyeh & Fadhullah, 2025).
The Al-Nahrawan Site is located on Al-Rusafa (east) side of the city, and has been recently identified as one of the important sources of soil and groundwater contamination because of the poor management of leachate.

4. Results and discussion

The two largest landfill sites in Baghdad city are the Al-Nubai and Al-Nahrawan sites, where the average waste transported daily to these landfills is estimated at approximately 9032.2 tons/day, distributed between 6111.8 tons/day for Al-Nubai and 2920.4 tons/day during 2023[Baghdad municipality] as presented in fig 1 and table 1.
Figure 1 indicates the waste loads collected at Al-Nubai and Al-Nahrawan landfill in tons per day, for one year period. The waste volumes to Al-Nubai are the highest and range from about 5,700 tons/day in August to 6,500 tons/day in October, and intermediate at 5,800 tons/day in June, 6,100 tons/day in February and March, 6,200 tons/day in April and May and 6,300 tons/day in November and December. Al-Nahrawan receives much lower volumes, ranging between 2,300 tons/day in June and 2,600–2,800 tons/day from February to May, 3,300 tons/day during November and 2,700 tons/day during October.
From the comparison it can be seen that the amount of waste processed daily by Al-Nubai is more than 2 times the daily waste processed by Al-Nahrawan for the entire year. The peaks at Al-Nubai (6,500 tons/day) are at slightly lower volumes at Al-Nahrawan (2,700 tons/day), suggesting waste distribution is not even and collection coverage may be different. The differences would be factors to consider when assessing Al-Nubai's landfill capacity, transport requirements and environmental management as the higher volumes of waste at Al-Nubai will likely lead to more leachate generation, gas emissions and operational stress.

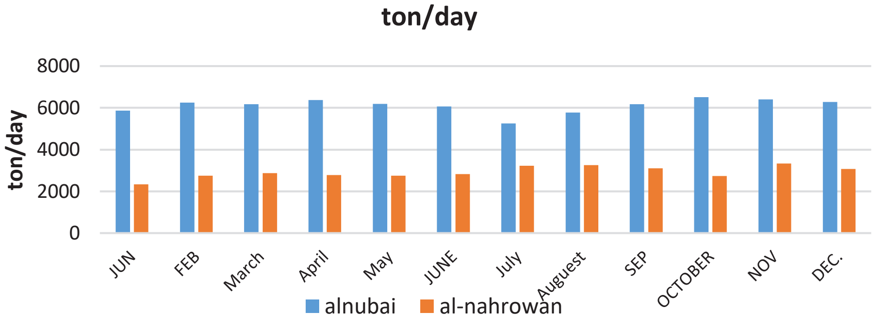

Fig 1. The average solid waste transported to the landfill in Baghdad city during 2023(ton/day).

The table 1 shows monthly average waste received by landfill sites (Al-Nubai and Al-Nahrawan) (tons/day) and the combined waste load (tons/day) received by both sites. Overall, the waste collected in Al-Nubai throughout the year was significantly greater than that collected in Al-Nahrawan. The average of wastes received at Al-Nubai was 6,111.8 tons/day, and at Al-Nahrawan was 2,920.4 tons/day. The average daily wastes load for both sites was thus 9,032.2 tons/day.
The minimum value recorded at Al-Nubai was for the month of July (5,251.9 tons/day) and maximum value was recorded in October (6,510.2 tons/day). The average of most monthly values for Al-Nubai was above 6000 tons/day, with an average of 6248.3 tons/day in February, 6379.1 tons/day in April, 6176.2 tons/day in September, 6402.1 tons/day in November and 6282.1 tons/day in December. This means that Al-Nubai always shouldered a greater burden of waste. Al-Nahrawan's minimum was 2340.8 tons/day in June and the maximum was 3328.7 tons/day in November. Other relatively high values were obtained in the months of July and August, 3,221.1 tons/day and 3,258.9 tons/day. This indicates that the seasonality effect on waste reception at Al-Nahrawan has a medium value in summer and autumn. Combined waste load varied from a lowest in June of 8,213.7 tons/day to a highest in November of 9,730.9 tons/day. The high value in November was attributed to simultaneous rise at both sites mainly 6402.1 tons/day at Al-Nubai and 3328.7 at Al-Nahrawan. These results have shown that both of the landfill sites have a considerable monthly difference, and the more dominant operational load is at the site of Al-Nubai. This could be significant for planning landfill capacities, transport planning, generation of leachate and emission potential of the landfill gases.

Table 1. The average solid waste transported to Al _Nubai and Al_ Nahrawan sites (ton/day)

month	Al _Nubai site	Al_ Nahrawan site	Sum of waste(ton/day)
JUN	5872.9	2340.8	8213.7
FEB	6248.3	2756.2	9004.5
March	6181.5	2872.5	9054
April	6379.1	2779.1	9158.2
May	6189.3	2750.6	8939.9
JUNE	6065.1	2824.6	8889.7
July	5251.9	3221.1	8473
Auguest	5782.4	3258.9	9041.3
SEP	6176.2	3100.2	9276.4
OCTOBER	6510.2	2735.6	9245.8
NOV	6402.1	3328.7	9730.9
DEC.	6282.1	3076.5	9358.6
Total waste ton/day	6111.8	2920.4	9032.2

The figure 2 illustrates the average of solid waste generated per day in Baghdad city in 2023 by month. The amount of waste generated presents marked seasonality, varying from a minimum of 8,213.7 tons/day in June to a maximum of 9,730.9 tons/day in November. The monthly values in the intermediate ranges are: 9,004.5 tons/day for February, 9,054 tons/day for March, 9,158.2 tons/day in April and 9,358.6 tons/day in December, and generally higher levels of waste produced during the late winter and autumn months. The minimum in July (8,473 tons/day) is a temporary decrease, may be associated with municipal collection programmes or seasonal differences in consumption. These figures highlight the strain on the city's landfill system, which is particularly high in October and November when the amount of waste is more than 9,200 tons per day. The figure also highlights the importance of strategic planning regarding the capacity of landfills, transportation and environment. This assessment is vital for city waste management planning in Baghdad because of the significant role played by the volume of monthly waste in the generation of leachate and greenhouse gases emissions and the efficiency of the landfill.

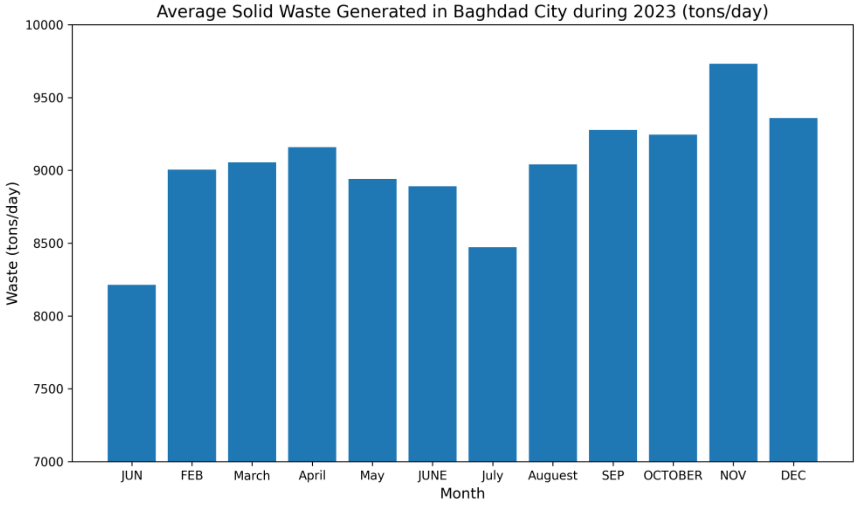

Fig. 2 The average solid waste generated in Bagdad city during 2023 (ton/day)

Most of these solid wastes are consist of organic, paper, plastic, metal, and others, that are dumped without separation for recycling or diverting. Fig 3 and 4 show the ratio of these components generated in Baghdad municipalities during 2023.

Figure 3 shows the percentage of solid waste from each of the 14 municipalities of Baghdad, categorized by six types of waste (organic waste, plastic waste, paper waste, metal waste, glass waste, waste other than the above). It is observed that all municipalities have organic waste as the main component of waste, varying from around 41% to 45%. About 45% of Al-Sader 2 waste is from organic fraction, while relatively lower values are recorded for the waste from Al-Mansour and Al-Adhamiya municipal area in which approximately 41%–42% of the waste is from plastic and paper. Plastic makes up about 21% – 22% in most municipalities and paper 21% – 22%. These values suggest that a significant portion of the Baghdad MSW is made up of recyclable waste. In the case of the municipality of Al-Shualah, Al-Mansour, Al-Jadida, Al-Shaab and Al-Adhamiya, these municipalities have proportions of plastic and paper waste higher than 22%, indicating high potential for source separation and recycling programs. Smaller portion of the waste composition is composed of metal, glass and other material. The concentration of metal varies in the range of 4% to 7% with a higher concentration in some municipalities like Al-Karkh, Al-Mansour and Karrada. The other materials range from 2% to 5% except for glass, which accounts for about 4%–6%. These fractions are important for recovery planning and landfill volume reduction, even though they are not as high as the other waste fractions, organic, plastic and paper.

The overall figure shows the high percentage of biodegradable organic matter in the MSW of Baghdad, followed by a recyclable plastic and paper fraction. The composition is significant for environmental and operational considerations. The high organic fraction can contribute to greater amount of methane generation and leachate production in landfill sites and the high proportion of paper and plastics indicate that recycling and waste sorting initiatives can have a significant impact on the quantity of waste sent to Al-Nubai and Al-Nahrawan landfill sites.

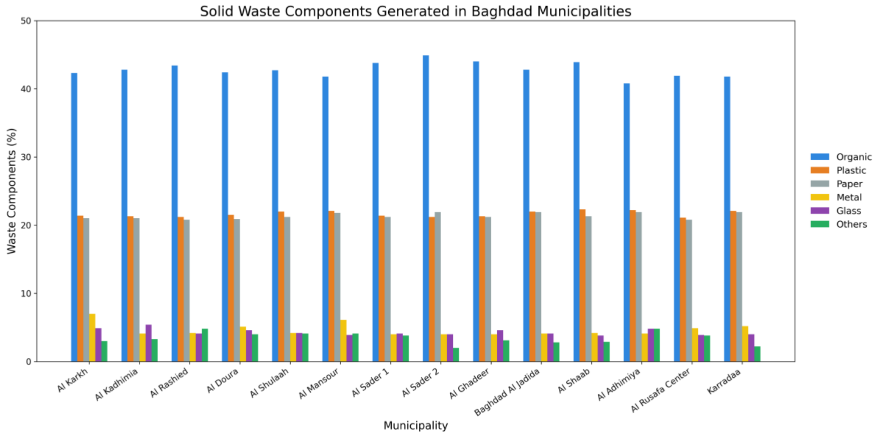

Fig. 3 The solid waste components generated in Baghdad municipalities.

The overall table for the amount of solid wastes generated in Baghdad during 2023 is shown in figure 4. Most of the waste stream is organic waste, accounting for 42% of all municipal solid waste. This high organic content suggests that more than the waste stream in Baghdad is biodegradable. This proportion has direct environmental consequences since all the organic waste in the absence of proper treatment/gas recovery system in the landfill site generates methane, creates odor issues and produces leachate. Paper and plastic are the second and third largest at 22% and 21%, respectively. These recyclable materials account for 43% of the waste stream, slightly more than the organic fraction. This discovery suggests that there is a huge potential for recycling and source separation initiatives in the city of Baghdad. Proper recovery of plastic and paper wastes can help alleviate pressure on Al-Nubai and Al-Nahrawan landfills and the amount of material sent to landfill sites. Other materials make up 4%, glass 5 and metal 6%. These categories have lower proportions but are still significant for integrated waste management as these contain recyclable and potentially dangerous materials. In general, the figure shows that 85% of the solid waste produced in the city of Baghdad is organic, paper and plastic waste, respectively. This composition reinforces the necessity of composting, recycling and material recovery strategies to decrease the reliance on landfill and enhance environmental sustainability.

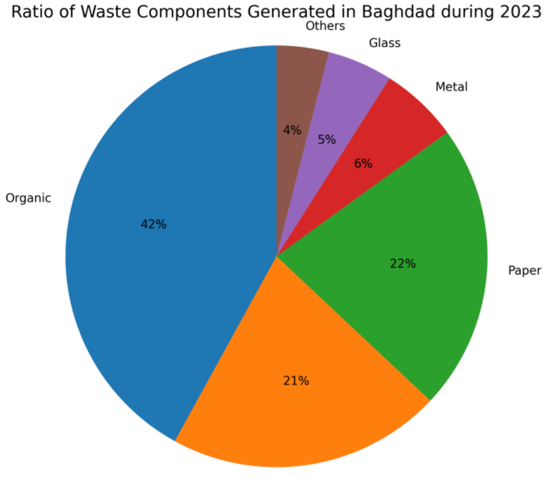

Fig. 4 ratio of waste components generated in Baghdad during 2023

Where the average generated rate (ton/day) for these components was as presented in The daily amount of various components of waste in Baghdad is shown in tons/day in figure (5). The high content of biodegradable material is reflected by the fact that the dominant waste stream is organic waste, amounting to about 3,800 tons/day. Paper and plastic come in next, with 1,950 tons/day and 1,900 tons/day respectively, suggesting significant recyclable content. Smaller contributions are seen for metal (520 tons/day), glass (480 tons/day) and other materials (330 tons/day). These values emphasize the environmental impact of organic wastes, which may produce high amounts of methane and leachate in landfill facilities. The high paper and plastic fractions highlight the opportunities for implementation of paper and plastic recycling and source separation initiatives to minimise landfill waste and enhance resource recovery.

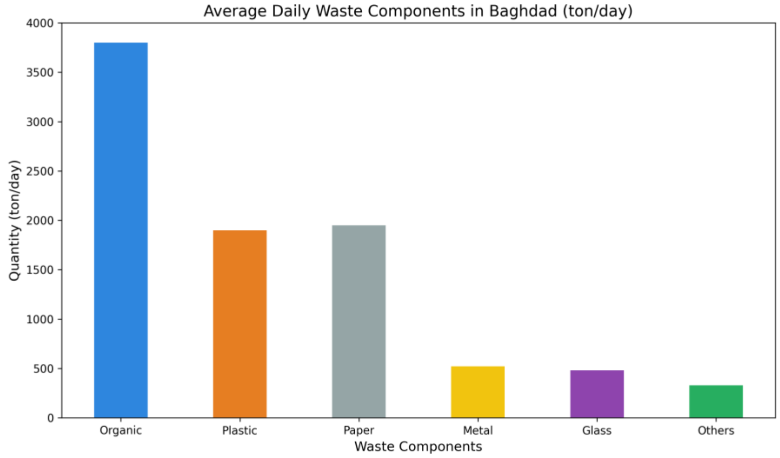

Fig. 5 The average generated rate (ton/day) for solid waste components in Baghdad during 2023

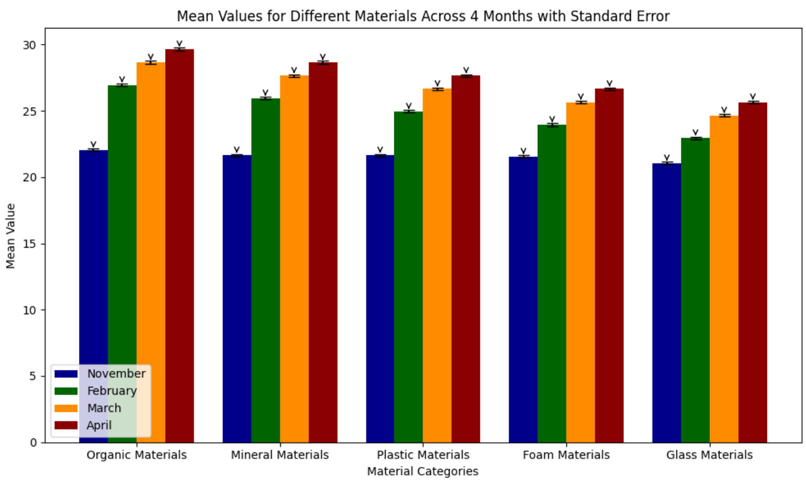

Fig. 6 Mean values for different materials across 4 months with standard error.

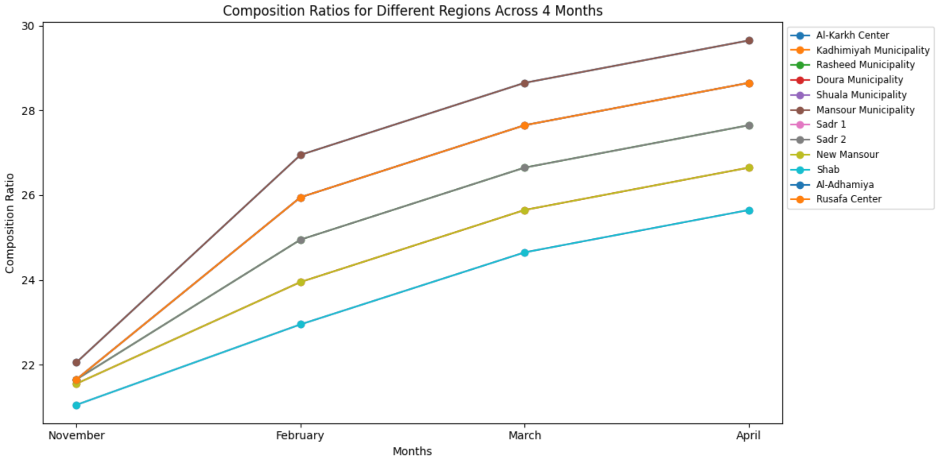

Fig. 7 The composition ratios for different regions across 4 months.

Average waste values in the figure 6 show a comparison between the percentages of sorted components over four months (November, February, March and April) for the various materials (organic, metallic, plastic, spongy and glass) in different regions. These data are presented as a percentage of the total for each region for each month over the four month period, and illustrate the percentage changes in these components over time. The results are analyzed and it is observed that all the regions showed significant rise in percentages from November to April. For instance, the highest percentages were recorded for the four months at the Karkh Center and Mansour Municipality, whereas the lowest percentages were recorded in Shuala Municipality. The rise is a reflection of better over time in the distribution or use of materials in these areas.

In the same way the figure 7 depicts the percentage changes of components for all the regions throughout the four months. The data is plotted graphically in a line for easy comparison with the other months. The lines indicate the trend of these percentages in the various regions, with Karkh Center and Mansour Municipality gaining in percentage, while other regions like Shuala Municipality had lower percentages for some months.

The data shows the tons of waste that is disposed of at each location, and how those amounts have changed over time. The chart shows that the waste levels for both sites have a similar pattern with some months increasing and others decreasing. The average values in Al-Nahrwan are slightly lower than the values in Al-Nubai, this was done in general and this suggests that the waste that enters Al-Nahrwan is less than the waste that enters Al-Nubai throughout the year. This may be attributed to the differences in population size, infrastructure or waste management systems at the two sites.

The highest average for both sites occur throughout the year, indicating that the waste load is not seasonal, but is dependent on other factors. The value of Al-Nubai for instance rises considerably in December, which seems to be an unusual rise in waste in that month. The figure 8 also illustrates the changes in waste management that may be required in different areas as waste trends change over time. It helps determine if there are any months that should be paid special attention to, such as December, or if there are regular patterns of higher waste volumes that should mean changes in how waste is managed or disposed of. Overall, the chart provides a comprehensive, comparative analysis of the performance of the two locations in terms of waste handling, which may prove useful when optimizing waste management in the future.

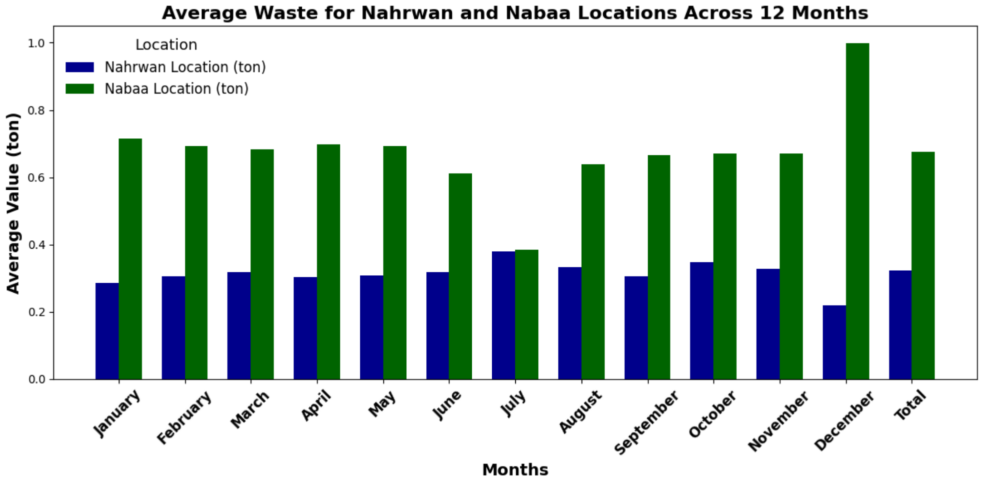

Fig. 8 The average waste for Al-Nubai and Al-Nahrawan across 12 months.

The average total waste is shown in the figure 9 for 2 locations—Al-Nubai and Al-Nahrawan. Average waste for each location is reported for all 12 months. The average waste value at the Nahrwan location is slightly lower than the Al-Nubai location, indicating that, on average, the Al-Nubai location receives more waste than the Nahrwan location all year round. The disparity could be explained by various factors, including population density, waste collection systems, or usage habits. The figure 9 provides a general idea of the amount of waste each location generates, which may be helpful in planning waste management resources. The average for each location can be used to identify specific needs and make targeted interventions if the goal is to optimize waste management practices. The new bars are narrower, providing a clearer visual representation of the comparison and making the differences easier to see and understand.

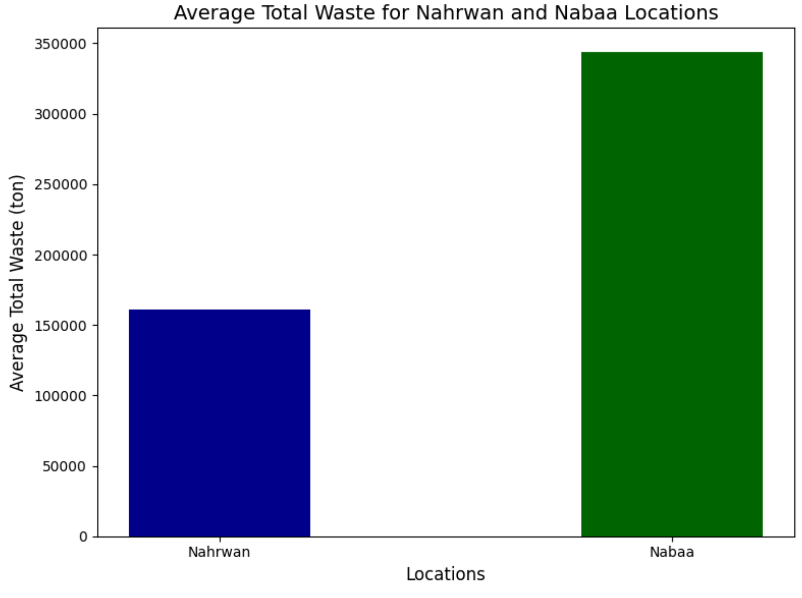

Fig.9 The bar chart shows the average total waste for two locations: **Al-Nubai** and **Al-Nahrawan**, The average waste is calculated across all twelve months for each location.

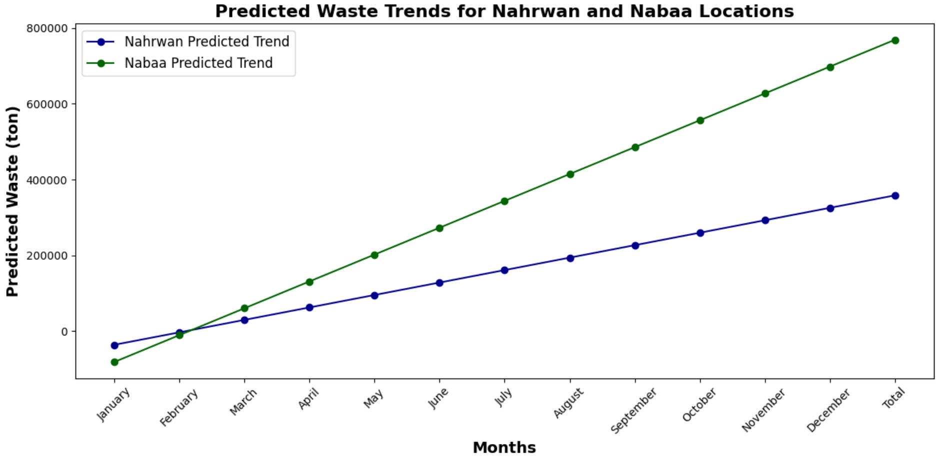

Fig. 10 The predicated waste trends for Al-Nahrwan and Al-Nubai locations.

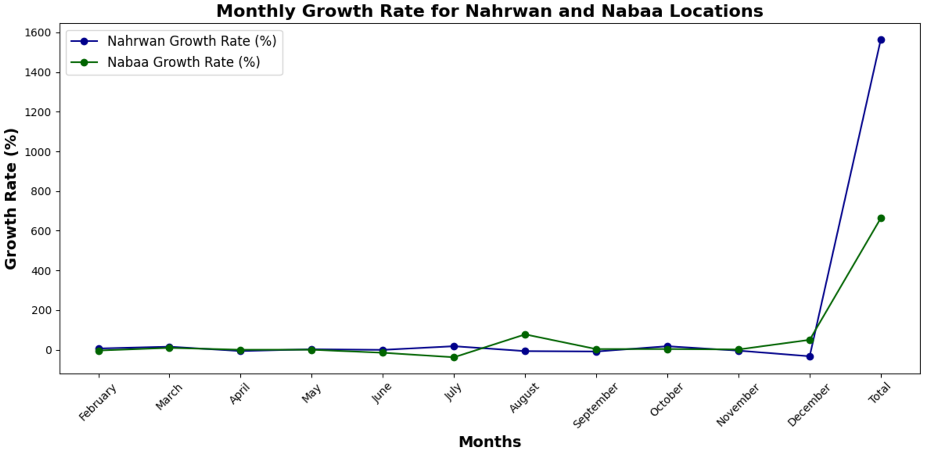

Fig. 11 Monthly growth rate for **Al-Nubai** and **Al-Nahrawan** locations.

Figure 10 shows the predicted waste inflow for the two locations Al-Nahrwan and Al-Nubai for each month. It demonstrates a general upward trend in waste for both locations, signifying a gradual increase in waste over time for both locations. The waste values are also increasing and similar at both locations however, Nabaa has slightly higher waste value compared to Al-Nahrwan throughout the months, indicating more waste volume at Nabaa than Al-Nahrwan throughout the months. This indicates that there may be a need to allocate more resources and attention to the waste management in Al-Nubai, as they are processing a higher volume of waste. Growth rates of waste inflow at both locations are shown in the figure 11 for each month. There are months of fluctuations in the growth rate, some months such as February having a great increase in waste and others, such as March, having a slight decrease in waste. This fluctuation means that the waste inflow is not the same for all months and there are months with more waste, and months with less waste. Data on growth rate allows to gain insights into waste generation variation and to identify months where increased attention may be required in terms of waste management. Combined these charts give a comprehensive picture of the behaviour of waste inflows over time at both sites, highlighting the overall rising trend and the variability in the pace of the rise to help ascertain future waste management requirements.

The T-Statistic is -1.045 which is small; hence, there is no statistical evidence that there is any difference between the waste inflow at Al-Nahrwan and Nabaa locations. The p value is 0.306, which is higher than the value of 0.05, indicating that there is no significant difference between the waste inflows at the two sites. The waste amount in the Predicted Trend for Al-Nahrwan is increasing, indicating continuous waste inflow.Likewise, the Predicted Trend for Al-Nuhai also shows a consistent rise in waste inflow, which suggests that the waste inflow into Al-Nuhai is on an upward trajectory as well. The Growth Rate for Al-Nahrwan is quite fluctuating; some months have substantial growth as in February, while some months have seen a decline as in March. The Growth Rate for Al-Nubai also fluctuates with a very high increase in February and a slight decrease in March.
The statistical analysis results give valuable information about the inflow of waste at Al-Nahrwan and Al-Nubai in each month.The t-test analysis shows that the waste inflow from Nahrwan location has no significant difference with the Nabaa location with t= -1.045 and p= 0.306 based at a significance level of 0.05. This indicates that while there may be some differences between the two locations in terms of values of wastes, statistically these differences are not large enough to consider as meaningful or significant.
The time series analysis indicated the expected trends of both Nahrwan and Nabaa. The amount of waste coming into both sites has been continually on the rise over the course of the months, indicating a continual increase in the amount of waste generated or received at these sites. The rising trend suggests that over time, there has been a greater increase in waste accumulation in both locations, and Nabaa's waste inflow is slightly higher than Nahrwan's. This could be because of the population density, infrastructure, or the pattern of waste generation locally. The growth rate showed variation with the seasons for both sites. For instance, as seen in the graph, there were months such as February, in which the waste inflow at both locations increased considerably, followed by months such as March, when the inflow of waste decreased slightly. This different growth rates indicate that the input of waste is not uniform throughout the months. The variation over time could mean that there is a particular factor operating in some months, perhaps a seasonal factor, holiday or changes in local waste production.
The trends in waste forecast indicate that waste management systems need to be more flexible, responding to these variations in waste volumes. More rapid inflow of wastes may require more resources or waste management approaches to be improved. The results from both combined give a clear picture of the distribution of waste over time and between the two locations. This analysis can be useful when planning future waste management activity as they will be able to understand where and when the most resources are needed to effectively manage waste in these areas.

5. Conclusion

In this study a comprehensive comparative analysis for the inflow of waste in Al-Nubai and Al-Nahrawan landfill sites in Baghdad has been carried out. An overall increasing trend of waste accumulation is observed in both locations, however, the waste volume received at Al-Nahrawan is higher than the waste volume received at Al-Nubai throughout the year and the waste growth rate and the seasonal pattern of the waste inflow fluctuates in both locations. The statistical analysis (t-test) showed that there is no statistically significant difference between the waste volumes at the two sites, implying that other factors such as infrastructure, population size or waste management practices are affecting the waste trends rather than any differences between the two sites. The outcomes of the time-series and growth rate analyses reflect the variable inflow of waste, suggesting that waste production is not consistent over the year. In some months, notably February, significant increases in waste were recorded and there was a subsequent decrease in March. The results suggest that it is critical to adopt a more flexible approach to waste management that can adapt to these fluctuations and optimally distributes resources. Both locations have a growing waste problem, particularly in Al-Nahrawan, which presents a demand for more flexible and efficient waste management systems. The findings of this research can help to find the best solutions for waste management strategies, improvements in infrastructure, and to respond to seasonal variations in waste generation. To sum up, both landfill sites share common problems, and it is important to have knowledge of them and apply the appropriate disposal methods to enhance the sustainability and efficiency of waste disposal in Baghdad.

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