doi.org/10.54473/IJTRET.2024.8404
International Journal of Trendy Research in Engineering and Technology
Volume 8 Issue 4 August 2024
ISSN No. 2582-0958

REVIEW OF SOLID WASTE MANAGEMENT CHALLENGES AND SOLUTIONS IN IRAQ

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Received 04 May 2024 Received in revised form 09 June 2024 Accepted 10 June 2024

ABSTRACT
Solid waste management (SWM) in Iraq faces significant challenges due to inadequate infrastructure, insufficient regulatory frameworks, and low public awareness. This review explores the current state of SWM in various Iraqi cities, highlighting key issues and proposing recommendations for improvement. In Babylon Governorate, open dumping and poor collection processes are prevalent, with waste production expected to increase significantly by 2030. Kerbala's SWM system is hindered by limited funds, requiring better disposal and recycling infrastructure and stakeholder engagement. Al-Nassyriah residents expressed dissatisfaction with current SWM practices, indicating a need for increased public awareness and proper waste sorting infrastructure. Sulaimania faces environmental threats from open dumping, with seasonal variations in waste generation and inadequate medical waste management. In Erbil, substantial recyclable materials remain untapped due to a lack of efficient treatment technologies and public awareness. Najaf's exploration of waste-to-energy solutions presents a promising alternative for addressing waste management issues. This review underscores the necessity of developing modern infrastructure, enforcing stringent regulations, enhancing public education, and integrating waste management with energy production to achieve sustainable SWM in Iraq.
Keywords: Solid Waste Management (SWM), Iraq, Environmental Pollution, Waste Collection, Recycling, Landfills, Public Awareness

I INTRODUCTION
Solid waste management (SWM) is a critical environmental and public health issue faced by countries worldwide, and it is particularly pressing in developing nations like Iraq [1]. Effective SWM is essential for maintaining urban cleanliness, preventing environmental degradation, and safeguarding public health [2]. However, Iraq's SWM system faces numerous challenges due to years of conflict, political instability, economic constraints, and infrastructural deficiencies. These challenges have led to inefficient waste collection, treatment, and disposal, resulting in significant environmental and health impacts [3]. Iraq, a country rich in cultural heritage and natural resources, has been plagued by decades of conflict and political instability [4]. These conditions have severely impacted its infrastructure, including its waste management systems [5]. The rapid urbanization and population growth in cities such as Baghdad, Basra, and Mosul have exacerbated the problem, increasing the volume of waste generated and putting additional pressure on already strained SWM systems [6]. The lack of adequate waste management infrastructure and services has led to the proliferation of illegal dumping sites and open burning of waste, contributing to air and water pollution [7].

One of the primary challenges in Iraq's SWM is the inadequate infrastructure for waste collection, transportation, and disposal. Many municipalities lack the necessary equipment and facilities to handle the growing volumes of waste [8]. Consequently, waste collection services are often irregular and inefficient, with significant portions of waste left uncollected. This uncollected waste accumulates in streets, vacant lots, and riverbanks, posing serious health risks to the population and contaminating natural resources [9]. Another significant issue is the lack of public awareness and participation in waste management practices. In many areas, there is a limited understanding of the importance of proper waste disposal and recycling [10]. This lack of awareness leads to poor waste segregation practices at the household level, making it difficult to implement recycling and composting programs effectively [11]. Additionally, the informal sector plays a considerable role in waste collection and recycling in Iraq, often operating without regulation or support, which can lead to hazardous working conditions and inefficiencies in the recycling process [12].

The regulatory framework governing SWM in Iraq is also a critical area of concern. Existing regulations are often outdated, poorly enforced, and lack the necessary clarity and comprehensiveness to address the complexities of modern waste management [13]. There is a need for updated legislation that incorporates international best practices and provides clear guidelines for waste management at the local and national levels [14]. Furthermore, coordination between different governmental agencies involved in waste management is often lacking, leading to fragmented and ineffective policies and practices [15]. Socio-economic factors also play a significant role in Iraq's SWM challenges. High levels of poverty and unemployment limit the financial resources available for waste management programs [16]. Municipalities often struggle with budget constraints, making it difficult to invest in necessary infrastructure and services. Moreover, the ongoing political instability and security concerns divert attention and resources away from environmental issues, further hampering efforts to improve SWM [17].

Despite these challenges, there are opportunities for improvement in Iraq's SWM system. International organizations and non-governmental organizations (NGOs) have been actively involved in supporting waste management projects in the country [18]. These projects often focus on capacity building, public awareness campaigns, and the development of sustainable waste management practices. Additionally, there is growing recognition within Iraq of the importance of addressing environmental issues, which could lead to increased political will and investment in SWM [19]. Solid waste management in Iraq is a complex issue influenced by a variety of factors, including infrastructural deficiencies, lack of public awareness, regulatory gaps, and socio-economic challenges. Addressing these issues requires a comprehensive approach that includes infrastructure development, regulatory reform, public education, and increased investment in waste management programs. By learning from successful practices in other countries and leveraging international support, Iraq can make significant strides toward improving its SWM system and achieving sustainable development. This study aims to critically analyze the current state of solid waste management in Iraq, identify key challenges and inefficiencies in the system, and propose comprehensive strategies for enhancing the efficiency, sustainability, and public health outcomes of waste management practices in the country.

II SOLID WASTE MANAGEMENT STATE IN IRAQ

Solid waste management (SWM) in Iraq faces numerous challenges across various cities due to inadequate infrastructure, lack of public awareness, and insufficient regulatory frameworks. In Babylon Governorate, which has a population of approximately 1,974,490, waste management involves open dumping and poor collection processes, with projections indicating significant increases in waste production by 2030 [20]. Kerbala, a major tourism hub, struggles with limited funds and an inefficient SWM system, highlighting the need for improved disposal and recycling infrastructure, as well as stakeholder involvement in planning [21]. Al-Nassyriah residents expressed dissatisfaction with current SWM practices, citing a lack of knowledge about relevant laws and regulations. Surveys revealed readiness among residents to participate in waste sorting if proper infrastructure is provided [22]. In Sulaimania, the majority of solid waste is disposed of in an open dumping area, posing environmental threats due to leachate contamination. Seasonal variations in waste generation and inadequate medical waste management were also noted [23]. Erbil's SWM assessment showed an average daily waste generation rate of 0.654 kg per capita, with over 50% being organic waste. Despite potential revenue from recyclables, the city lacks efficient treatment technologies and public awareness [4]. A study in Najaf explored the feasibility of using municipal solid waste for energy production, proposing a waste-to-energy model that could offer a competitive alternative to conventional energy methods. Across these cities, common issues such as irregular waste collection, inadequate landfills, and mismanagement of medical waste were identified, along with recommendations for establishing sorting and recycling stations, sanitary landfills, and enhanced community engagement in SWM practices. The integration of waste management with energy generation and the involvement of the private sector are seen as crucial steps towards sustainable SWM in Iraq [24].

In 2013, Iraq produced 31,000 tons of solid waste per day, with Babylon generating 483,221 tons annually. Waste management in Babylon involves open dumping and inadequate collection processes that fail to meet scientific and environmental standards [25]. Projections for 2030 estimate waste production between 761,104 tons and 943,055 tons annually, with cumulative waste reaching between 12,494,521 and 14,095,437 tons. In Kerbala, a major tourism hub, SWM is hampered by limited funds, necessitating prioritization of improvements. Using Wasteaware benchmark indicators, a 2016 study highlighted the city's weak SWM system, underscoring the need for enhanced disposal and recycling infrastructure, a clear SWM strategy, and the inclusion of all stakeholders in planning [26]. A comprehensive study of Iraq's SWM revealed significant issues including irregular waste

collection, inadequate landfills, and insufficient regulatory frameworks. Surveys indicated a lack of waste sorting at the source and a readiness among residents to participate in waste sorting if provided with the necessary infrastructure. Recommendations include the establishment of sorting and recycling stations, sanitary landfills, and greater involvement of the private sector.

III RECOMMENDATIONS FOR IMPROVING SOLID WASTE MANAGEMENT IN IRAQ

To address these challenges and move towards sustainable SWM in Iraq, the following key actions are recommended:

1. **Infrastructure Development:** Invest in modern waste collection, disposal, and treatment facilities, including sanitary landfills, recycling plants, and waste-to-energy projects.
2. **Regulatory Frameworks:** Develop and enforce stringent SWM regulations that align with national and international standards to ensure compliance and efficiency.
3. **Public Awareness and Education:** Implement extensive educational campaigns to promote waste segregation, recycling, and proper disposal practices among residents.
4. **Stakeholder Engagement:** Actively involve local communities, private sector entities, and informal waste collectors in the planning and implementation of SWM strategies.
5. **Financial Mechanisms:** Establish sustainable funding models such as waste collection fees and recycling incentives, and explore international funding opportunities to support SWM initiatives.
6. **Integration of Technology:** Leverage modern technologies for efficient waste treatment, resource recovery, and energy production to enhance the overall SWM system.

By addressing these areas, Iraq can develop a robust, sustainable, and efficient SWM system that protects the environment, improves public health, and creates economic opportunities through resource recovery and energy production.

IV CONCLUSION

This review has highlighted the critical state of solid waste management (SWM) in Iraq, emphasizing the urgent need for comprehensive reforms across various cities. The challenges faced by cities such as Babylon, Kerbala, Al-Nassyriah, Sulaimania, Erbil, and Najaf are rooted in inadequate infrastructure, weak regulatory frameworks, low public awareness, and inefficient waste treatment technologies. These deficiencies contribute to environmental pollution, public health risks, and missed economic opportunities from resource recovery and energy production.

In Babylon, the reliance on open dumping and inefficient waste collection is unsustainable, with waste generation projected to rise sharply by 2030. Kerbala's limited funds and weak SWM system necessitate a strategic overhaul focused on enhancing disposal and recycling infrastructure and engaging stakeholders. In Al-Nassyriah, widespread dissatisfaction with current practices underscores the need for increased public education and proper waste sorting infrastructure.

Sulaimania's open dumping practices are causing significant environmental damage, particularly through leachate contamination, highlighting the need for sanitary landfills and improved medical waste management. Erbil's large amounts of untapped recyclable materials point to the necessity for efficient waste treatment technologies and heightened public awareness. Najaf's innovative exploration of waste-to-energy solutions offers a promising approach to address waste management issues sustainably.

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