*Pol. J. Environ. Stud. Vol. XX, No. X (XXXX), 1-13*
DOI: *10.15244/pjoes/192766* ONLINE PUBLICATION DATE:

*Original Research*

# Improving Solid Waste Management Using a Geographic Information System in Algeria (Case of Algers)

**Leila Bouchama*, Ammar Drias**

Faculty of Earth Sciences, Geography and Territorial Planning, University of Science and Technology Houari Boumedien

*Received: 3 June 2024*
*Accepted: 29 August 2024*

**Abstract**

This study seeks to identify, examine, and evaluate the repercussions of solid domestic waste generated by the expanding population of Algiers, which is projected to reach 4388,000 by 2020, as indicated in the National Statistics Office's annual report. Disposal of household waste can have adverse impacts on both individuals and their surroundings. Algiers is confronted with a challenge owing to the substantial daily waste output, estimated at approximately 1 kg per inhabitant per day, leading to complexities in its collection and regulation. The primary aim is to establish a spatial analytical framework utilizing geographic information systems to enhance the management of municipal waste within the province of Algiers, the capital city of Algeria. This includes the creation of an extensive database model that will be beneficial to both technical services and the general populace, supplying critical information to facilitate informed decision-making and augmenting public awareness. This research also underscores the significance of GIS technology in the decision-making process.

**Keywords:** Algeria, Algiers, decision-making, household waste, environment, GIS

## Introduction

Demographic growth, urbanization, and the development of industrial and economic activities have resulted in a sharp increase in the volume of waste, which is one of the greatest challenges facing the world because of the dangers it poses to people and the environment. [1-3] Household solid waste is considered one of the most important environmental problems, and it is therefore necessary to find solutions to reduce the risks caused by this waste [4]. Given the seriousness of the solid waste problem and the importance of the political, social, cultural, and environmental issues involved, the international community [5, 6], including Algeria, has become more aware of the problems associated with waste. In Algeria, the quantity of solid household waste has increased in the past decade [7, 8], owing to a combination of population growth and unregulated urban development. Specifically, the amount of solid waste in Algeria was recorded as 10.3 million tons per year in 2011, surpassing 13.5 million tons annually in 2020. Projections indicate an estimated 20 million tons per year by 2035[7, 9] with a continual upward trend in quantity. Therefore, it is imperative

* e -mail: l.bouchamar@yahoo.fr

to mitigate the nuisances and risks associated with the hazardous properties of this waste, which can lead to adverse health and environmental consequences[10]. Currently, this situation poses significant financial and environmental challenges. Therefore, it is imperative to execute a waste management plan through a diverse array of initiatives and methodologies. Accomplishing the successful implementation of such initiatives necessitates adherence to social, economic, and environmental measures. [11, 12], and one of these techniques is to use geographic information systems in waste management [13]. Currently, integrated GIS technology is acknowledged as a highly promising approach to automating waste planning and management processes [13]. This technology enables the simultaneous capture, storage, display, manipulation, and analysis of various data [14]. The utilization of GIS tools has been evident in modeling different waste management applications, including the selection of landfill sites and the enhancement of waste collection and transportation [15-17]. In the realm of household waste management in Algiers, it was deemed that a valuable contribution could be rendered through the exploration of waste evaluation and supervision by employing a geographic information system as a tool for decision-making [15, 16]. This could facilitate the analysis of the depletion of natural resources and safeguarding the environment from the repercussions of waste [18]. Furthermore, recent research draws attention to the broader ramifications of pollution and the monitoring of the environment. For example, investigations into heavy metal pollution have established effective approaches for monitoring various contaminants. A study focusing on barium (Ba) levels in plants in Pakistan revealed that Azadirachta indica leaves are particularly valuable for tracing Ba levels associated with traffic density [19]. Likewise, research on boron (B) and aluminum (Al) in indoor plants highlights the significance of controlling these substances due to their toxicity and potential health implications [20, 21]. The efficacy of biomonitors for other metals, such as tin (Sn) and lithium (Li), has been validated by various studies, further demonstrating the role of plants in environmental surveillance [21-23]. The examination of the impacts of climate change on the distribution of plant species, such as fir trees, illuminates how global climate change is influencing vegetation patterns and emphasizes the necessity for adaptive management strategies [24, 25]. Similarly, research on the consequences of mining activities on soil organic carbon (SOC) [26] has devised practical approaches for evaluating these effects utilizing remote sensing and GIS technologies [27]. In summary, the integration of GIS in waste management and the application of environmental monitoring techniques are critical for addressing the pressing challenges of pollution and resource management [28-30]. These approaches contribute to more effective and sustainable practices, aiding in the protection of natural resources and improving environmental quality. A comparable investigation examines the increasing international apprehension regarding urban waste management. By conducting practical field research on domestic waste generation on-site and utilizing Geographic Information System (GIS) technology, this research puts forward a model for forecasting the volumes and categories of recyclable household waste [31]. This study employs a methodical approach to improve waste management and reduce associated environmental impacts. The data utilized in this research was obtained from various sources, including the National Waste Agency, the Directorate, and the Ministry of the Environment. Furthermore, the survey was conducted in the field between February and March of the year 2022. Through the results of this inquiry, valuable insights are obtained regarding how different types of waste are generated at the source before being collected by waste collectors. The procedure involves establishing goals (such as optimizing collection routes, evaluating treatment sites, and enhancing public awareness), carrying out a comprehensive collection of geographical and waste-related data, and analyzing this data using Geographic Information Systems (GIS). GIS enables the visualization and interpretation of data, modeling waste movements [32], and evaluating potential treatment sites while considering diverse environmental factors [33]. The outcomes aid decision-makers in making well-informed choices regarding waste management, including optimizing collection routes and selecting suitable treatment locations. Continuous monitoring evaluates the efficacy of the interventions and adapts strategies based on the findings.[34] In essence, the incorporation of GIS in waste management in Algiers signifies a step forward towards more effective and sustainable management practices, thereby contributing to environmental protection and the conservation of natural resources. This opening segment effectively delineates the subject matter, issues, methodology, and objectives of the research.

## Materials and Methods

### Study Area

Algiers is the political and economic capital of Algeria. The province of Algiers covers an area of 809,22 km2 and is bounded by (Fig. 1):

To the north by the Mediterranean Sea,

- To the south by the province of Blida,
- To the east by the province of Boumerdes,
- To the west by the province of Tipaza

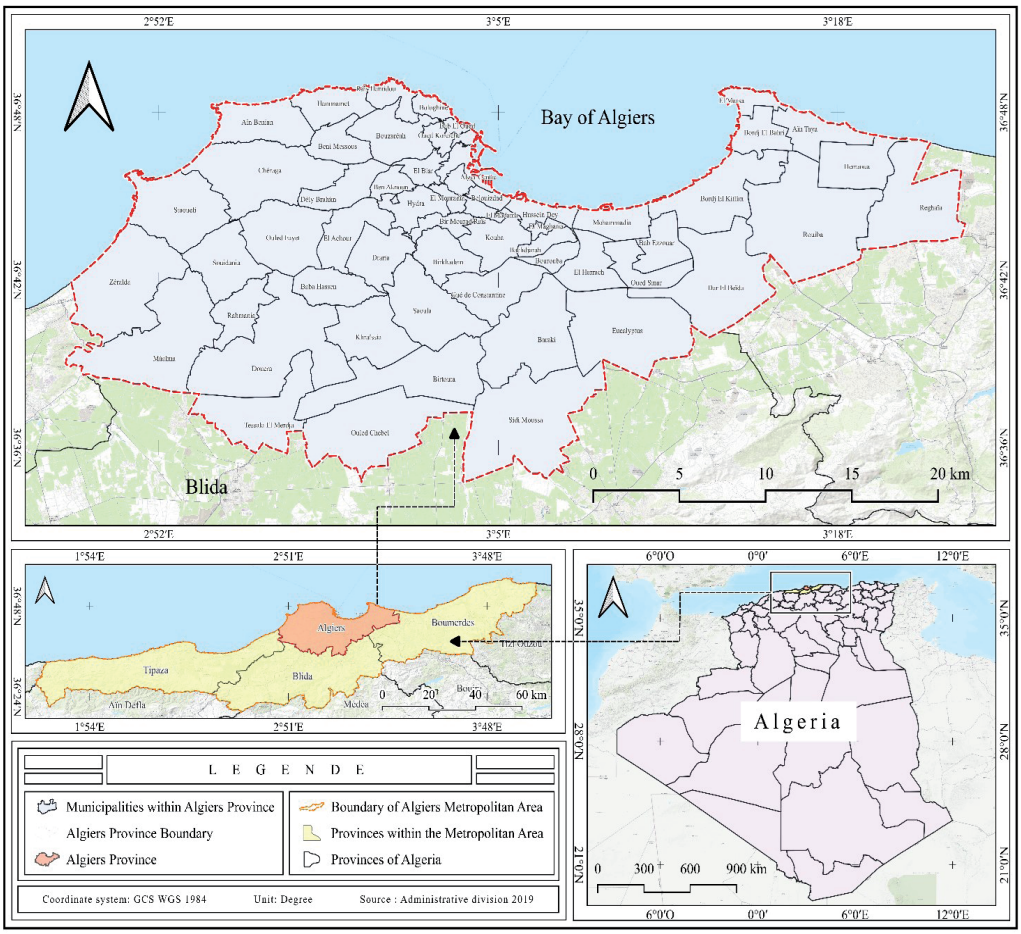


Fig. 1. Geographical location of the province of Algiers.

## Methodology

### Data Collection

The primary aim of this study is to ascertain the present condition of solid waste, establish a database for managing and analyzing this waste, and produce detailed thematic maps. Geographic Information Systems (GIS) will be utilized to create a database that will aid waste management planners and decision-makers in Algiers province [35]. The methodological approach employed in this study was primarily empirical, emphasizing fieldwork. Empirical data was gathered through two methods to acquire the necessary quantitative and qualitative data. The documentary research involved examining various documents, such as doctoral theses, websites, reports, articles, magazines, and newspapers, as well as technical documents like legislative texts and laws. The empirical research, which is the primary source of information for our study, involved collecting data from different organizations, including the National Waste Agency, the National Statistics Office, and the Environment Directorate. The second part of the data encompasses empirical studies centered on collecting qualitative data to comprehend the current status of household solid waste collection. A field survey was carried out in the province from February 2022 to May 2022 to establish an original waste collection point database based on primary data. A Geographic Information System serves as a computerized tool for storing and managing territorial information. GIS performs crucial functions such as archiving data digitally, analyzing spatial and thematic data, and visualizing analysis results through thematic maps. Within the realm of household waste management, GIS provides several advantages. It enables visualization of the situation, making it easier to understand reality with visual aids like thematic maps. Stakeholders can pinpoint priority areas for sanitation service improvement and quickly identify problem areas where immediate action is required, facilitating coordinated and effective responses tailored to each sector's specific needs. GIS advantages in waste collection include optimizing waste collection rounds to adapt to urban growth and efficiently plan routes to reduce fuel consumption. GIS software like ArcGIS (10.8) is tailored for functions like acquiring and manipulating geographic data, managing large databases, querying and analyzing databases, and describing real-world objects through conceptual and logical models, ensuring a high level of user-friendliness.

Table 1. Demographic trends in the province of Algiers, 1936-2030.

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Year | 1936 | 1954 | 1962 | 1987 | 1998 | 2008 | 2020 | 2030 |
| Population (hab) | 367000 | 595678 | 400000 | 2128419 | 2568430 | 2948446 | 4388000 | 5130900 |

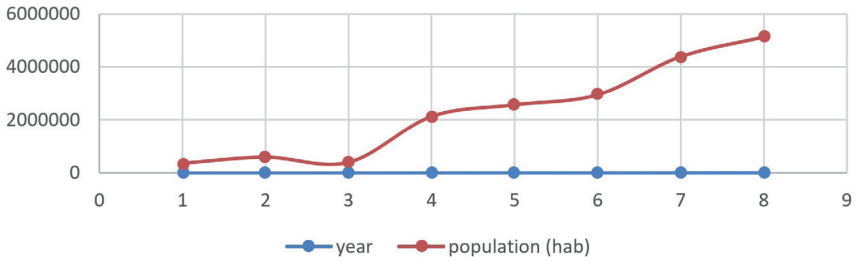


Fig. 2. Demographic trends in the province of Algiers, 1936-2030.

## Results

Population Trends in the Province of Algier The population of the province of Algiers grew rapidly during the 20th century According to Table 1 and Fig. 2, in 1830, it was estimated at just 30,000 inhabitants. In the space of a century, it increased more than 12-fold, reaching 367,000 inhabitants in 1936, making Algiers the fourth-largest French city at the time. This trend continued, and by 1954 the Algerian capital had almost 600,000 inhabitants [36, 37]. However, the population of Algiers declined significantly at independence in 1962, when some 400,000 French citizens left the country. This was followed by a massive rural exodus to the northern coastal towns. After 1962, population growth in Algiers remained sustained atan annual rate of 3.48%, reflecting a veritable demographic explosion [38].

Following a deceleration in the 1990s, the population expansion in Algiers picked up pace again (Fig. 3) from 1997 onwards. Statistical data from the 1987 and 1998 censuses demonstrate a decrease in the annual growth rate from 3,1% to 2,15% during this timeframe. Projections suggest that the population might surpass 5 million by the year 2035 [39].

Nonetheless, the demographic patterns varied significantly across the Algiers province between 1998 and 2008. The municipalities surrounding the historic core experienced the most substantial reduction in population, both in absolute numbers and in relative terms. In the stretch between Bab El Oued and Hussein Dey in the Bay of Algiers, the population dwindled by nearly 26%, dropping from 876,206 to 649,301.

The phenomenon of depopulation in the central area, which intensified from 1998 to 2008, can be elucidated by various factors. Notably, the investment in residential projects on the peripheries has spurred urban expansion and prompted the exodus of inhabitants from the city center. Furthermore, the proliferation of residential complexes has reshaped the demographic composition, transitioning from a predominantly rural populace to one dominated by professionals and executives. Furthermore, this trend has persisted, with demographic expansion observed between 2008 and 2018 in a majority of the province's municipalities.

The population projection for 2035 (Fig. 4) illustrates that the alterations observed in the territorial distribution of the population of the province of Algiers over time are primarily attributed to three key factors: Internal migration from the center to the suburbs; a housing policy that, within public housing programs, has resulted in the development of residential units in the suburbs; and unregulated proliferation of spontaneous housing - often precarious and illegal - in the suburbs, primarily associated with the rural exodus towards the capital.

In Algiers' wilaya, the significant increase in household waste production has been evident since the 1990s. Consequently, a qualitative enhancement of the regulatory framework concerning waste management was established in December 2001 through the enactment of Law 01-19. This legislation imposes restrictions on the selection of landfill sites and their operational procedures.

Our primary goal is to evaluate both the qualitative and quantitative dimensions of solid household waste in the province. The findings from our on-site investigation will facilitate a comprehensive understanding of the challenges associated with household waste management in Algiers and help us discern the community's concerns regarding our research. These insights will inform the development of efficient strategies for waste collection, disposal, and treatment.

### *Change in Quantities of Solid Household Waste Generated (T/Year) by 2035*

The diagram presented in Fig. 5 and Table 2 illustrates the progression of annual household waste generation over the years, along with the anticipated value by the year 2035.

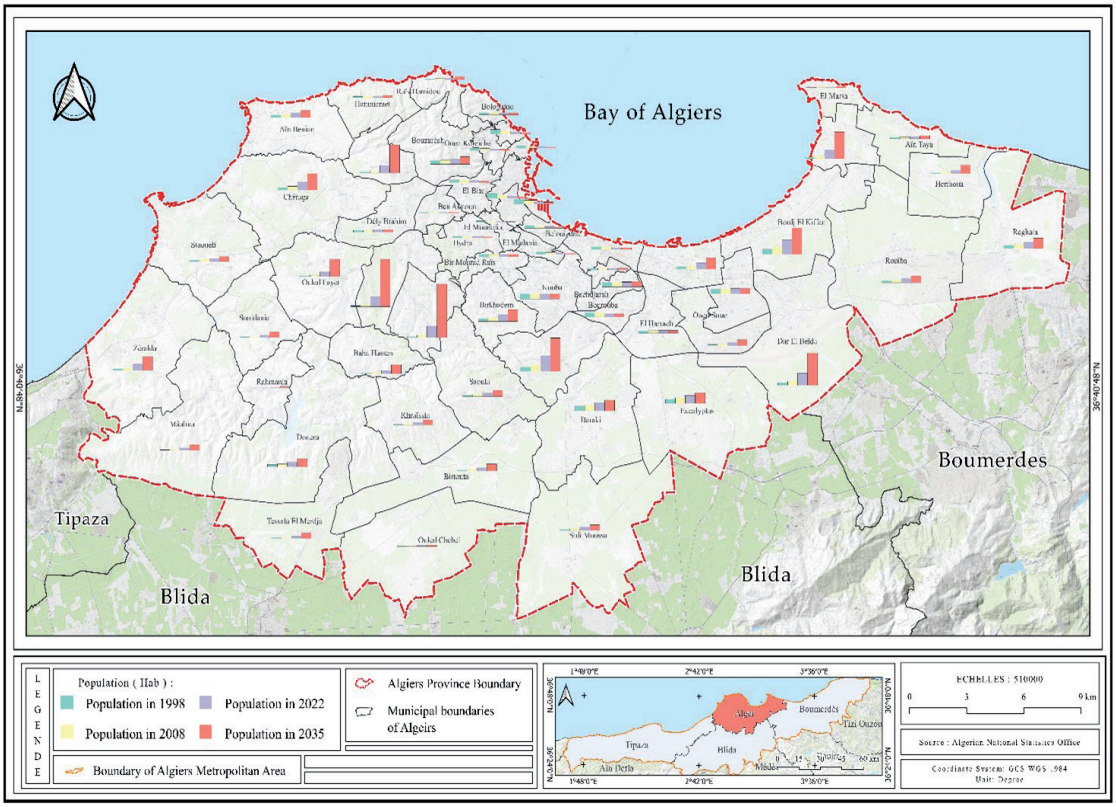


Fig. 3. Population trends by municipality in the province of Algiers, 1998-2008-2018-2035.

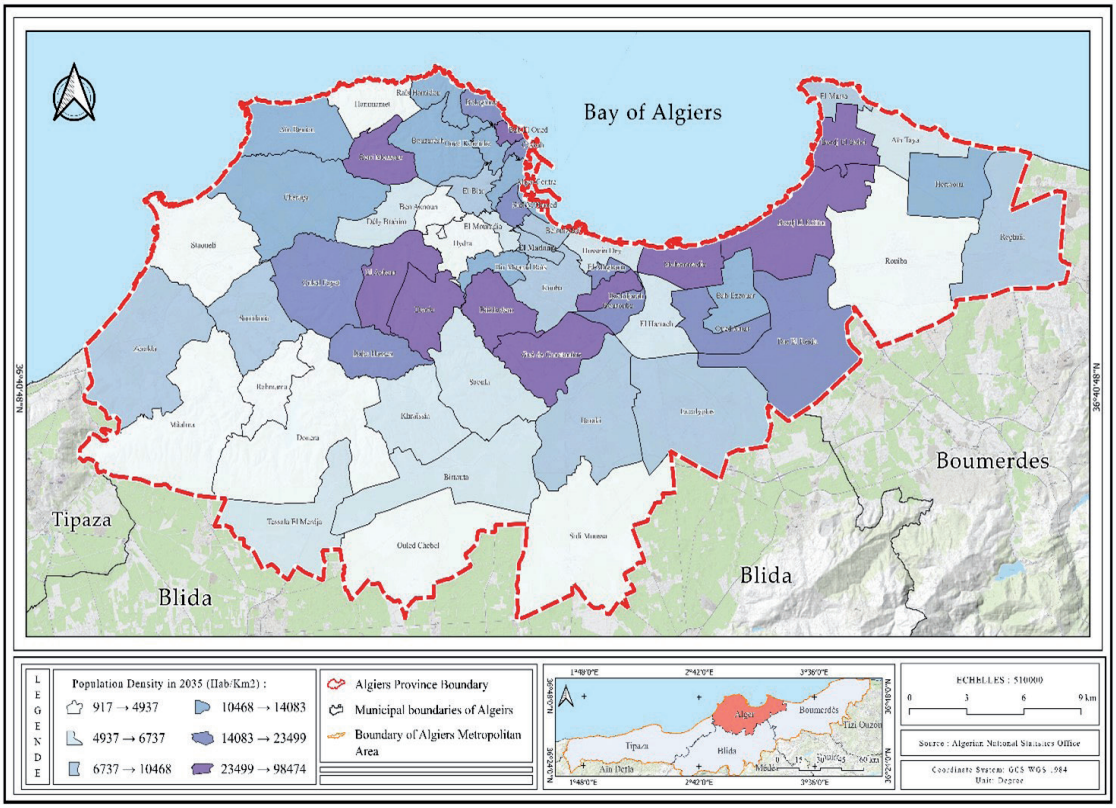


Fig. 4. Population density in the province of Algiers in 2035.Algiers has undergone substantial demographic expansion, manifesting in a twofold rise in population density from 2008 to 2030 in various municipalities within the province, such as Draria, Oulad Fayet, El Achour, Khraisia, Douera, Oulad Chbel, and Rouiba.

Table 2. Evolution of the quantity generated Million (T/year).

| Year | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 | 2026 | 2027 | 2028 | 2029 | 2030 | 2035 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Evolution of the quantity generated Million (T/year) | 2,2 | 2,4 | 2,6 | 2,8 | 2,95 | 3 | 3,15 | 3,22 | 3,41 | 3,6 | 3,8 | 4 | 4,2 | 4,4 | 4,6 | 4,8 | 5 | 20 |

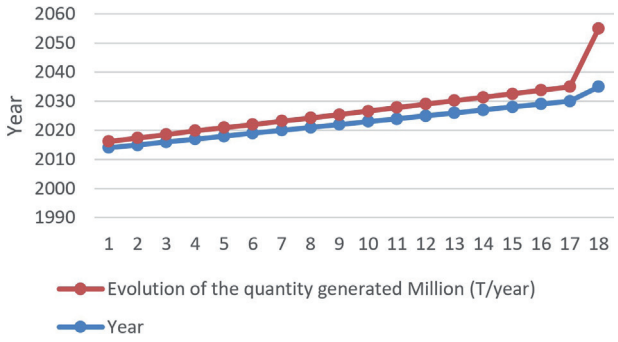


Fig. 5. Evolution of the quantity generated (T/year) by 2035.

As per the analysis by AND, the forecast regarding the volume of solid waste in the northern region by 2035 indicates that the province of Algiers will uphold its position as the primary province in terms of solid waste generation. This will be characterized by a substantial rise of 213% in comparison to the quantities recorded in 2007, amounting to 4,39% by the year 2025.

The justification for this growth can be attributed to the high population concentration and commercial appeal, which serve as the primary contributors to waste generation in these municipalities. The escalation in population numbers results in a significant increase in the consumption of food items. The emergence of novel technologies has incentivized households to upgrade their outdated electronic devices, such as televisions. These electronic products necessitate packaging, with a specific emphasis on cardboard.

## Composition of Household Waste

The distribution of waste types in the province reveals that household waste consists predominantly of organic matter, totaling 673,403 tons per year, followed by 208,953 tons per year of plastic and 156,220 tons per year of textile waste. Additionally, there are significant quantities of paper, metals, and miscellaneous waste, amounting to 120,693 tons per year, 35,156 tons per year, and 29,090 tons per year, respectively. Lastly, glass waste is the smallest category, with only 14,359 tons per year.

Figs. 6 and 7 illustrate the correlation between the quantity and quality of waste generated in the Algiers metropolitan area in relation to the demographic trend. This trend is characterized by a notable surge in growth.

Concerning the quality aspect, it is pertinent to highlight that, as per the forecasts, the constitution of municipal solid waste is anticipated to remain consistent until 2030. This stability will serve as a resource for the various sectors involved in recovery.

The volume of waste generated is subject to multiple factors, with the predominant one being the number of residential units: a rise in the number of dwellings corresponds to an increase in waste production. By the year 2020, the annual waste output is projected to peak at 3150000 kilograms. A visualization of waste

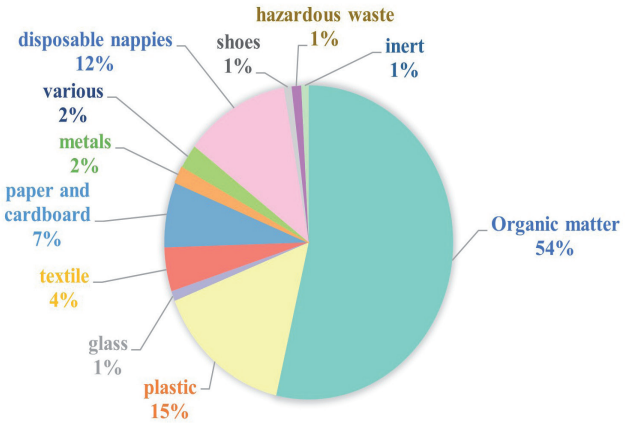


Fig. 6. Composition of waste in the province of Algiers for 2019.

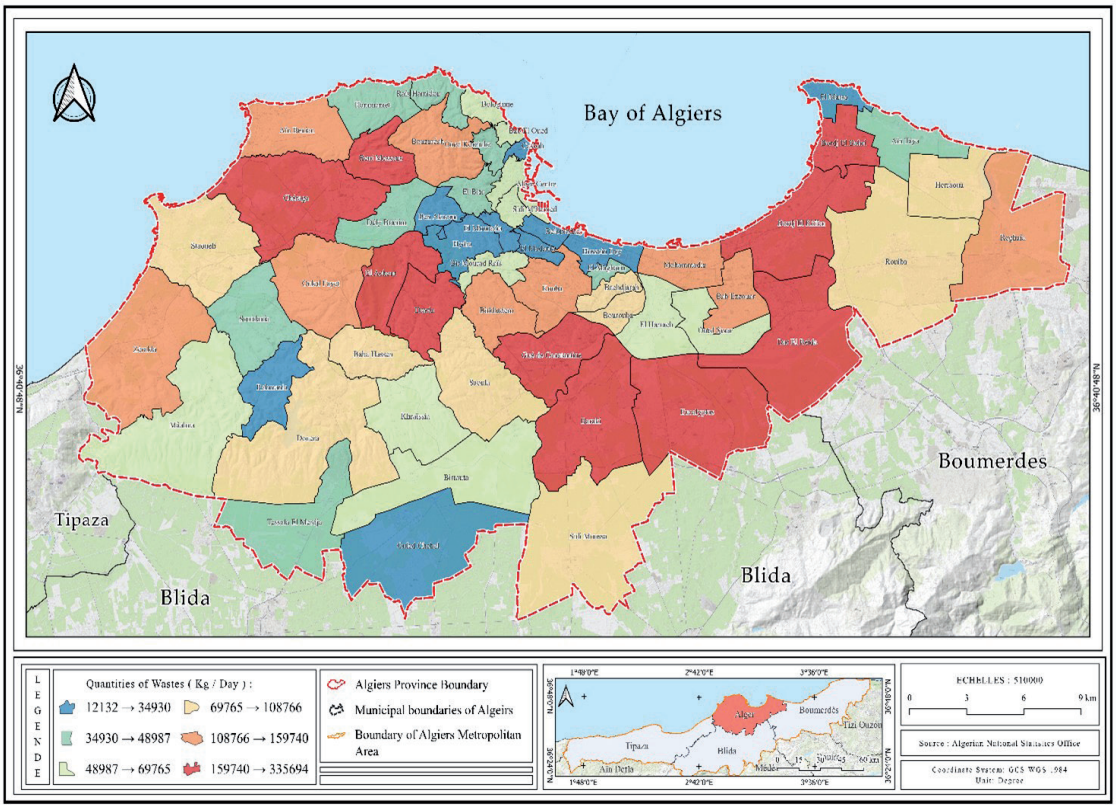


Fig. 7. Production of household waste per day in the province of Algiers by commune in 2020.

quantities in the Algiers province has been presented in the subsequent map (Fig. 7).

The Fig. 7 shows the distribution of the quantity of waste produced in each commune of the province. There is a reciprocal relationship between these two factors: the higher the number of inhabitants in a commune, the higher the quantity of waste produced, and vice versa. So the increase in the rate of waste production takes accounts of the fact that as the urban population increases, so does the rate of waste production.

We conclude that population growth is one of the factors influencing household waste production, as shown in Fig. 8. Using ArcGIS 10.8, we can produce maps that allow us to compare the quantity of waste and the population, which allows us to better analyze and understand the situation. The results areas follows (Fig. 8).

The communes with the highest populations produce more waste such as Algiers Center, Birtouta Hussein dey el Biar, and the communes with lower populations produce less waste.

## Analysis of the Field Survey in February-May 2022

It is challenging to ascertain the present status of household waste within the entire province of Algiers.

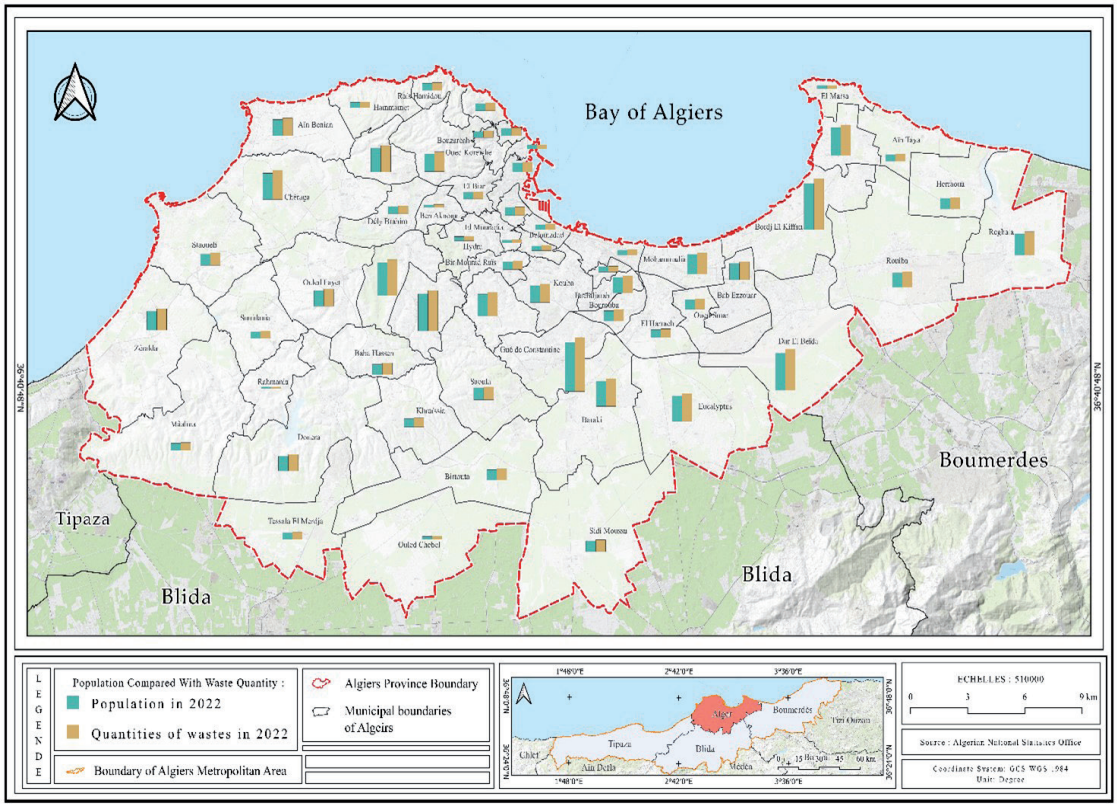


Fig. 8. Population distribution and quantity of waste per municipality.

In our study, it is imperative to consider the findings of a household survey conducted between February 2022 and May 2022.

## Profile of Participants

The survey encompassed 168 individuals from diverse communes. Data collection took place over a period, from February 10 to May 27. Distribution of participants based on geographical location: All participants resided in the province of Algiers, spanning 38 communes as detailed below.

### *Pre-Collection*

In order to enhance waste management efficacy, the government has allocated the necessary resources and tools for waste collection, such as collection vehicles and personnel. It is important to distinguish between the concepts of collection and pre-collection. Pre-collection encompasses all activities conducted prior to waste pickup by the waste collection service. One example of a pre-collection task is the act of placing the bin outside on the public road.

### *Throwaway Days*

Interrogated survey participants regarding the specific days of the week they discarded their household waste. The data revealed that a significant majority, According to Fig. 9, 85,11% of respondents, disposed of their rubbish on a daily basis, signifying a daily disposal routine. The remaining 14,88% acknowledged not disposing of their household waste daily.

### *Opening Times*

Observations indicated (see Fig. 10) that 32% of participants engaged in waste disposal activities in the morning, while 29% preferred disposing of their rubbish after 8 pm, categorizing it as a nighttime activity. Furthermore, 27% exhibited variability in the timing of waste disposal, and a final 12% opted for

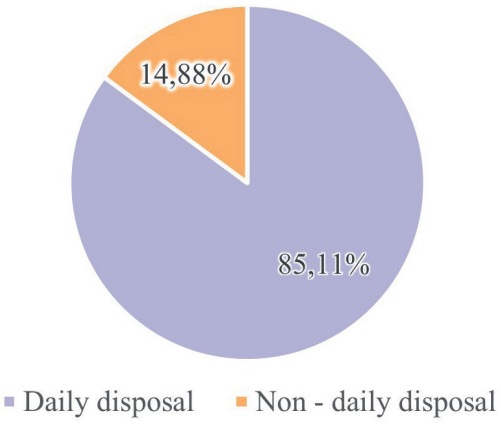


Fig. 9. Throwaway days.

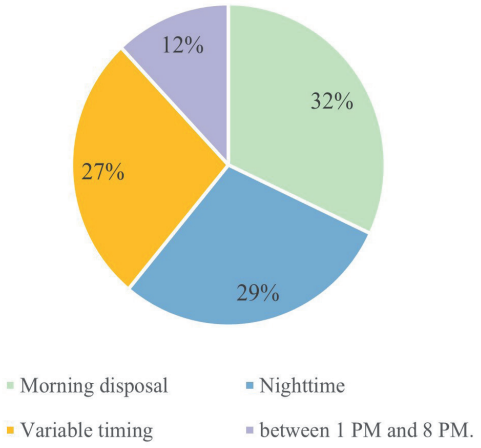


Fig. 10. Opening Times.

evening disposal between 1 pm and 8 pm. In essence, approximately one-third of the surveyed individuals disclosed their inclination toward morning waste disposal. Noteworthy is the fact that other popular disposal timings include post-8 pm disposal (29%), variable disposal timings (27%), and evening disposal between 1 pm and 8 pm (12%).

*Collection Method*

The survey findings highlighted that a substantial 73,21% of the total respondents, equating to 123 individuals, reported waste collection occurring at designated grouping points within their locality. Conversely, the remaining 26,78% indicated the presence of door-to-door waste collection services (Fig. 11).

In summary, an overwhelming majority, accounting for almost three-quarters of the surveyed population, availed of waste collection services at centralized collection points within their respective administrative regions. A smaller fraction, slightly over a quarter,

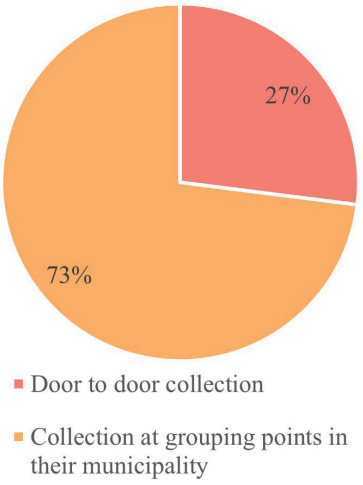


Fig. 11. Collection Method.

opted for the convenience of doorstep waste collection services.

*Volume and Number of Litter Bins*

The capacity and quantity of litter bins deployed in an area are contingent upon various factors such as area size, resident count, and the volume of waste generated within the locality. Several respondents expressed dissatisfaction with the adequacy of both the number and size of litter bins available to accommodate the generated waste. Notably, 65 respondents believed that the size of the litter bins sufficed to contain the waste volume, while a majority, comprising 103 individuals, contested this assertion. Conversely, 53 participants opined that the existing number of waste containers was adequate, in contrast to the remaining 115, who deemed the quantity insufficient to cater to the populace's waste disposal necessities.

*Condition of Litter Bins*

The operational efficiency of the waste collection process is influenced by the mechanical state of the containers utilized. Optimal container conditions significantly reduce the time taken for emptying, minimize the physical exertion demanded from the cleaner, and avert spillage or waste accumulation in the vicinity during collection. Statistical analysis unveiled (Fig. 12) that approximately 45,23% of the containers were deemed to be in good condition, whereas containers categorized as average constituted 48,8% of the total, with 5,95% classified as poor and necessitating maintenance.

## Distance Traveled to the Nearest Bin

Proximity and accessibility of waste bins to residential areas are crucial to preventing illegal dumping. The survey findings indicate that the majority of respondents (42,8%) travel a distance ranging from 10 to 50 meters to dispose of their waste, while the rest are divided between less than 10 meters (36,3%) and over 30 meters (20,8%).

*An Act of Population*

People want to get rid of their rubbish as quickly as possible, even if it means throwing it anywhere. At the same time, many residents can no longer stand the containers, especially when they are full.

60,71 of respondents to the questionnaire admitted that they throw their rubbish on the groundwhen there is no space in the containers.

*Transporting Waste*

The transportation of waste is a critical component in various stages of waste management, encompassing

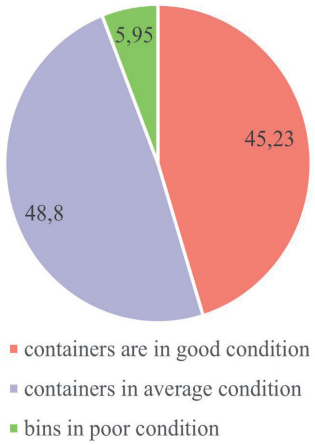


Fig. 12. Condition of Litter Bins.

production and treatment processes. The primary objective revolves around ensuring the traceability of waste materials. Public opinion on waste collection services: Divergent views exist regarding waste collection services, with half of the respondents expressing concerns about the frequency of collection cycles not aligning with the waste volume, while the others hold opposing views.

## Discussion

### Utilization of GIS Tools for Waste Management in Algiers Province

Geographic Information System (GIS) technology [40] has been effectively applied in waste management practices, aiding in tasks such as site selection for transfer facilities and landfills, as well as optimizing waste transportation and collection processes.

Integration of data elements in the GIS system:

The selection of geographical attributes within the municipal waste management framework of Algiers includes general province data, demographic information, waste collection site data, resident data, waste management operator data, and landfill site data.

#### *Geographic Database Structure*

A geographic database serves as a structured data repository that facilitates the storage and retrieval of information for multiple users. Geographic databases play a crucial role in organizing and managing geographic data in digital formats.

#### *Modeling the Geographic Database*

The Geographic Database Model (GDMB) serves as a comprehensible representation for describing information systems. This model aids in formalizing the information stored within the GIS, particularly in the context of waste management practices.

#### *Functionality of Waste Management GIS*

The Waste Management GIS encompasses a geographic database with thematic layers, enabling data entry, quality control, spatial analysis, and cartographic visualization. This tool supports the activities of local departments involved in waste management operations.

#### *Database Creation Process*

The practical study consists of four key phases, beginning with the establishment of a database that incorporates spatial and attribute data. Spatial data includes information on geographical features, collection points, and the road network.

#### *Key Findings of the Study*

The analysis reveals that organic waste accounts for over 53.61% of solid household waste in Algiers province. Disparities exist in the distribution of collection points across different sectors, leading to residents traveling long distances to dispose of their waste.

### Role of GIS in Waste Management Decision-Making

GIS tools play a crucial role in decision-making processes related to waste management, offering capabilities such as determining bin requirements based on household quantities, optimizing collection routes, and identifying suitable landfill locations [40].

#### *Significance of Integrated GIS Tools for Waste Management*

Establishing a database for solid waste management using integrated GIS technologies enhances data organization, analysis, and problem-solving capabilities [41]. This approach facilitates the identification of optimal collection point locations based on environmental factors and waste generation rates.

#### *Community Involvement in Waste Management*

Effective waste management practices necessitate active community participation [42] and awareness campaigns. Various initiatives can be undertaken to raise awareness about waste management, including promoting waste sorting, recycling, and composting among residents [43].

*Educational Strategies for Waste Management Awareness*

Educating individuals about responsible waste disposal practices, recycling, and composting is crucial. Awareness campaigns can target different groups, such as waste handlers and schoolchildren, to instill sustainable waste management habits from an early age.

*Waste Management: Key Benefits*

Effective household waste management provides a multitude of environmental, economic, and societal advantages. The conversion of organic waste into compost enhances soil fertility and diminishes reliance on chemical fertilizers, thereby fostering sustainable agricultural practices [44, 45]. Furthermore, the reuse of materials like plastic, glass, and paper diminishes landfill waste, leading to a decrease in greenhouse gas emissions and the conservation of natural resources. The incorporation of geographic information systems (GIS) in waste management [46] enables the visualization and examination of waste data, streamlining the planning of collection and treatment procedures [47]. GIS furnishes decision-making tools that optimize collection routes and pinpoint areas requiring special attention, thereby enhancing the efficiency of interventions. This strategy also stimulates job creation in waste management sectors and yields cost savings for local authorities by reducing transportation and treatment expenses [48, 49]. By embedding these strategies within a circular economy framework [50, 51], where materials are reused continuously, we can not only lessen waste production but also enhance citizens' quality of life and foster a more sustainable tomorrow [50, 52, 53].

## Conclusions

The investigation was carried out to evaluate the present state of waste control in the specified region (Algiers Province) and to identify the factors that impact this control by means of diverse surveys and examinations. Thus, the accomplishment of the research goal was effectively illustrated through the utilization of the suggested approach, which relied mainly on the correlation among data gathering. Additionally, a meticulously planned, organized survey was employed to obtain initial data with the purpose of establishing a digital repository (DGMB).

Today, the prioritization of environmental preservation has arisen due to the recognition of the environment as the fundamental source of all life on Earth. The disposal of waste into the natural environment on a daily basis stands out as a primary contributor to ongoing pollution issues, posing a significant challenge for Algerian municipalities, particularly those within the province of Algiers. Our research endeavors focused on investigating the waste management practices within the province of Algiers, conducting a thorough assessment of the current state, analyzing emerging policies, forecasting waste quantities, and determining the necessary steps for enhancing this service. Additionally, a case study demonstrating the utilization of a geographic information system to spatially represent diverse data sources was presented within a research initiative on solid waste management.

Upon engaging in a comprehensive exploration of the subject matter, we arrived at a conclusion that substantiated the validity of our initial hypotheses.

The utilization of geographic information systems in household waste management was elucidated, emphasizing their role in facilitating informed decision-making processes crucial for the enhancement of waste management initiatives.

The province of Algiers has shifted its waste management strategy towards a new trajectory, resulting in notable advancements. By incorporating geographic information systems alongside conventional methods, the province aims to achieve superior outcomes in waste management optimization.

Geographic databases play a pivotal role in structuring and managing geospatial data in a digital format, enabling the organization and modeling of objects and phenomena within spatial contexts, including their attributes and interconnections. The formalization of data descriptions within a geographic database model is integral to the functioning of a geographic information system.

In this manner, Geographic Information Systems (GIS) streamline the organization of waste management data efficiently, with geographic databases serving as essential components for spatial analysis of phenomena.

Based on the outcomes of our study, we anticipate the practical implementation of these concepts, advocating for the integration of GIS to bolster decision-making processes and mitigate the adverse impacts of household waste on both individuals and the environment.

## Acknowledgement

The authors warmly thank the editor and the anonymous reviewers for their careful proofreading and editing which considerably improved the quality of the manuscript.

## Conflict of Interest

The authors declare no conflict of interest.

## References

1. DURAND J. La gestion des Déchets dans les pays développés. Paris: PUF, **2020**.
2. MARTIN L., DUPONT C., GERMAIN A. Les conséquences environnementales de la surproduction de

déchets. Géographie Environnementale, **12** (3), 5, **2019**.
3. KHATIB I.A. Municipal solid waste management in developing countries: Future challenges and possible opportunities. Integrated Waste Management, **2**, 35, **2011**.
4. WANG Y., SHI Q. The impact of municipal solid waste sorting policy on air pollution: Evidence from Shanghai, China. Plos One, **17** (11), e0277035, **2022**.
5. Gestion des déchets solides : risques et opportunités. Edition de l'Environnement, **2020**.
6. ABDEL-SHAFY H.I., MANSOUR M.S. Solid Waste Issue: Sources, composition, disposal, recycling, and valorization. Egyptian Journal of Petroleum, **27** (4), 1275, **2018**.
7. MINISTÈRE DE L'ENVIRONNEMENT ALGÉRIEN Rapport national sur l'état de l'environnement 2016-2017, **2018**.
8. AGENCE NATIONALE DES DÉCHÊTS Rapport sur la gestion des déchets ménagers et assimilés, **2017**.
9. CENTRE NATIONAL DE L'ETUDES ET DE RECHERCHES APPLIQUEES EN URBANISME (BUREAU D'EUDE). Schéma Directeur Des Déchets Solide de la wilaya d'Alger, **2008**.
10. YAPI A.C., TOKPA M.D., COULIBALY S. Gestion des déchets ménagers et risques sanitaires dans la ville de Dimbokro, **2021**.
11. SAIFI M., AZEM S., TALEB F. Évolution de la production des déchets ménagers en Algérie de 2010 à 2020. Revue des Sciences et de la Technologie, **8** (2), 10, **2020**.
12. OFFICE NATIONAL DES STATISTIQUES Données démographiques de l'Algérie Office National des Statistiques, Alger, **2020**.
13. BENZERROUK S., KERBACHI R., BOUGHEDAOUI M. Mesures socio-économiques pour la réussite des programmes de gestion des déchets en Algérie. Revue des Sciences Sociales, **12** (1), 45, **2018**.
14. MAIZI A., BENKADA F., DAOUDI R. Apport des SIG pour une gestion optimisée des déchets ménagers : cas de la ville d'Oran Revue des Sciences de l'Information géographique, **5** (2), 35, **2022**.
15. MINISTÈRE DE L'ENVIRONNEMENT ALGÉRIEN Stratégie nationale de gestion intégrée des déchets 2021-2035. Ministère de l'Environnement Algérien, Alger, **2020**.
16. JOHARI A., AHMED S.I., HASHIM H., ALKALI H., RAMLI M. Integrated technologies for solid waste bin monitoring system. Environmental Monitoring and Assessment, **186** (9), 5663, **2014**.
17. SINGH S., BEHERA S.N. Development of GIS-based optimization method for selection of transportation routes in municipal solid waste management. Springer, **2019**.
18. ABADI D.J., MADDEN S.R., HACHEM N. Column-stores vs. row-stores: how different are they really? Proceedings of the 2008 ACM SIGMOD International Conference on Management of Data, **2008**.
19. CETIN M., JAWED A.A. Variation of Ba concentrations in some plants grown in Pakistan depending on traffic density. Biomass Conversion and Biorefinery, **14** (3), 3785, **2024**.
20. AISHA A.E.S.A. Determination of boron for indoor architecture plants used in indoor architectural designs. Scientific Research Communications, **3** (2), **2023**.
21. CETIN M., ABO AISHA A.E.S. Variation of Al concentrations depending on the growing environment in some indoor plants that used in architectural designs. Environmental Science and Pollution Research, **30** (7), 18748, **2023**.
22. CESUR A., ZEREN CETIN I., CETIN M., SEVIK H., OZEL H.B. The use of Cupressus arizonica as a biomonitor of Li, Fe, and Cr pollution in Kastamonu. Water, Air, & Soil Pollution, **233** (6), 193, **2022**.
23. CICEK N., TUCCAR M., YUCEDAG C., CETIN M. Exploring different organic manures in the production of quality basil seedlings. Environmental Science and Pollution Research, **30** (2), 4104, **2023**.
24. TEKIN O., CETIN M., VAROL T., OZEL H.B., SEVIK H., ZEREN CETIN I. Altitudinal migration of species of Fir (Abies spp.) in adaptation to climate change. Water, Air, & Soil Pollution, **233** (9), 385, **2022**.
25. VAROL T., CETIN M., OZEL H.B., SEVIK H., ZEREN CETIN I. The effects of climate change scenarios on Carpinus betulus and Carpinus orientalis in Europe. Water, Air, & Soil Pollution, **233** (2), 45, **2022**.
26. CETIN M., ISIK PEKKAN O., BILGE OZTURK G., CABUK S.N., SENYEL KURKCUOGLU M.A., CABUK A. Determination of the impacts of mining activities on land cover and soil organic carbon: Altintepe Gold Mine Case, Turkey. Water, Air, & Soil Pollution, **234** (4), 272, **2023**.
27. CETIN M., ISIK PEKKAN O., BILGE OZTURK G., SENYEL KURKCUOGLU M.A., KUCUKPEHLIVAN T., CABUK A. Examination of the change in the vegetation around the Kirka Boron mine site by using remote sensing techniques. Water, Air, & Soil Pollution, **233** (7), 254, **2022**.
28. ZERHOUNI M., ZELMAT M., DIAB Y.A. GIS-based methodology for an optimized municipal solid waste collection system in Setif, Algeria. Journal of Environmental Management, **267,** 110622, **2020**.
29. CETIN M., ALJAMA A.M.O., ALRABITI O.B.M., ADIGUZEL F., SEVIK H., ZEREN CETIN I. Determination and mapping of regional change of Pb and Cr pollution in Ankara city center. Water, Air, & Soil Pollution, **233** (5), 163, **2022**.
30. CETIN M., AKSOY T., BILGE OZTURK G., CABUK A. Developing a model for the relationship between vegetation and wind power using remote sensing and geographic information systems technology. Water, Air, & Soil Pollution, **233** (11), 450, **2022**.
31. HIDALGO-CRESPO J.A., VELASTEGUI-MONTOYA A., SOTO M., AMAYA RIVAS J. L., ZWOLINSKI P., RIEL A., RIVAS-GARCÍA P. Improving urban waste management: A comprehensive study on household waste generation and spatial patterns in the Grand Guayaquil Metropolitan Area. Waste Management & Research, 0734242X241262714, **2024**.
32. HAERANI D., BUDI S.S. Review modeling of solid waste transportation routes using Geographical Information System (GIS). EDP Sciences, **2019**.
33. LE HOANG T., PHAM T.H., VO N.Q.T., NGUYEN N.T., DANG N.D.P., TRAN T.N., NGUYEN K.L. GIS Application in Environmental Management: A Review. VNU Journal of Science: Earth and Environmental Sciences, **39** (2), **2023**.
34. RAFIAANI P., KADRI B., NURUL S.B., SHARIFAH MASHITA S.M., DAUD M. GIS-based decision support system for municipal solid waste management in Malaysia. Proceedings of the International Conference on Computational Science and Its Applications (ICCSA), **2018**.
35. MAGOURA A., DEHIMI S., REDJEM A.A GIS-based multi-criteria evaluation of landfill site selection in the region of Hodna, Algeria. Journal of Degraded & Mining Lands Management, **10** (4), **2023**.

36. SLIMANI A., BAHRI W., DJEMAI S. Assessment of the environmental and health impacts of solid waste: A case study of the city of Skikda, Algeria. Journal of Environmental Health Science and Engineering, **19** (2), **2021**.
37. OFFICE NATIONAL DES STATISTIQUES La démographie de la ville d'Alger 1830-1954. Office National des Statistiques, Alger, **1975**.
38. BOUCHAREB A. Dynamiques démographiques en Algérie depuis l'indépendance. Insaniyat, **3** (79-80), 167, **2018**.
39. AGENCY N.W. Rapport sur l'Etat de la Gestion des Déchets en Algerie, **2020**.
40. LONGLEY P.A., GOODCHILD M.F., MAGUIRE D.J., RHIND D.W. Geographic Information Science and Systems. Wiley, **2015**.
41. BÉDARD Y., PROULX M.-J., RIVEST S., BADARD T. Merging hypermedia functionalities into spatial data infrastructures. Developments in Spatial Data Handling Springer Berlin Heidelberg, 131, **2005**.
42. TU X., ZHANG X. How Waste Sorting Has Been Implemented in Urban Villages in China. A Co-Production Theory Perspective. Polish Journal of Environmental Studies, **33** (3), 2345, **2024**.
43. MBAT C.O., BANGA M.A., HANXAI P. Electronic waste management and recycling challenges in Africa. Journal of Material Cyagement, **21** (1), 1, **2019**.
44. MALAL H., ROMERO V.S., HORWATH W.R., DORE S., BECKETT P., AIT HAMZA M., LAKHTAR H., LAZCANO C. Vermifiltration and sustainable agriculture: unveiling the soil health-boosting potential of liquid waste vermicompost. Frontiers in Sustainable Food Systems, **8**, 1383715, **2024**.
45. KULIGOWSKI K., KONKOL I., ŚWIERCZEK L., CHOJNACKA K., CENIAN A., SZUFA S. Evaluation of kitchen waste recycling as organic N-fertiliser for sustainable agriculture under cool and warm seasons. Sustainability, **15** (10), 7997, **2023**.
46. GOPAL D., MIR A.H.T., KOMAL., IMTIAZ C. Municipal Solid Waste Management using GIS Analysis: A Case Study of Sehwan City. Sir Syed University. Research Journal of Engineering and Technology, **13** (1), 17, **2023**.
47. YESHITELA K., CILLIERS S.S. Spatial modelling for municipal solid waste disposal site selection using geographic information system and analytical hierarchy process: Case of Debre Tabor Town. Journal of Environmental Management, **245** (1), 1, **2019.**
48. YESHITELA Y. Optimized municipal solid waste disposal site selection by integrating GIS- MCDM techniques in Debre Tabor Town. Environmental Systems Research, **10** (1), 1, **2021**.
49. TOLBA T., MORONCINI A., KEHILA Y. Le recouvrement des coûts: un défi pour une gestion durable des déchets ménagers en Algérie: cas de la Commune d'Annaba. Liège (Belgium): CIRIEC International, Université de Liège, **2020**.
50. VISCUSI W.K., HUBER J., BELL J. Changes in household recycling behavior: Evidence from panel data. Ecological Economics, **208**, 107819, **2023**.
51. GUIDE D'AMÉLIORATION DE L'IMPLANTATION DES POINTS D'APPORT VOLONTAIRE Une approche globale du système, Eco-emballage, Expertise ADELPHE recyclage, **2012**.
52. DAS S., LEE S.-H., KUMAR P., KIM K.-H., LEE S.S., BHATTACHARYA S.S. Solid waste management: Scope and the challenge of sustainability. Journal of Cleaner Production, **228**, 658, **2019**.
53. WIKURENDRA E.A., CSONKA A., NAGY I., NURIKA G. Urbanization and Benefit of Integration Circular Economy into Waste Management in Indonesia: A Review. Circular Economy and Sustainability, 1, **2024**.