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THE IMPACT OF LANDFILL DIVERSION ON LAND USE AND LIFESPAN: A CASE STUDY OF THE BOUGHAREB TECHNICAL LANDFILL CENTRE IN CONSTANTINE, ALGERIA

Imen SOUKEHAL*
Urban Techniques Management Institute, University Salah Boubnider Constantine 3 PO Box N°73 New City Ali Medjeli, Ain Lbey, Constantine, Algeria, e-mail: imen.soukehal@univ-constantine3.dz

Roukia BOUADAM
Urban Techniques Management Institute, University Salah Boubnider Constantine 3 PO Box N°73 New City Ali Medjeli, Ain Lbey, Constantine, Algeria, e-mail: roukia.bouadam@univ-constantine3.dz

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Abstract: Land filling is one of the most common methods of disposing of solid waste all over the world, however, with constantly increasing waste volumes and land scarcity, waste diversion and recovery are more likely the best answer to these concerns. This research paper presents an estimation of the diversion impact on the required land area and on the lifespan of a technical landfill centre (TLC) in Constantine, Algeria. Our methodology consists in drawing up three scenarios of operation of TLC, over a period of 15 years, with each scenario, applying a different waste diversion rate, results show that: waste diversion reduces land consumption and increases the TLC's lifespan in all three scenarios but diverting for composting is the most efficient one.

Key words: Technical Landfill Centre, Waste Diversion, Land Use, Lifespan, Households and Similar

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INTRODUCTION

Developing and developed countries are facing increasing population growth, industrial development, financial progress and improvement, which are main factors, associated with production of huge amount of solid waste especially in the fast growing cities and urban dwellings (Akhtar et al., 2017). The disposal and management of municipal solid waste (MSW) is one of the most pressing issues confronting cities around the world. To ensure the protection of public health and the environment, effective solid waste management requires the use of a variety of treatment methods and technologies (Reza et al., 2013).

Land-filling is one of the dominant options for solid waste disposal all over the world (Laner et al., 2012). Landfills are the most environmentally friendly final destination for waste, but only waste that has no chance of being reused, recycled, or converted into energy should be disposed of there (Carević et al., 2021). However, landfills can pose serious risks to human health

*Corresponding author

and the environment, not designed or managed properly: in developing countries, the discharge of heavy metals into the ecosystem would have been decreased, but the use of landfills as a waste disposal method has been a big issue (Eludoyin and Gafar, 2020).

Landfills have been widely used for various reasons, which include their exploitation simplicity, low investment, and cheap operating costs (Vaverková et al., 2018), some studies indicated that almost 95% of municipal solid waste (MSW) was disposed of by land filling worldwide (Ghosh et al., 2015).

In Algeria, uncontrolled open dumping waste disposal has been applied for decades to dispose of solid waste, for many reasons including: low investment and low operation costs, but since 2001, the ministry in charge of environment has promulgated the first law on: management, control and waste elimination, and launched a national program of municipal solid waste management, whose objectives include: elimination of uncontrolled dumping sites, promoting recycling and selective sorting activities. Moreover, this program aims to ensure that solid waste is collected, stored and disposed of in a manner that guarantees public health and environment protection. According to Algerian regulations, MSW is identified as of household and similar waste (HSW), the total generation of HSW, in Algeria in 2018, is about 13.1 million tonnes with a rate of 0.8 kg/inhabitant/day (AND, 2019). According to a report published by the National Waste Agency: waste sorting and recovery could generate economic gains exceeding 56 Billion Algerian Dinars, thousands of job opportunities and rationalize the use of land required for land filling (AND, 2021).

Today, despite all the efforts made in the field of solid waste management, HSW is a major environmental issue in Algeria, as it is in many developing countries. The impact of dumping solid waste in uncontrolled landfills, population growth in urban communities, increases in per capita HSW generation rates, gaps in current related legislation, lack of strategic planning, limited collection services, lack of know-how, inappropriate technology and the inadequate financing are all major challenges facing solid waste management (AND, 2019). All HSW are collected in a mixed form without source sorting, which reduces the possibility of recycling and recovery and puts pressure on the capacity of the landfill which will push the authorities to build more landfills and thus consume more land. The choice of waste disposal technology is a key issue in the field of solid waste management; this decision may have long-term consequences for environmental development and economic growth (Torkayesh et al., 2021).

Land management and conservation objectives should be the foundation for proper landfill management. To limit landfill capacity loss, this should entail controlling the site to ensure that unsuitable waste is not accepted and the nature of received waste is known, as well as diverting waste that can be recycled or reused from landfills. Several research indicates that waste land-filling can be reduced by diverting recyclable waste fraction to alternative beneficial uses (Ajayi and Oyedele, 2017; Assamoi and Lawryshyn, 2012; Mueller, 2013; Smith, 2015), diverting waste from landfills is an important factor in increasing resource efficiency, reducing waste management's environmental impacts and increasing land availability. According to the United Nations Environment Programme, diverting organic waste from landfills can decrease methane emissions by 15-20 percent (Wilson et al., 2015), several countries have already started to encourage waste diversion from landfills, for example recycling and recovery are encouraged by European waste legislation, while disposal is avoided (Scharff, 2014) according to the Directive 1999/31/EC on landfill of waste: member states of the European Union, must reduce the amount of biodegradable municipal waste going to landfill to less than 35% (EEA, 2009). In Algeria, most of (HSW) are disposed in technical landfill centres or controlled disposals, only 7% of the global waste amount are recovered and recycled.

This study was carried out in 2017 in Boughareb technical landfill centre, a class II TLC for household and similar wastes, located in the Wilaya of Constantine, eastern of Algeria. The study's major aim is to shed light on the relationship between waste diversion from landfills and the availability of land required for this operation. The information it will provide is of interest on two levels: at the local level, this data is necessary for better management of the Bouhareb TLC, and at the national level, it can provide state authorities with a different perspective on Algeria's only mode of disposal of household and similar waste, i.e. landfill. Furthermore, despite the fact that many researchers in developed countries have already addressed this issue, it is still relevant in developing countries such as Algeria. Indeed, in Algeria technical landfills centres are a novel method for disposing of more than 90% of waste generated in all the country. Despite the fact that landfilling consumes a significant quantity of land in Algeria, that's the only method of eliminating household and similar waste. Land is a scarce resource whose sustainable use could lead to the good social and economic adaptation capacity of communities (Linc et al., 2017).

Waste management in Algeria

Algeria has a surface area of 2,381,000 km^2 and a population of roughly 43 million inhabitants. Solid waste generation is at a rate of 0.8 kg/person/day. With an annual growth rate of around 3%, the country now generates 34 million tonnes of waste, comprising 13.1 million Mt of HSW. In Algeria, the waste management policy is part of the National Environmental Strategy (NES), as well as the National Environmental and Sustainable Development Action Plan (PNAE-DD), which was concretised by the promulgation of law 01-19 of 12 December 2001 relating to the management, control and disposal of waste. It is based on the National Programme for Integrated Solid Household Waste Management (PROGDEM), which was adopted in 2002. Solid waste management in Algeria, is divided into three sectors (the public sector, the formal private sector, and the informal private sector) (Swep-net, 2014):

- The public sector which is in charge of controlling and enforcing solid waste management and collection rules in communes;
- The official private sector which is involved in waste management, including collection and recycling;
- The informal private sector which is active in waste recovery.

Waste production and population growth in Algeria

Driven by significant demographic growth combined with a change in consumption patterns and a concentration in cities, in 2018, according to statistical data published by the national statistics office (ONS, 2018) more than 70% of Algeria's 42.22 million inhabitants were urban; whereas in 2014, the urban population was estimated at 65% (ONS, 2019). As for the production of waste per inhabitant, it has increased from 0.76 kg/d/h in 1980, to 0.8 kg/d/per inhabitant in 2018. The evolution of the population has been accompanied by a considerable increase in household and similar waste, after seven years (from 2011 to 2019), it has increased from 3.9 MT to 13 MT with a growth rate of about 3% per year (table 1).

Table 1. Population growth and waste generation in Algeria
(Data source: ONS & AND)

Years	Population M In.	Waste generation MT
2011	36.3	3.9
2014	39.1	11
2016	39.6	11.6
2018	42.23	13

Waste composition and disposal in Algeria

The 2018 waste characterization report shows that: 53.6% of waste composition is organic, plastic represents 15.2%, paper and cardboard are about 7.07%, disposal dippers are 11.5%, textile is 4.5%, and metal is about 1.72% (AND, 2019). Despite the fact that household and similar waste in Algeria includes large quantities of biodegradable materials which, when land-filled, this waste pose significant difficulties from a technical (operational), ecological, and economic point of view, we note that the most common method of disposing of collected solid waste is land-filling: up to 95% of waste produced is dumped in various technical landfill centres and controlled dumpsites, without pre-treatment (AND, 2019). In Algeria, there are three classes of technical landfill centres (TLC): class I TLC for hazardous and special wastes, class II TLC for household and similar wastes (HSW) and class III TLC for inert wastes. Class II landfills are defined in Algeria as classified facilities designed for the storage of waste while minimizing the risks of pollution or contamination of the environment. The Algerian government has made significant investments in waste treatment facilities during the previous two decades. By 2020, around 221 treatment facilities have been built, with 191 of them already in service. Between 2014 and 2020, the number of operating waste treatment facilities in Algeria climbed from 141 to 191. This evolution is linked to demographic growth and economic development. Depending on the available acreage, each landfill typically consists of one to three or more cells (figure 1).

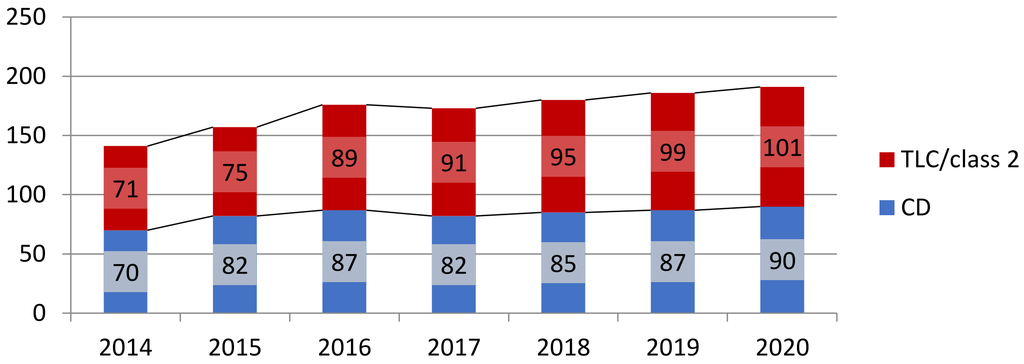


Figure 1. Evolution of HSW treatment facilities 2014-2020)
(Source: AND, 2021)

In 2020, there are 280 cells nationwide, 62 of which have achieved saturation and are thus closed, 197 of which are operational, and 21 that have been established but are not yet operational, figure 2 shows that, of the 197 cells in operation, 87 are between 50% and 100% saturated, 24 are saturated and 25 are oversaturated. This reflects a critical situation in terms of life span and future land consumption (AND, 2021).

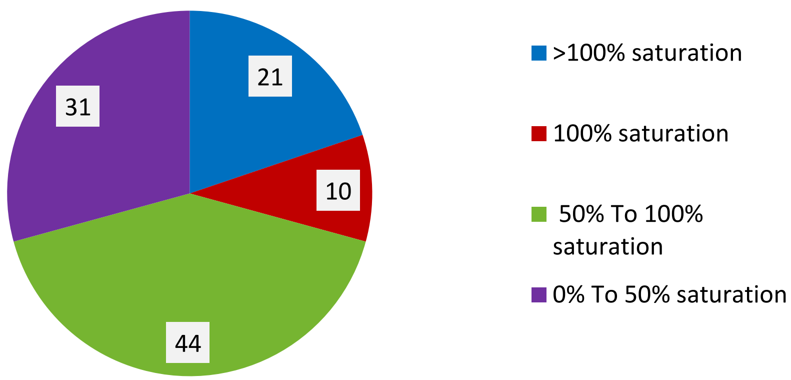


Figure 2. Cell's saturation rate (2020)
(Source: AND, 2021)

MATERIALS AND METHODS

Study area

As shown in figure 3, the study area is a technical landfill centre (TLC) in the wilaya of Constantine, in the East of Algeria, called Boughareb TLC. This class II (TLC) is located 40 Km EST of the wilaya of Constantine, precisely in Ibn Badis municipality. The geotechnical study carried out on the TLC site yielded the following results:

- The topography of the site is moderately uneven, with a slope ranging from 3 to 10%;
- The geological structure is not homogeneous: clay and sandstone are found together;
- Clays have extremely high impermeability indices, ranging from 10-6 to 10-9 cm/s;
- The sandstone has a strong compressive resistance.

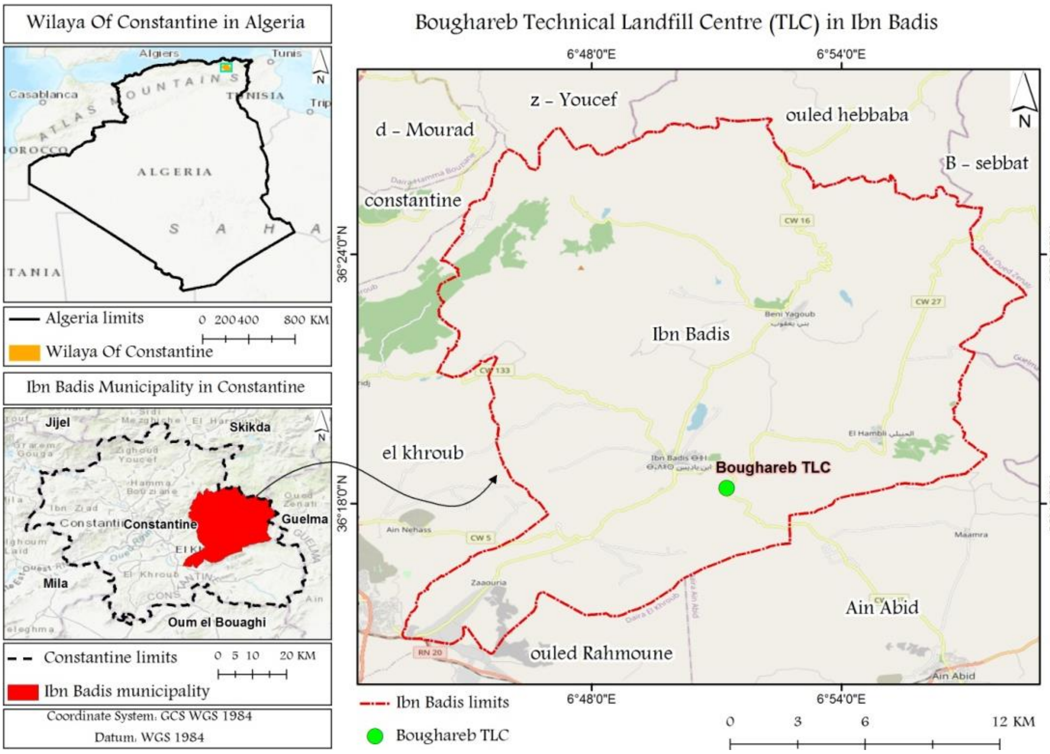


Figure 3. Localization of the study area
(Source: Authors)

Given the unavailability of land capable of housing a project as large as the TLC project, the choice of the municipality of Ibn Badis was imposed despite: the slight unevenness of the site, its remoteness from the collection communes, the vocation of the neighbouring land (agricultural) the livestock activities surrounding it.

Boughareb TLC covers a total area of 78 ha, of which 41 ha are allowed for landfilling. Currently, it consists of only one (01) realized cell that spreads over an area of 3 ha, the remaining area allowed for landfilling is 39 ha. With a volume of 200,000 m³ and a total number of cells of 9, the overall landfill volume is 1,800,000 m³, this volume will be filled with 80% of compacted waste which represent 1,440,000 m³, and 20% of cover land which represent 360,000 m³.

Since the TLC has only been operated for 05 years from a 20 years estimated service life, the remaining period is 15 years.

Data collection

For this research paper, data was collected from variety of sources and covers the entire landfill's first cell life service (from 2010 to 2014), consultation of legislative documents, annual operational reports prepared by the undertaking in charge of operating the landfill, characterization reports prepared by the national waste agency, in-depth reading of scientific studies and articles, and on-site observation were all part of the data collection process.

Primary data was collected from the technical landfill management company since it is required to provide monthly reports on received waste from each municipality and an annual report on the recovered waste, it consists; the amount and type of the waste arriving on the landfill facility, as well as the waste provenance.

Secondary data includes: demographic data and the national characterization report, it was collected from the national waste agency (AND). Both data were examined and synthesized into Excel files, graphs and tables.

Data treatment

The method consists of setting up three possible scenarios for the operation of the TLC over a period of 15 years (2022-2036), in order to demonstrate the impact of the diversion of TLC waste on the consumption of land as well as its duration of operation. The first scenario is a reference situation; it is based on waste land filling with no diversion (diversion rate = 00%), it is an operating method that was already used for the first cell; this scenario is known as BAU scenario, or business as usual. The second scenario is based on the use of only recyclable materials that are present in waste streams arriving at the TLC (textile, plastic, cardboard), Scenario A will be assigned to this scenario. In the third scenario (scenario B): the diversion will only affect the organic fraction and will be used for composting. Table 02 shows the different filling scenarios.

Table 2. Filling scenarios for Boughareb TLC
(Data source: Authors)

Waste global volume entering to the TLC (m³)	Scenarios	Diversion rate	
		Recycling	Composting
9,110,271.62	Scenario BAU	0%	0%
	Scenario A	30.24%	0%
	Scenario B	0%	53.5%

However, the composition of waste admitted to the landfill has been only recorded for two years: 2011 and 2012. As a result, calculations will be based on data from the National Waste Agency's national characterization report established for the wilaya of Constantine for 2018. All of the equations used are listed below in chronological order.

"1" Waste diversion rate: WDR = (weight of diverted waste / weight of all waste) x 100.

"2" Landfill space: LFS = Σ (MSWT/ Waste density).

MSWT = Total Municipal solid waste disposed in the landfill (tonne): the equivalent of total household and similar disposed in the TLC (tonne).

Density of the waste = 0.75 tonne per cubic meter (t/m^3) (ME, 2018).

"3" Required Land Area (ha): RLA = Σ ({LFS/ Landfill height}/ 10000).

LFS: Landfill Space required annually in cubic meter per year (m^3/year).

Landfill height = standard height of landfill, Algerian standard = 15 meter (ME, 2018).

10,000 = the conversion of m^2 to hectare (ha).

Note that TLC area calculation is done using Gerard's recommended method from 1998, Eq.2 and Eq.3 were used (Uding Rangga et al., 2019).

RESULTS & DISCUSSION

The Boughareb technical landfill centre receives the waste generated by six of the twelve communes of the wilaya of Constantine, this waste is mainly composed of organic matter, which represents 53.50%, the recyclable fraction represents a total of 30.24%, and it is made up of: plastic, paper/cardboard and textiles (figure 4).

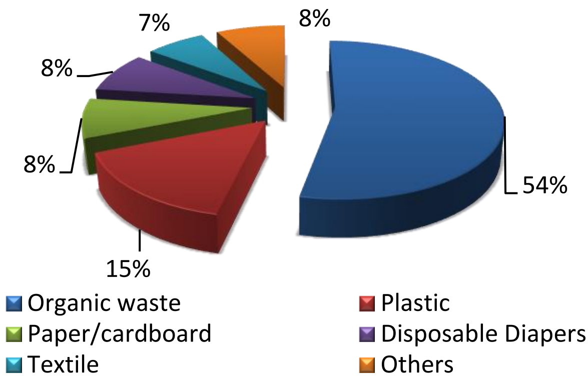


Figure 4. Constantine's waste composition 2018
(Source: AND, 2019)

Boughareb TLC is the only operational landfill in all the wilaya, it was receiving waste since 2010, from 06 municipalities: Constantine, ibnbadis, ainsmara, el khroub, ainabid and ouledrahmoun. Since it was put into operation, the quantity of waste admitted to the Boughareb landfill has steadily increased from 72,261.34 tons in 2011, to 331,930.5 tons in 2016, this increase is related not only to the parameters of population and consumption patterns but also the increase in the number of municipalities, which dump their waste in the landfill. There was a slight decrease in 2017 with 316,897.55 tons due to the commissioning of the transfer station in the municipality of Ain Smara, which is experiencing an evolving recovery activity.

Within the framework of the Study on the National Strategy and Action Plan for Integrated Waste Management and Recovery by 2035, the annual generation rate of household and similar waste was estimated at 3% (figure 5).

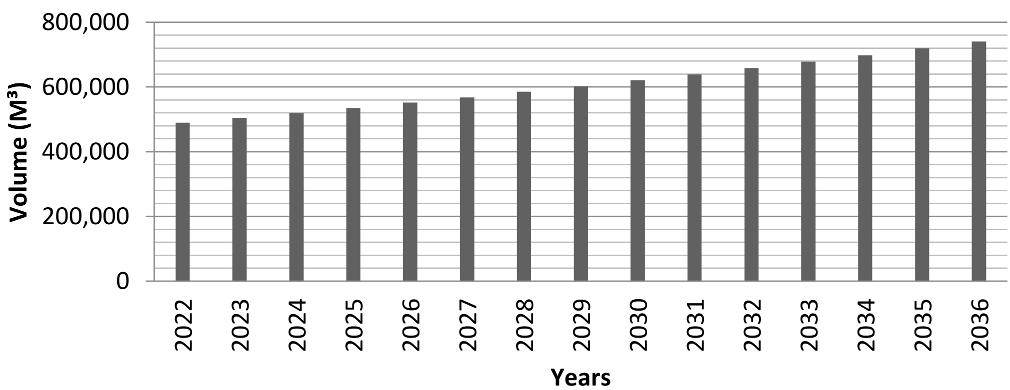


Figure 5. Amount land-filled waste at CET Boughareb
(Source: Author’s estimation)

As indicated in the data treatment section, three filling scenarios were developed. The BAU scenario is considered a reference. Under this scenario, there is no diversion. 100% of the waste will be landfilled, which represents 9,110,271.62 m³. The results show that the TLC will reach saturation (calculated at 1,440,000 m³), in 2 years and 313 days of operation, instead of the 15 years estimated in the technical study (figure 6).

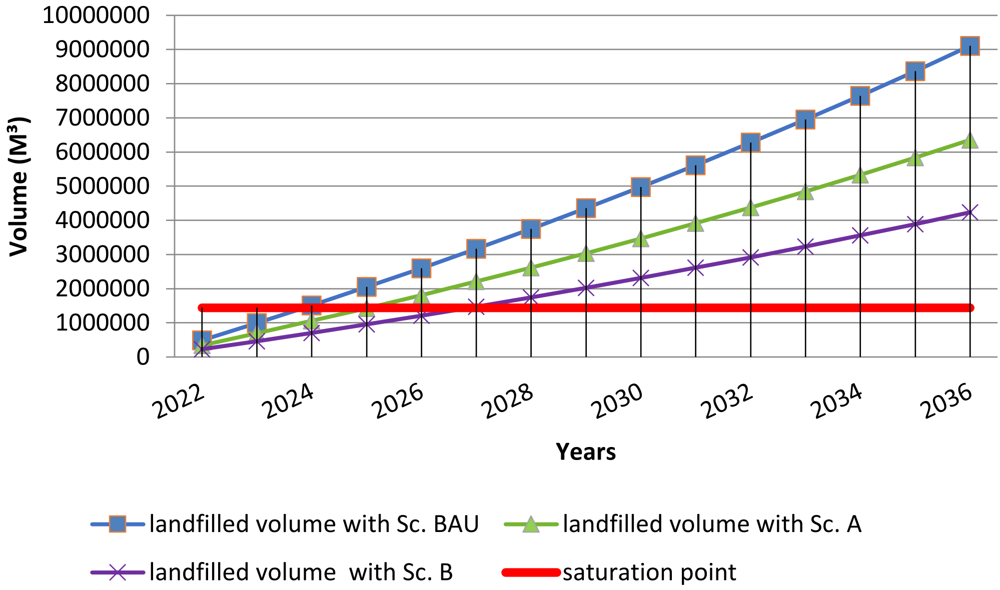


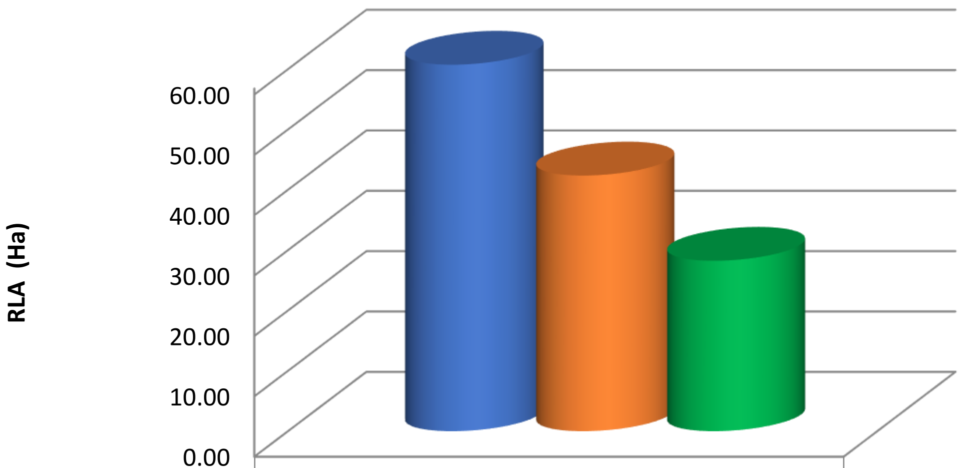
Figure 6. Filling scenarios for BougharebTLC
(Source: Author's estimation)

For scenario A, which is applied for a waste diversion rate of 30.24%, including only the recyclable fraction, the results indicated an operating time of 04 years and ≈ 10 days (9.90), instead of the 15 years estimated in the technical. The total amount of waste that needs to be land filled is 6,355,325.48 m³.

For scenario B the operating time obtained was 05 years and 319 days, instead of the technical study's projected 15 years. The total amount of waste that will be deposited in landfills is 4,236,276.30 m³.

The results support the positive impact of waste diversion on reducing the amount of waste entering the TLC, which helps to extend the operating life of the TLC, the scenario that includes composting has the greatest advantage, due to the important presence of organic matter in the waste streams that reach the TLC.

Landfilling is considered the most economical and acceptable method for disposing of waste, but even so, it generates toxic leachate and biogas, which are considered greenhouse gases, and comsume large land areas. Therefore, waste diversion from landfills is an important part of lowering waste management's environmental consequences and enhancing resource efficiency. The Boughareb TLC is intended to dispose household and similar waste over a 39-hectare area for 15 years. Data reveal that the BAU scenario will result in a land overconsumption of 60.74 hectares, or 21.74 hectares overrun. The functioning of the TLC under scenario A will also result in a 3.37 ha request land area (RLA) excess. The only scenario that matches the TLC technical study's estimations is scenario B, which requests for waste diversion for composting, land consumption under scenario B is estimated at 28.24 ha (figure 7).



	Total
RLA (Ha)/ Sc.BAU	60.74
RLA (Ha)/ Sc. A	42.37
RLA (Ha)/ Sc. B	28.24

Figure 7. Required land filling area
(Source: Author's estimation)

Because household waste and similar generation will increase, significantly larger land areas will need to be used for landfills. Waste disposal will necessitate a vast amount of land. The wilaya of Constantine extends over 224,549 hectares. In 2015, the land cover was: 61.69% for agriculture; 10.04% for built-up area; 9.81% for forest; 13.12% for grassland; 5.06% for water surfaces and 5.06% for barren land (Gana et al., 2017). Barren land is composed mostly of areas of exposed soil or areas with very little vegetation cover and includes bare rocks, quarries, and gravel pits. Their surface was estimated in 2015 at about 11,358 ha. They are the most suitable lands for building landfills. According to the results of this study and the land availability, the increased creation of household waste and similar in Constantine will necessitate the usage of a significantly larger area for waste disposal. The land demand will be so important that there will be a shortage of land required for land filling area. As a result, future crises will arise owing to the scarcity of land space, a valuable natural resource.

CONCLUSION

In Constantine, the elimination of household and similar waste is done either in controlled dumps, in wild dumps or in the technical landfill centre, despite the guarantees that the TLC present in terms of environmental protection, they consume large areas of non-recoverable land considering the enormous quantities of waste produced each year. The present study shows that landfilling waste without any recovery form is affecting massively not just the technical landfill centre's lifespan, but also the required land area, furthermore the results attest the significant impact of waste diversion on the Boughareb TLC in Constantine, Algeria. In a business as usual (BAU) scenario where the diversion rate is 0%, the TLC will consume 60.74 hectares instead of 39 hectares and will not even reach the estimated lifespan in the engineering study. The TLC will be closed in 2 years and 313 days. While by applying waste diversion the land consumption will decrease and the lifespan of the TLC will increase considerably: by diverting for recycling only, it will consume 42.37 hectares and lifespan will increase by 1 year and 60 days, but by diverting for composting, the required land area will be under the estimated area, the TLC will need only 28.24 hectares and it's lifespan will increase by 3 years and 6 days.

Algeria's waste land filling rate will definitely lead to a waste and land crisis in the near future. This is due to a number of factors, including a lack of efficient household and similar waste recovery, the dominance of landfill as the only waste disposal option, and the absence of selective waste collection. This situation could have negative consequences such as: a land problem that will have an influence on future development projects, a decline in land and property values, and a land use changing of areas surrounding the TLC, this land use changing is a result ofanthropic factors which transform the natural landscape (Kerekes and Alexe, 2019). Therefor, there is a need to integrate existing and future landfills into the general city-level spatial planning framework for a coherent development planning process (Dada, 2020).

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