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Review article

Toward Sustainable Development of a Landfill: Landfill to Landscape or Landscape along with Landfill? A Review

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ABSTRACT

Among prevalent methods of disposal for municipal solid waste, landfilling is the most common one. A landfill requires a piece of land and receive a huge amount of wastes for a certain period of time. Many landfills all around the world are located into or nearby urban areas where the land is scarce and highly demanded. Therefore, an important question arises on how to re-use this piece of threatening land. The aim of this study is to highlight the benefits of landscape work with the roles of landscape architects or equivalent disciplines to succeed a sustainable development of a landfill site not only after the landfill being closed but also from the beginning of it. To achieve this, a comprehensive investigation has been done among related literature to address these issues and prove that landscape work is one of the key factors that can lead a landfill project to a more successful and beneficial one which eventually makes the project sustainable. The findings of the study are useful for those who are engaging in landfill industries both practitioners and academicians and will contribute knowledge about sustainable development of landfill from a different perspective.

Keywords: Landscape architecture, landfill development, landscape work, sustainable development

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INTRODUCTION

Three common methods of municipal solid waste (MSW) disposal are landfilling, incineration, and recycling. Between these, the landfill is still the most common methods of waste disposal all around the world and it is likely to remain the most used method at least in the near future (Laner et al., 2012). There are several types of landfill for MSW,

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but one of the most recent ones is sanitary landfill that can control the landfill hazards such as gas and leachate in a better way. In this study for the term of "sanitary landfill," we simply use "landfill".

Due to receiving a huge amount of rubbish for a long period of time, the landfill has a specific condition that requires taking proper cares. The concerns about the landfill, in general, can be categorized in terms of engineering, environmental, social, economic, and last but not least planning and designing issues (Misgav et al., 2001).

In our rapidly growing urban areas having a piece of land for the benefits of community is usually highly demanded. On the other hand, landfill creates a harmful and eyesore environment. It has a negative impact on the public, especially on adjacent communities. Therefore it is significantly important to develop landfill site in a manner of sustainability (Ayalon et al., 2006).

The development process should be sustainable to achieve a high level of success (Lélé, 1991). This requires proper attention of environmental, economic and social issues (Ribic, 2008). Following the principle of sustainability, landscape work is one of the significant and useful factors that lead the project to approach this goal. In addition, each stage of landfill lifecycle requires given landscaping as one of the appropriate solutions (Misgav et al., 2001). Thus the aim of this study was to highlight the most essential and auxiliary landscape work that landfill owners/managers should take into account. The study also found that landscape architectures or equivalent disciplines can perform a major role in the landfill development project and help to make it sustainable. Before explaining the landscape work and tasks of landscape architects it is needed to know about the life of landfill as well as the principle of sustainability.

MATERIALS AND METHODS

The methodology used in this study contained two main parts. The first part was a comprehensive critical literature review among related valid resources. In addition, this study as a review paper relied on existing information about landfill development to represent a conceptual paper in this field. The second part was site observation and analysis for the subsection titled "Landscape Work on Design Stage" only. It should be noted that the paper did not intend to collect its entire data from site observation, rather for only abovementioned subsection the site observation and analysis carried out. Since the study had a novel subject, a profound cycling discussion and revision were done by the authors' team (as professional landscape architects) for both findings of the literature review and analysis of site observation. The objective of this discussion and revision was to ensure that the suggestion and proposition of the papers were correct and could be applied in landfill and landscape profession. Figure 1 illustrates the methodology in a graphical manner.

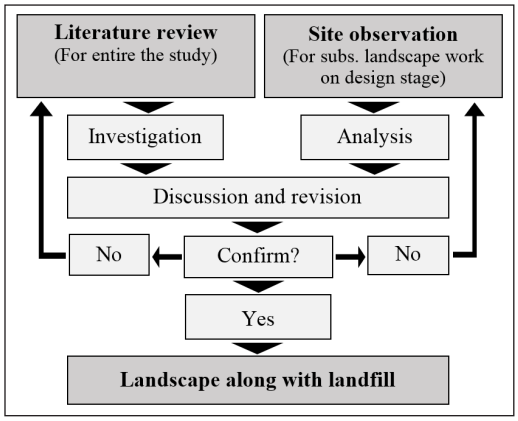

Figure 1. The study methodology

LIFE OF LANDFILL

A landfill is a complex project. It needs both knowledge and experience such as engineering, environment and other fields of expertise. From the early stage of a landfill project, many disciplines should come together to build up a successful project (Jaramillo, 2003).

The stages of landfill life can be generally categorized as explained in following sub-section.

Landfill Siting and Planning Stage

To minimize the impacts of a landfill on the surrounding environment the selection of a new landfill site is critical. Proper selection will also decrease the design and operational challenges (Al-Jarrah & Abu-Qdais, 2006). Thus the influence of landfill harmfulness on the environment could be reduced by meticulous site selection (Sasao, 2004).

Design Stage

Proper design of a landfill site earlier to construction can lessen environmental impacts throughout its operating lifespan and will decrease the requirement for expensive technologies later. (Komilis et al., 1999).

Construction Stage

This stage talks about the construction of the provisions and facilities both essential and auxiliary for developing and closure of a landfill. These facilities normally contain general site work, ground and surface water controls, side and bottom liners, gas capturing and controls, leachate collection and treatment systems and final cover work (capping) (Tasmanian Department of Primary Industries, 2004).

It should be noted that the development of a landfill, in general, takes place in some cells/units/phases/sections/zones over the entire landfill's life (Jaramillo, 2003). Development starts in the primary construction phase and carries on as the landfill operation occupies the prepared phase. The following phase is excavated for regular cover and finally becomes the next construction phase. This progression will be repeated through the landfill cells/units/phases/sections/zones operation and construction complete (see Figure 2). Due to this cycling construction, the development of a landfill could be considered a long-standing construction procedure (Yuan, 2013).

Operation Stage

This stage refers to the actual waste disposal practices and other landfilling actions plus the operation and maintaining the services

and facilities (Tasmanian Department of Primary Industries, 2004). Although in real life the construction and operation stages go hand-in-hand, landfill construction refers to the construction of the facilities both essential and non-essential to the development and closure of a solid waste landfill. These facilities normally comprise site work, groundwater controls, surface water controls, side and bottom liners, treatment systems and leachate collection, gas controls, and final cover systems. However, operation refers to the actual landfilling activities and waste disposal practices as well as the operation and maintenance of the facilities mentioned in the construction stage. Figure 2 illustrated this. The figure reveals that the construction and operation stages have many overlapping works (Avery & Marc, 1987).

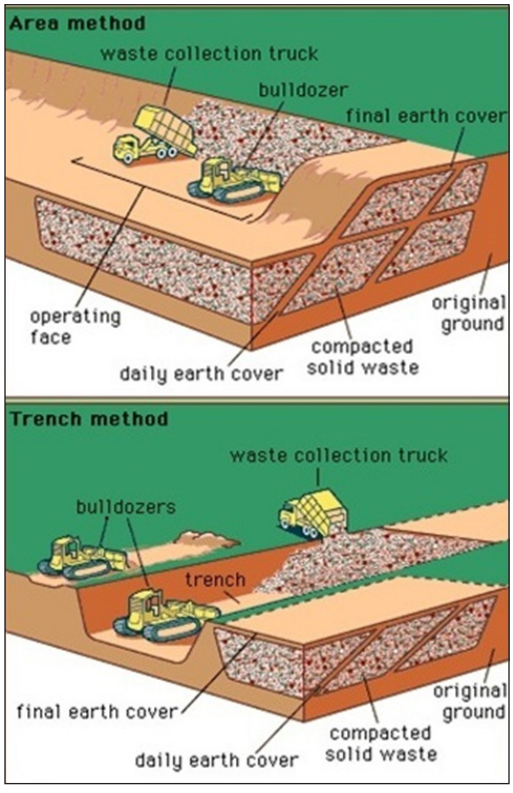

Figure 2. Landfill operation stage: The area and trench method (Wroblewski et al., 2009)

Closure and Post-Closure Care Stage

This stage begins when any landfill units/section/phases/zones being closed. In other words, the closure and post-closure program impairment for each landfill units/phases/sections/zones as well as landfill site as a whole when it reaches to its final capacity (Environmental Protection Agency, 1999). Some important terms of use in this topic include restoration/rehabilitation, after-care, and after-use/end-use.

A landfill will impact on surrounding environment many years even after the accomplishment of filling wastes and engineering activities. Thus it is important that the closed landfill site being restored and the after-care program applies upon closure (Laner et al., 2012). This will allow to reduce potential environmental hazard and help the land to be ready for compatible after-use choices (Saberi, et al., 2018; Stegmann et al., 2003). Continuing restoration should be run right after landfill units/phases/sections/zones are completed. Final restoration should start after a short while upon the final covering of each phase/zone.

SUSTAINABLE DEVELOPMENT PROCESS

The development process of a landfill includes technical/engineering area, administrative area, and financial area. In

terms of sustainable development, each aforementioned area can respectively be equivalent to environmental, social and economic aspects (Nochian et al., 2016). Like other projects, landfill development considers sustainable when all three areas are in an optimized status (Kalantari, et al., 2018; Thornton et al., 2007).

In order to understand how landscaping can help to have a sustainable development process, the study explains the importance of it based on each landfill life stage explained before. But prior to that, a general explanation regarding the role of landscape work provided.

ROLES OF LANDSCAPE WORK IN THE DEVELOPMENT OF A LANDFILL

As already mentioned, landfill life can be categorized in several stages. To start the understanding of roles of landscape work we need to be cleared about some crucial questions. The very first question is why landscaping and what is the importance of it in the development of a landfill. The second one is in what stage we should think of having vegetation and landscape areas; how and why. The third one would be to what extent the landscape work should be taken into account. And last but not least is what criteria and technical guidelines, in general, are useful for having proper and beneficial landscape areas. At the next, the study is going to answer the questions by elaborating some of the most highlighted landscape significance in each landfill life stage.

THE IMPORTANCE OF LANDSCAPE WORK FOR SUSTAINABLE DEVELOPMENT OF A LANDFILL

In this part of the paper, landscape work as a beneficial component and significantly useful means for sustainable development of landfill is explained. Landscape work is commonly used in the closure and post-closure stage to stabilize landfill's topsoil (capping), control run-off, integrate the rehabilitated site into its surrounded environment, and eventually build a green space for the benefits of communities. In other words, in landfill industries landscape mainly bring into consideration in the final stage which called closure and post-closure (Laner et al., 2012; Tasmanian Department of Primary Industries, 2004). However, this study found out that the landscape can play a significant role along with landfill from a very early stage to the last to create a real sustainable project.

For a better understanding and answering the questions mentioning in the previous section, we explain the importance of having landscape along with landfill and some of its outstanding functions on the basis of each stage of landfill life.

Landscape Work on Siting and Planning Stage

In this stage, a proper site selection for landfill development is a critical point to ensure minimizing of environmental impacts of the landfill on adjacent areas (Al-Jarrah & Abu-Qdais, 2006). Moreover, selecting the site in regard to the choice of landfill after-use (end-use) is also vital to reduce

post-closure care efforts. On the subject of landscape work for the new landfill site selection, three out of several factors are most important to know to let the landfill be under less threatening for adjacent areas. These three factors are as follow.

- After-use consideration,
- Buffer distance, and
- Flora and fauna analysis.

These three factors are respectively explained below.

As mentioned earlier, a landfill will be closed when it reaches to its final capacity and usually turns into a new beneficial land-use (e.g. park) for the benefits of community as well as the elimination of its environmental impacts (Thornton et al., 2007). That is why it is recommended to consider the final choice of after-care in the early stage. In general, the choices of after-care are open space, agricultural purpose, woodland and hard uses (Environmental Protection Agency, 1999). Among these major choices, the open space which has absolutely a landscape functionality recommends by scholar and experts and enforced by law in many countries (Nochian et al., 2016). Therefore, the selection of a new landfill site should take this into account in the siting and planning stage to make the transformation process cost-effectively. For instance, cut and fill techniques or maintenance program would be less by an appropriate selected site. Some important factors that need to be studied regarding this matter are neighborhood areas, landform, accessibility to the site in future, the distance of the site to existing and future housing areas, and community preferences toward the type of open space (Nochian et al., 2015).

An appropriate landfills siting requires to be located with adequate distance between neighboring land-uses and the border of the landfill site because the landfill has the potential to impact on adjacent areas (Ding et al., 2019). Sufficient distance prevents surrounding land-uses to be less affected by unpleasant odors, vermin, dust, noise, contamination and sediment carried by surface water, and also litter (Young, 2010).

To locate a landfill at the best possibilities a comprehensive inventory and analysis to obtain existing data on current flora and fauna of the place need to carried out. This is important to control spreading and introducing diseases, weeds, and invasive species into nature. In addition, a good analysis also minimizes the impact of the landfill hazards on endangered flora and fauna.

Landscape Work on Design Stage

As already mentioned landfill has several off-site impacts on the environment at the time of operation and long-term after being closed. Some of the landfill operational impacts are odor, dust, noise, and litter. Therefore, the landfill has to be designed to guarantee that operational off-site impacts will be minimized as much as possible (Komilis et al., 1999). Three most usefulness of landscaping in the design stage are:

- Enforcement of buffer zone (shelterbelt),
- Blocking eyesore view, and

- Design criteria association with restoration and after-use plan.

To enforce the buffer zone, a shelterbelt (also defined as a windbreak as in some resources) is a privilege option. Dust, noise, and litter can be reduced by shelterbelt (Tyndall & Colletti, 2000). There are few choices of shelterbelt; but one of the best choices for it can be a green shelterbelt using vegetation both existing and planted ones (Cornelis & Gabriels, 2005). The buffer zones do not necessarily be located only around the boundary of the site rather, depending on the landfill design, it can also be inside the site and around each phase development. Figure 3 below illustrates this.

In this figure, a conceptual green shelterbelt for Air Hitam Sanitary Landfill in Malaysia proposed. As you see the landfill has several phases and also some infrastructures such as leachate treatment lagoons (Hatfield, 2009). So, the green shelterbelt proposed for the site in order to create a buffer zone for the site boundary as well as around trash burying phases and infrastructures (inside the landfill site). For the matter of an efficient shelterbelt, proper landscape design is very significant. For example, besides the site-specific analysis, some of the most general important factors that need to carefully look at, include height, density, species selection, orientation, width, length, composition, shape, and spacing. In addition to the mentioned factors, regional privilege wind is important too (Cornelis & Gabriels, 2005).

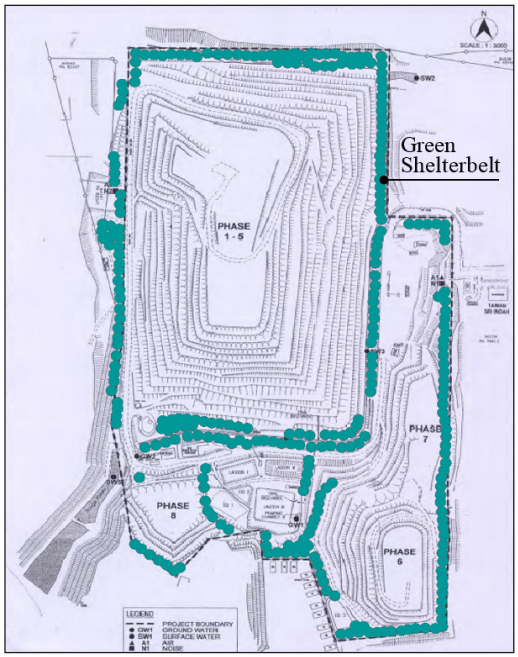

Figure 3. Conceptual green shelterbelt for Air Hitam Sanitary Landfill in Malaysia as a demonstration (Hatfield, 2009)

Regarding, blocking eyesore view the shelterbelt, as already mentioned, is a proper choice; but there are other choices that may be proposed by landscape architects. These are the physical characteristics of the landfill site, natural and/or man-made site features, and natural and/or manipulated site landform. In addition to the aforementioned propositions, individual consideration should also be concentrated on special and attractive areas, view direction and visitor routes, conservation areas, residential areas/ main buildings, and so on.

For the third landscaping role, it can be indicated that the preliminary design of the landfill should be based on final restoration of the landfill site. It means that the conceptual plan of the after-use option should be taken into account in this stage. Different land-use has its own landscape characteristics that involve in the design

process. To achieve this goal, designers should suit the needs of the premeditated after-use in terms of contours, adjoining habitats, slopes, soil properties and depth, site run-off and drainage, accessibility, routes circulation, and planting design in advance (Laner et al., 2012). As already mentioned in the sitting and planning stage, one of the most recommended after-use choices is open space as a subset of landscaping. If so, it had better to purposely provide the needs for this matter in the design stage.

Landscape Work on Construction Stage

Some of the most beneficial landscape work in this stage that can be of uses are as follows.

- To build any amenities in accordance with the post-closure plan,
- To implement the buffer zone (shelterbelt),
- To preserve in situ natural vegetation, and
- To transplant existing plants.

In landfill construction stage also needs to pay attention to the after-use and post-closure care program to minimize costs of landfill restoration. For instance, the amenities and facilities suitable for future uses should be built according to the post-closure plan.

To reduce the concerns of the community over the construction stage, the landfill operator/contractor need to decrease dust, noise, litter, and traffic. Implementing a buffer zone is a useful means prior to commencing landfill construction to solve these issues.

Removing of existing vegetation is quite often to happen in construction stage because of lack of consultation. Therefore, it would be the tasks of landscape architects to check and control the landfill site in order to preserve natural vegetation to use them for buffers and/or erosion control (Tasmanian Department of Primary Industries, 2004).

Landscape Architects also can advise how to relocate any specimen plants that cannot be kept in their original locations to a new location where they are needed by transplanting techniques.

Landscape Work on Operation Stage

The issues of this stage in regard to the landscape work can generally be in two categories. The first are those issues that solely belong to this stage including:

- Landscape maintenance program and separation, and
- Storage of useful stuff to be reused later on.

The second category is those tasks that are in conjunction with previous (construction) and next (closure and post-closure) stages such as

- The initial establishment of landfill cover greening,
- Usage of groundwater and/or leachate, and
- Weed and vermin control.

The maintenance of planted vegetation in the construction stage is vital and it is an ongoing work. The landfill gas and leachate are hazardous elements for plants. So, a proper landscape maintenance/management program is a very helpful tool to avoid

vegetation dying off and ensure that they are in a healthy condition.

With regards to the waste separation and storage that suggested to be part of landfill operation, reusing some materials is a practical option. Reusing is a good solution for the stuff that can still be used in their current shape and are feasible to be salvaged. For instance, household goods might be suitable for building some furniture. Based on the after-use choice of the landfill, Landscape Architects can give consultation to landfill operators to separate and store some of the materials to use for the future design of landfill after closure (Lamey, 2004). These materials with proper design can reduce the cost of construction while it is a very good method of education for the public as well as salvaging materials. The reused materials can also help to keep the history of the site long after restoration. Example of application of this technique applied in the Vall d'en Joan landfill site, Spain are shown in Figure 4 below (Batlle & Joan Roig, 2011).

Any landfill units/phases/sections/zones that reach to its final capacity will basically be covered and vegetated as mentioned before. Initial landscaping and establishment of vegetation on top of completed landfill units/phases/sections/zones as a part of restoration (rehabilitation) program is a significant landscape work in operation stage (Do et al., 2014). This helps for soil erosion control and slope stability and avoids penetrating surface the water into the waste portion (Loch, 2000).

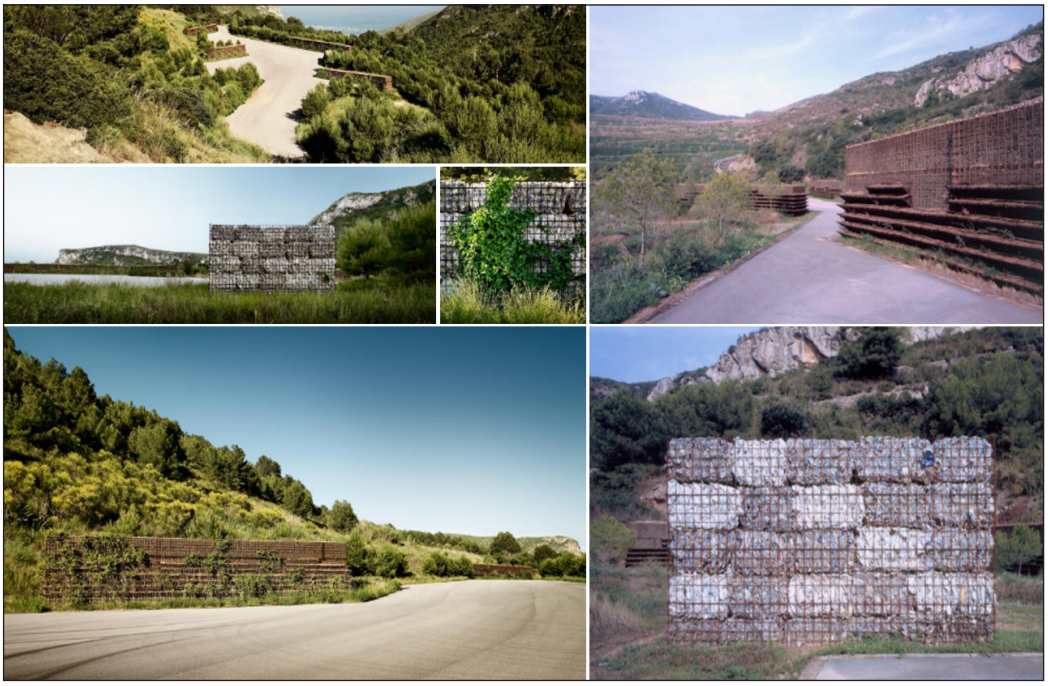

Figure 4. Landscape features made by waste materials to keep the history of the site and educational purposes in the Vall d'en Joan landfill site, Spain (Batlle & Joan Roig, 2011)

One of the most important factors for landscape maintenance is the irrigation of plants. As the source of water is a problematic issue in many parts of the word, using surface water for irrigating plants is recommended. Surface water needs to be precluded from mixing with trash (therewith producing leachate). Thus a proper design can help to store the surface water and use it as irrigation water. Research also indicated that it would be possible to use leachate for plants watering purpose (Cureton et al., 1991). To do this a careful consideration of compatible species with chemical properties of leachate is necessary. Another concern of using leachate is to carry contamination by it into the environment. Therefore it may require certain treatment first then to be applied as a source of watering for the in-site vegetation (Rawlinson et al., 2004).

Another issue that should be part of the landscape maintenance plan is weed and vermin nuisance. Weeds species and nuisance animals have to actively be controlled to prevent the environment and public health from the negative impact of them.

Landscape Works on Closure and Post-Closure Stage

The most body of landscape work is in this stage because it is the time that a landfill does not further receive wastes and the final maintenance and restoration process is commenced. As already mentioned some of the closure work is done in the operation stage when any units/phases/sections/zones of a landfill reach its final capacity and sealed. When all the landfill sections filled or the landfill owner decides to stop receiving wastes, the closure (in fact final closure) begins and followed by post-closure care. In this part of the paper, some of the common landscape work is briefly explained. In short, they are:

- Completing of vegetation's establishment,
- Association to final after-use, and
- Surveillance and maintenance of existing soft and hard landscaping.

Completing the establishment of vegetation on top of capping. Besides the consideration that already noted for selecting of vegetation, the particular deliberations for species selection in this stage are the capability to prevent erosion, suitability with the design of landfill cap, minor maintenance requirement, and association with final after-use. Vegetation can be established through planting sapling and direct seeding depends on conditions and requirement of the site (Tasmanian Department of Primary Industries, 2004). To avoid of failure of planting procedure and also damaging landfill cap by vegetation roots, it is better that a stepwise approach uses for planting plants. It means that initially the grasses and shrubs which are leachate tolerant should be planted and then as the generation of leachate reduce over time, plants with deeper root can be planted (Rawlinson et al., 2004).

Landscape work on this stage should also consider final after-use of the landfill site and integrate any requirements of such usages into the design and implementation of

the land-use. In other words, any landscape elements in term of planning, design, and construction should meet the criteria that the final land-use planned for as different after-uses have specific landscape characteristics.

Another important factor for landscaping is managing, monitoring, and maintenance of existing and constructed landscape. Landfill requires an average of 30 years of an after-care program once it is closed. Therefore, vegetation and other landscape elements need to be inspected regularly. A management/maintenance landscape plan that is incorporated with the restoration/ after-care plan, as well as the intended after-use of the restored site, should be prepared as early as possible. Vegetation should be appropriately maintained to ensure that they get enough nutrients and moisture to prevent dying off. Irrigation has a major role in the failure or success of plant species. As mentioned in the operation stage surface water and leachate (under certain conditions) should be collected and used for irrigation purpose. It is also advised that a proper gas and heat surveillance be part of the routine site inspection. To enhance the chance of success it is strongly recommended to select the plants that are most compatible with these issues (Laner et al., 2012).

DISCUSSION

The study has elaborated the importance of landscape to achieve sustainability in landfill development. It revealed that landscape can play significant roles in this regard from a very beginning of landfill life cycle to the end. Therefore, the presence of Landscape Architectures or any equivalent disciplines in consultation and/or implementation team would contribute essential assistance to accomplish the project. The significant landscape work based on each landfill life cycle is summarized in Table 1.

Table 1
Significant landscape work based on each landfill life cycle

	Significant landscape work				
Sitting and planning stage	After-use consideration	Buffer distance	Flora and fauna analysis		
Designing stage	Enforcement of buffer zone (shelterbelt)	Blocking eyesore view	Design criteria association with after-use plan		
Construction stage	Building any amenities in accordance with after-use plan	Implementing buffer zone (shelterbelt)	Preserving in-situ natural vegetation	Transplanting existing plants	Weed and vermin control
Operation stage	Landscape maintenance/ management program	Separation and storage of useful stuff to be reusing	Initial establishment of landfill cover greening	Transplanting existing plants	
Closure and post-closure stage	Completing of vegetation's establishment	Association to final after-use	Surveillance on existing soft and hard landscaping		

Referring back to the crucial questions mentioned in section "roles of landscape work in the development of a landfill" the paper has briefly addressed them. The importance of landscape work in each stage as a very beneficial approach to achieve sustainability was highlighted to address the first question. It is defined that the landscaping can play its major role from the early stage (sitting and planning) to the end (closure and post-closure). This answered the second question. For question three, it should be noted that due to the limited scope of the paper, the study only highlighted some of the landscape work in landfill development just to light up its importance and necessity. However, the power of landscaping in this matter can go in a much greater extent than what has been mentioned in this paper. The last question has been responded by giving some criteria and guidelines for each stage as an introduction to this subject.

CONCLUSION

In conclusion, it can be stated that turning a landfill site to a landscape area after the site being closed (which is common practice in many parts of the world) does not guarantee the achievement of sustainability, rather landscape has to be along with landfill from beginning stage to the end.

The findings and recommendations of this research are beneficial for landfill stakeholders, managers and those who engage in landfill and landscape industries -both practitioners and academicians- to open this subject up and apply it for the benefits of our endangered world. However, further research on this topic needs to be carried on to investigate other aspects of it. The recommendation of this study for other scholars is to profoundly work on the importance of landscaping in each stage of landfill life and drawn up more criteria and guidelines based on each stage and/or different type of landfills.

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