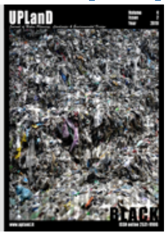
UPLanD – Journal of Urban Planning, Landscape & environmental Design, 4(2), 5-16 [2019]

UPLanD
Journal of Urban Planning, Landscape & Environmental Design



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LANDSCAPE REQUALIFICATION OF LANDFILLS: AN OPEN ISSUE BETWEEN LEGAL AND TECHNICAL ASPECTS

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HIGHLIGHTS

- A sanitary landfill, intended as the last step in the circular economy philosophy, occupy an unavoidable rather than a disputable position in the waste management.
- The landscape requalification depends on the specific regulations, on the long term emissions, on the cost analysis, on the assessment of the territory and on the creation of new conditions of use.
- The landscape requalification of a landfill assumes a fundamental role to increase the acceptability of the plant and to give back it to the people, back to the hydrological cycle, "Back to the Earth" in a full, safe, healthy and sustainable state.

ABSTRACT

The functional requalification of a modern landfill over the aftercare phase represents a landscape challenge since, in addition to technical and legal problems (also common to other waste management plants), long-term emissions must be taken into account. In fact, if for plants such as incinerators or composting after the operational phase an environmental recovery can be considered full, safe and healthy usable for the society in a relatively short period of time (1-5 years), for landfills the achievement of a sustainable and stable state of waste may require, a time much longer than that of the post-closure phase even for modern landfills (30 years). This state known as "final storage" refers to the quality reached by emissions and waste in chemical, biological and geological terms when all active control measures can be safely removed and it represents the necessary condition to guarantee the landfill requalification and its return back to the community with a new planned use as natural, recreational, didactic and social ones. Also, principles of landscape planning such as the specific legislation, the costs analysis and the territory analysis must be considered.

ARTICLE HISTORY

Received: March 08, 2019
Reviewed: April 02, 2019
Accepted: July 11, 2019
On line: July 31, 2019

KEYWORDS

Landscape requalification
Landfill aftercare
Long term emissions
Back to the Earth

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ISSN online 2531-9906

1. Introduction

Italian (art. 179 of D. Lgs. 152/2006) and European norms (art. 4 of Directive 98/CE/2008) that regulate the prevention and management of waste consider sanitary landfills at the bottom of the hierarchy which includes the following strategies: prevention, preparation for re-use, recycling, other recovery (e.g.: energy recovery in incinerators) and disposal. In this regulatory framework, sanitary landfills in Italy can only accept pre-treated waste with the exception of few specific cases (art. 7 of D.Lgs 36/2003 and ISPRA, 2016).

However, sanitary landfills can properly meet waste management objectives while ensuring higher safety standards and operating flexibility compared to other final waste destinations. In fact, a landfill can operate within a wide range of potentiality (tons of waste per year) without requiring substantial structural changes and without significantly increasing emissions.

The sanitary landfill technology responds better than any other systems to waste composition variability and it can be used, without any particular problems, to dispose of waste fluxes with different chemical compositions.

The sanitary landfill still represents a reliable technology in areas where waste production is very low and/or where significant distances discourage waste transportation to other waste facilities. It can represent the only solution for developing countries who find it difficult to implement more complex and often more expensive plants.

The international scientific community commonly accepts the disposal of Municipal Solid Waste (MSW) in controlled landfill as a necessary step in the waste management strategy, even though some voices from society hold the opposite opinion (for example the "zero waste philosophy").

In Italy, the MSW production is around 29.5 million tons per year and 26% of it is disposed in landfills (ISPRA, 2016); in practice, it is roughly needed the same volume of a 30 meters hight football pitch per week to landfill all the Italian MSW.

For these reasons, there is no doubt that landfilling represents nowadays a challenge for landscape planning to increase the acceptability of this land use for a long time.

However, the peculiar legal and technical aspects (including long term emissions and costs) that regulate the management of the whole landfill life cycle, have probably influenced the bias of considering the site lost for a full social usability and have limited the typology of the requalification.

In fact, functional requalification of the majority of landfills, when envisaged, consists mainly of the siting of revegetation works on the final cover with the aim of mitigating impact, although these works are frequently limited to a mere restyling that rarely leads to an effective functional reuse of the area (Artuso & Cossu, 2017).

The present paper aims to explore the following factors represented in Figure 1 that can drive the planning activity:

- the landfill legislations that regulate the aftercare phase, a specific long phase (30 years if the landfill emissions don't cease before) where the usability of the site is limited by some activities and the manager of the landfill is the person responsible for any impacts to humans or to the ecosystem;
- long term emissions. They represent an obstacle to achieve a landfill reuse in a short time (<30 years) because a stability state is necessary before any functional requalifications; therefore, innovative technologies are required to reduce the time to make a full, healthy and safety usable the site;
- cost analysis. Any intervention including the requalification needs to be defined in an economic plan and covered by the "landfill gate fee" that is a fee managed during the operative

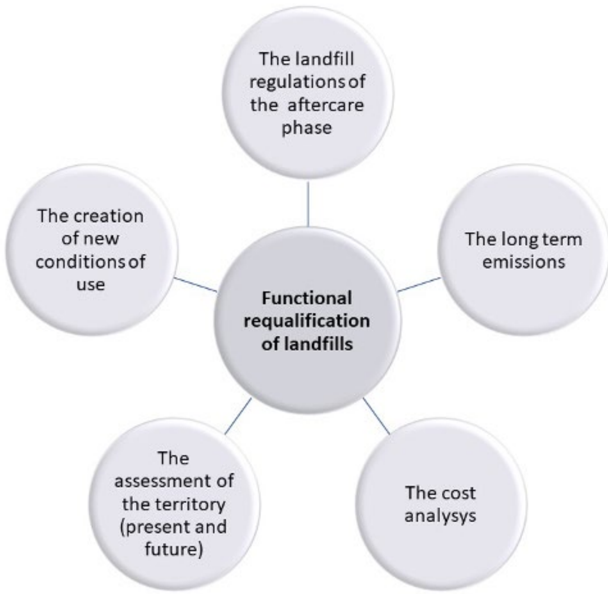

Figure 1: Driving forces for the planning activity applied on the landfill requalification. *Source: Authors' elaboration.*

Table 1: Examples of successful landfill requalifications

Landfill site	Location	Area (ha)	Total Waste (Mt)	Landfill Closed	Existing and Proposed Afteruse
Shuen Wan	Ting Kok Road, Tai Po Hong Kong	55	15	1995	A 145-bay golf driving range has been opened for use by the public since April 1999.
Sai Tso Wan	Sin Fat Road, Lam Tin Hong Kong	9	1.6	1981	Sai Tso Wan Recreation Ground for soccer and baseball.
Gin Drinkers Bay	Kwai Chung Hong Kong	29	3.5	1979	The Hong Kong Jockey Club International BMX Park situated on the Gin Drinkers Bay Landfill was opened in October 2009.
Jordan Valley	New Clear Water Bay Road, Jordan Valley Hong Kong	11	1.5	1990	Jordan Valley Park was opened to the public in August 2010. The Park is featured with a radio-controlled model car racing circuit, horticultural education center, community garden, children's play areas, elderly exercise corner, jogging track, etc.
Tseung Kwan O Stage I	TKO development area 77 Hong Kong	68	15.2	1995	Waterfront of the former Tseung Kwan O Stage I Landfill was developed into a cycle track cum footpath and was opened to the public in June 2012.
Tseung Kwan O Stage II/III	TKO development area 105 Hong Kong	42	12.6	1994	In 2005, top platform of the former Tseung Kwan O Stage II/III Landfill had been developed into a model airplane training field for the Hong Kong Air Cadet Crops to use during weekends and public holidays. It is now used as a training field of Unmanned Aerial Vehicle for land surveying.

Source: https://www.epd.gov.hk/epd/english/environmentinhk/waste/prob_solutions/msw_si_lra.html

phase to pay the posterior operations/works/activities of the landfill;
- assessment of the territory. In line with the most elementary principles of territorial planning, the analysis of the area (urban end environmental bonds, etc.) and the existing or designed landfill components has to be carried out to enhance a functional integration between the landfill site and the surrounding area;
- creation of new conditions of use for these requalified landfills not only for their "renaturalization" rather to give them back some social functions: as integrated part of landscape, as a place voted to public facilities as well as to every uses the community requires for them.

This is a strategic challenge for landfill regeneration interventions, for two reasons:

1. development of regenerated landfill for new public uses, therefore, involves an interdisciplinary approach to find suitable design solutions - even without denying its original purpose, rather exalting it with original landscape solutions (for instance some outdoor art installations or architectural marks) for the localization of public facilities (even parks and gardens by an original and innovative landscape design that makes this place pleasant and attractive), infrastructures or industrials zones;
2. definition of new uses must be planned and coherently integrated in the policies and strategies for the development of the community, which in turn involves a very strong-minded interaction among technicians, politicians and citizens (Savino, 2016).

Table 2: Examples of successful landfill requalifications

Landfill site	Location	Area (ha)	Total Waste (Mt)	Landfill Closed	Existing and Proposed Afteruse
Pillar Point Valley [1]	Part within Tuen Mun Area 46 and part within Castle Peak Firing Range Hong Kong	65	11	1996	Part of the site was developed into a shooting range in July 2016.
Barcelona landfill [2]	Val d'en Joan in the natural Garraf Park Spain	72	> 20	2006	The restoration project is defined by a pattern of topographic configurations consisting of terraces, side slopes, a drainage system of internal fluids (separated from the external drainage network), a biogas extraction network, pathways and revegetation being conducted in phases.
Valdemingómez landfill [3]	Valdemingómez, Madrid Spain	100	-	1999	The restoration project completed in 2006 represents a new public educational and cultural facility, situated in a strategic position for the development of the city. It can be considered an example of continuity between the forest and the surrounding area; a pseudo-botanical garden with indigenous species seeking integration into the Parque Regional del Sureste (Southeast Regional Park). It was transformed into a free, public area with pedestrian paths and bicyclelanes, along with woods and wetlands, which have helped to create small, localized ecosystems.
"Fresh Kills" landfill [4]	Staten Island - New york	2200	-	2001	The requalification project consists of an equipped park functional for the city of New York, a place made up of unusual species of wild flora and fauna, a landscape which would be continuously animated by a lively social life and where every citizen of New York would find space for leisure, play and doing sports. The realization of the project is in progress.

Source: (1) https://www.epd.gov.hk/epd/english/environmentinhk/waste/prob_solutions/msw_si_lra.html
(2) http://www.batlleiroig.com/en/landscape/landscape-restoration-of-garraf-waste-landfill
(3) http://www.israelalba.com/en/proyectos/recuperacion-del-vertedero
(4) Dazlero, 2016

These factors depend strongly to the state condition of the landfill:

- existing closed landfills (in or the out after-care phase) requiring works of environmental reclamation or recovery, whose costs could be not included in an economic plan; the works should be financed by external plans;
- existing modern landfills either undergoing construction or operational (or in which extension works are required); in these cases, a requalification plan is present and the re-use is mostly represented by a grassland; the

achievement of a sustainable level of emissions (biogas and leachate) could be not achieved within the aftercare period even if all the regulatory requirements have been adopted;
- landfills still to be designed (details relating to siting, waste volumes and typology, etc. may not be known); the achievement of a sustainable level of emissions before the closure of the aftercare period is the most important aim to include in the project. But it could be not enough for a real recovery of these places and their integration in the landscape. These goals imply in fact to draw of a specific and careful project for environmental new set-up and a project to embody landfills in an "ordinary" environment and make it available for other social and public purposes. Over last years, urbanism is paying very great attention to these territorial "wrecks" – neglected places, vacant lands, dismissed plants, unused infrastructures – for their rehabilitation and utilization as strategic localization for new uses, often underlining them as strategic element of local identity and place peculiarity to consider (Antoniadis & Redetti, 2019).

In this framework, successful cases of functional reuse of landfills have been described worldwide, attesting the real possibility of undertaking works for the good of the community. Some examples are reported in Tables 1 and 2.

2. The legislation background of the aftercare in Italy

In Italy, legislation regarding landfills is the Legislative Decree 13.01.2003, n° 36, derived from the Directive 99/31/EC. This Decree sets the operative and technical requirements for landfills and waste, measures and procedures aimed at preventing or, at least, reducing the negative impacts on health and environment. Ministerial Decree 27.09.2010, replacing M.D. 03.08.2005, gives criteria and procedures to accept waste in landfills; considering the different types of waste, it creates a distinction between landfills for inert waste, for hazardous waste and for non-hazardous waste. The manager of the landfill is the person responsible for the management of the landfill from its realization to the end of aftercare phase (Cassazione Penale, judgment n° 32797/2013).

By art. 8 of the D.Lg. n° 36/2003, for construction and operation of a landfill, a request for authorization must be submitted. It includes five plans: (1) operational management plan; (2) aftercare management plan; (3) control plan; (4) financial plan; (5) environmental site restoration plan and closure of the landfill. During the aftercare phase, the operator "*does not have lesser responsibility than the conditions laid down in the authorization*" (Council of State, judgment no. 572/2007); thus, he will have to ensure site control after closure, mainly through the management of leachate and biogas emissions. Art. 14 of D.Lg. n° 36/2003 states that the operator must provide two financial guarantees: the first, for activation and operational management, including closure; the second, for post-operative management. The financial guarantees for aftercare phase are retained for at least thirty years from the date on which competent authority informed the manager of the closure of the landfill. The term of thirty years was identified by assuming that in this timeframe, the landfill will cease its emission production. If it was not, the operator should take an interest in consequences; in fact, paragraph 3 of Art. 12 (D.Lg. n° 36/2003) states that "*even after the final landfill closure, the operator is responsible for its maintenance, monitoring and control throughout the period during which the landfill may pose a risk to the environment*." Likewise, if the emissions ceased in advance of the thirty-year term, the manager could legitimately ask for an early release of financial guarantees or at least remodelling them proportionally for risk reduction.

These regulations impose the following consequences:
- nowadays the aftercare period lasts practically 30 years after the closure of the landfill and in this period the achievement of a full usability of the site is limited because some monitoring and maintenance activities have to be assured such as: top cover maintenance and monitoring, leachate collection system operation and maintenance, LFG collection system maintenance and monitoring, LFG migration control and monitoring, groundwater and surface water monitoring, security and ground stability maintenance;
- a central consideration is given to solutions that reduce the risk associated with long-term emissions of landfills not only in terms of legal and economic responsibilities, but also for a full reuse of the site without limitations within a "reasonable" time".

3. Long term emissions and solutions to reduce them

Controlled landfills, by legislation (D.Lg. n° 36/2003), are designed and managed to minimize leachate and biogas emissions during both the operational and aftercare phases. Anyway, the management solution usually adopted only delays the environmental impact that could become relevant many years after the end of planned aftercare period (30 years) (Pivato, 2011; Kjeldsen et al., 2010; Lavagnolo & Pivato, 2008; Pivato & Cossu, 2007). Modern sanitary landfills focus on preventing rain infiltration to avoid leachate production to have low emissions in the operational and aftercare phase, which correspond to the period of higher efficiency of landfill barriers (top covers, bottom liners, etc.). On the other hand, hydraulic isolation of landfills will maintain waste potential emissions. When the aging of material reduces the efficiency of the top and bottom barriers, water infiltration, that may happen, will cause waste degradation reactions; therefore, leachate and biogas emissions will be produced, causing environmental impacts and increasing intervention costs that become higher than those budgeted in the financial plan and, consequently, reduce the budget for final requalification. In Figure 2 the long term emission trend for a traditional sanitary landfill is reported and it is compared with the duration of operational and aftercare phases covered by the waste gate fee. After these phases, the site is not interested in any activities, neither covered by any financial fee. The usability of the site can be considered full and open to society, but healthy and safe conditions can't be assured.

The main goal is to obtain a steady condition in chemical, biological and geological terms in lower time (5 to 15 years from landfill closure) and guarantee the landfill conditions required to implement the requalification of landfill area to return it back to the community, with a new planned use offering a place where recreational, didactic and socialization activities can be carried out, increasing the quality of life.

This state is called "final storage" and it was coined in the mid-eighties by Baccini, Henseler and others from the Swiss working group on landfills (Belevi & Baccini, 1989). It refers to the quality reached by emissions and waste at a specific point in time, when all active control measures (leachate drainage systems, biogas collection system, etc.) can be safely removed. To guarantee sustainability, this equilibrium needs to be reached within the span of one generation, commonly taken to be approximately 30 years, so as not to "*compromise the ability of future generations to meet their own needs*" - Brundtland, 1987 (Keeble, 1988). In this context, landfill should act as a final sink to isolate non-useable concentrated residual waste from environment (Cossu & Stegmann 2018a) and to avoid any further environmental impacts.

Some innovative technologies can reduce long-term emissions; for example: application of in-situ aeration (Raga et al., 2015; Raga and Cossu, 2014); leachate recirculation; the on-site and natural leachate treatment by means of energy crops application on top cover (Garbo et al., 2017; Lavagnolo et al., 2016).

Long term emissions characterize the requalification of a site peculiarly for landfills respect to other waste management facilities. In fact, if for plants such as incinerators or composting plants when the operational phase ceases, an environmental recovery can be considered full, safe and healthy usable for the society in a relatively short period of time (1-5 years), for landfills the same level of usability may require, even for modern landfills, a time much longer than that of the post-closure phase (30 years).

4. Cost analysis

All costs of the landfilling including the requalification project and its realization has to be covered by the "landfill gate fee" that represents a unit payment (typically per tonne of waste landfilled or per volume of landfill authorized) for the whole landfill life cycle service.

To estimate the "landfill gate fee", landfill cost analysis must consider all landfill life phases:

- design and authorization phase: permission procedures, testing and security coordination, meetings, feasibility study, economic study, siting, etc.;
- construction phase: site operation (excavation, backfilling of soil, etc), construction of the main parts of landfill body (barrier layer, leachate and LFG collection), construction of other facilities at the landfill site (such as monitoring system, internal road and office building) and realization of compensations and mitigations measures such as tree plantation;
- operational phase (10 years): several opera-

tions such as the transport of waste from the outside, the placement and compaction of waste, the daily coverage, the environmental monitoring (groundwater, surface water and air around the plant) and the leachate and LFG management;

- aftercare phase (30 years): operations planned for this phase mainly consist of monitoring and maintenance activities (top cover maintenance and monitoring, leachate collection system operation and maintenance, LFG collection system maintenance and monitoring, LFG migration control and monitoring, groundwater and surface water monitoring, security and ground stability maintenance) and landfill after-use implementations. Besides, in this phase, technologies to reduce the long term emissions can be provided.

Cost analysis imposes the following consequences:

- the project and realization of landfill requalifications must be clearly defined and covered by the "waste gate fee";
- unexpected costs generally attributed to long-term emissions reduce the entity of requalification since it represents the last intervention and the one that can be sacrificed;
- costs of functional dismissions for landfill re-use related to infrastructures and facilities (see paragraph 3) must be clearly defined because they are often absent and can represent a high cost;
- to design a realistic requalification, the whole landfill gate fee has not to be exceeded – also for political reasons – the mean gate fee of the country where landfill is located. A recent study (Pivato et al., 2018) shows that the mean cost of a landfill in Italy can be assumed equal to 86.70 € per cubic meter of authorized volume of waste, mainly due to leachate and biogas management (40%), while requalification (mostly oriented to an easy naturalization) represents a percentage below the 5-10% of the total costs.

5. The assessment of the territory and the final re-use

In line with the most elementary principles of territorial planning, the analysis of the area and of the existing or designed landfill components has to be carried out to enhance a functional integration between landfill site and the surrounding area.

Regarding the analysis of the area (infrastructures, urban developments, natural bonds, etc.), due to the decade-long operations of landfills and even longer aftercare times, planning should also consider future vocations of the area.

Regarding the facilities and infrastructures of landfill that can be built at any stages of its life, they include (derived from Cossu and Stegmann, 2018b):

- landfill area with its specific morphology, the top cover, the surface water control system, the biogas and leachate system;
- security fencing to separate the landfill area from the outside and visual signs indicating the danger of entering the landfill;
- entrance with an automatic gate equipped with video surveillance;
- the weighing station and a lifting barrier for traffic control;
- a center for the private delivery of source segregated different kinds of household or commercial waste installed in the entrance;
- a multipurpose building containing office rooms, a conference room (also for visitors), small kitchen, bathrooms with showers and changing room as well as a small laboratory and a storage room for samples, equipment;
- a wastewater treatment plant (not leachate) produced in the office building that can be replaced by a green engineered wetland;
- parking lots for visitors and employees;
- a building containing a workshop and garage for the vehicles on site (compactor, street cleaning machine, tank vehicle for dust control, etc.;
- a storage area for daily cover;
- a wheel washing station;
- a tank/pond for intermediate storage of raw or treated leachate;
- an inspection area for incoming waste;
- an installation of an intermediate storage facility for bulky and hazardous waste from households;
- a device for measuring at the gate the radioactivity level of waste to be landfilled (if justified and requested by the Authorities);
- a fire-safety system;
- a climatological station;
- a fuel and lubricant storage area;
- environmental compensation areas such as green belt with a minimum width of 25 m and wide wooded zones with a minimum surface

of 2000 m^2 (Pivato et al., 2013).

The following additional infrastructures may be envisaged:

- a recycling plant (waste segregation);
- a MSW pre-treatment plant;
- a composting/anaerobic digestion plant for separately collected kitchen and yard and/or green waste;
- a biological soil treatment plant.

It is worth mentioning that the final use of landfill can influence the quality and typologies of the previous infrastructures and facilities. For example, office buildings built during the operation phase are often simply constructed (at times mere containers) and poorly maintained. However, if the final reuse is a public park, these could be easily reconverted into visitor centers justifying the provision of a high-quality and well-designed house. Another example is represented by the morphology of landfill given the ultimate use established; knowing the settling properties of materials, wastes may be employed from the start of the project to shape and model the final morphology of landscape.

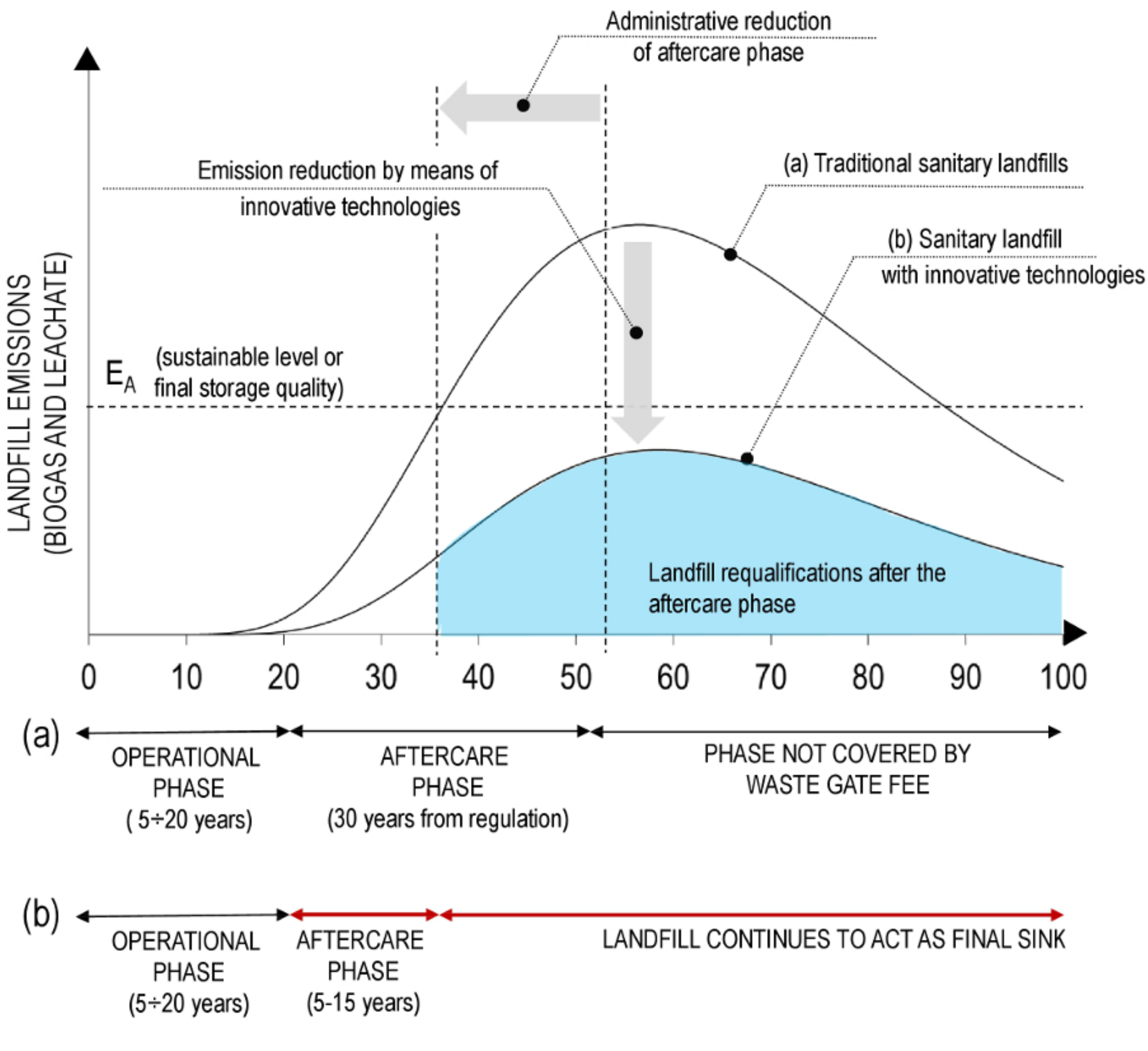

Figure 2: Long-term emissions for a traditional sanitary landfill (line ”a”) and for a sanitary landfill where new technologies for the achievement of sustainability within the aftercare phase are applied (line “b”). The sustainable level or final storage quality (horizontal line “EA”) represents the quality reached by leachate and biogas emissions and by the solid waste inside the landfill when all active control measures (leachate drainage systems, biogas collection system, etc.) can be safely removed. At this state, landfill doesn’t represent more a risk for human health and for the surrounding ecosystem. *Source: Authors’ elaboration.*

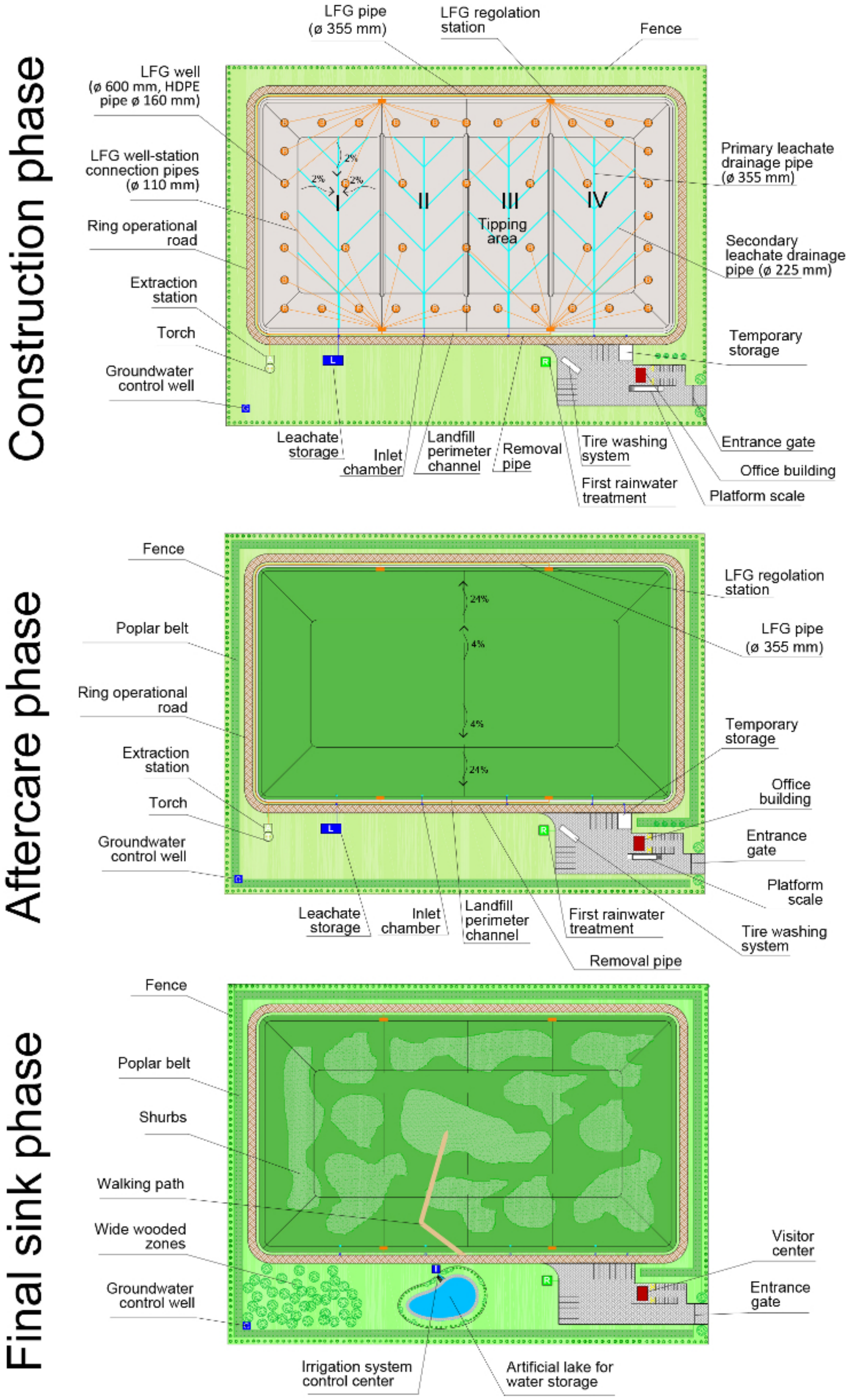

Figure 3: Scheme of a landfill area during (a) the operation phase, (b) the aftercare phase and (c) the final sink phase where it is requalified as a natural area. *Source: Authors' elaboration.*

All these elements, if not assessed previously with a view to final requalification, will further limit any possible form of reuse.

Final landfill reuse should be designed at project startup, but it should not be implemented before the achieving of desired environmental targets (Final Storage quality, see Figure 2).

The numerous possibilities for re-utilization of a landfill include:

- "natural" biotope or "greenway" with or without significant maintenance;
- agricultural use: grazing land for animals; plants for food production (in greenhouses or not); grassland; woodland production;
- public park with or without installations, infrastructure facilities, buildings: recreational and/or sports area; thematic parks; education center; botanic garden; golf course; bike or motorcycle cross tracks;
- energy use: realization of photovoltaic fleets, cultivation of energy crops for biofuel production and/or lignocellulosic plants (Pivato et al., 2018); windmill for electricity production;
- commercial use: storage facilities; handicraft businesses; small production business (mostly with office building);
- industrial and infrastructural use: new waste treatment facilities (e.g. composting, AD plants, recycling center, etc.);
- infrastructure: passage areas of roads or railways.

Houses for a permanent living should, in general, be avoided in proximity of a landfill. Even if potential risks have been overcome by means of adequate measures there will always remain the psychological stress living on a landfill (Cossu & Stegmann, 2018b).

These goals involve necessarily a very strong-minded process of planning and mostly a coherent integration among plans and other urban and regional policies, for every decision about new uses of landfill must be embedded in the general strategy of sustainable development and community social and economic enhancement (Fabian & Munarin, 2018). Furthermore, the peculiar features of recovered landfills many times would require a participatory process involving stakeholders and citizens promoting and marking their usefulness for an effective process of recycling and landscape integration. In Figure 3 a scheme of a landfill area during (a) the operation phase, (b) the aftercare phase and (c) the final sink phase is reported.

6. Conclusions

A sanitary landfill, intended as the last step in the circular economy philosophy, occupy an unavoidable rather than a disputable position in waste management.

The landscape requalification of a landfill assumes in this context a fundamental role to increase acceptability of plant and to give back it to people, back to the hydrological cycle, "Back to the Earth" (Cossu, 2016) in a full, safe, healthy and sustainable state. Landfills should be perceived as an integral part of local area in line with the needs of the territory and with urban spaces thanks to a functional rather than a "disposable' intended use.

The design of landfill re-use as a "new form of intended use" should be carried out by a multidisciplinary approach that can only be achieved by relying on a team of designers with competence in numerous sectors: legal aspects, economy, environmental engineering, geology, agronomy, landscape architecture.

This represents an open issue in planning and nowadays many requalification plans still show a lack of knowledge in cost analysis, in long term emission analysis, in legal implications or in a design of a re-use further than a simplistic grassland.

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