Reclamation and architectural requalification of an old landfill using in situ aeration, phytotreatment of leachate and energy crops

Anna Artuso, Elena Cossu
Arcoplan Studio Associato di Ingegneria e Architettura, Padova, Italy studio@arcoplan.it

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Abstract

The requalification of a landfill provides an opportunity to undertake qualified territorial reorganization work in which the procedures applied in plant management and redevelopment of the environment may constitute a key factor in effective rezoning of the area. The available options geared towards renewing the functional status of the area undergo a decision process to assess the most appropriate end use in terms of territorial reorganization, impact on the landscape, environmental sustainability and public consensus.

However, landfill redevelopment projects carried out to date have only given marginal consideration to the above aspects. In Italy, there is a tendency to intervene with projects that merely envisage landscaping of the areas concerned, and rarely take into account functional reuse of the site. In other countries, thanks to a vastly diverse cultural approach, greater emphasis is placed on these aspects, and old landfills are frequently transformed into public parks featuring leisure and sports facilities. The present project focussed on requalification of an old landfill, designed and developed by Studio Arcoplan in conjunction with the Universities of Padova and Brescia, fits into this context and envisages a series of innovative features. In particular, the project aims to adopt an integrated approach to aspects relating to landscaping, the environment and energy, in order to develop an extensive park with a prevailing theme of renewable energy.

Keywords

Afteruse, Waste, Landscape, Phytoremediation, Community, Park

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Site characteristics and aims of the project

The old landfill, situated in the proximity of a residential area in northern Italy, extends over an area of 10 hectares with a maximum height of approximately 15 metres from the ground and contains more than one million tons of landfilled wastes. The landfill, which stopped accepting waste in 1992, is currently in the post-management stage, and is characterized by a virtually constant production of leachate, still of concern because of the high treatment costs.

The numerous zones of stagnant water in the concave areas created through land subsidence and inefficacy of rainwater drainage systems result in a constant infiltration of water inside the landfill body, worsening the already critical situation of leachate management. The area currently occupied by the landfill appears as a fenced off and well maintained green hill with a scarce number of trees lacking any functional status (fig. 1).

The project therefore was designed on the basis of the following aims:

- to regulate the quantity and quality of leachate; the landfill will be capped with a soil and clay cover to limit water infiltration and, consequently, leachate production;
- to reduce the pollutant potential of the accumulated material; the *in situ* aeration of the waste mass will be introduced to improve biological stability and decrease the risk of pollution;
- to ensure environmental sustainability of the landfill; *in situ* aeration will provide an end quality of the stabilised mass in equilibrium with the environment;
- to produce renewable energy and render the site energetically self-sufficient; photovoltaic panels will be installed on the landfill and oleaginous plant species for biodiesel production will be cultivated;
- to reduce the production of greenhouse gases; *in situ* aeration oxidises organic substances and prevents biogas production (60% CH_4, 40% CO_2) and the use of solar energy reduces the production of CO_2;
- to treat leachate on site with a low energy demand plant; a phytoremediation plant will be set up using oleaginous crops cultivated;
- to create new functions on the closed landfill and provide added value for the territory; a Park featuring cycle tracks, foot paths and recreational lakes will be established using the aforementioned crops and structural plants on the slopes;
- to limit the quantity of water used to irrigate green areas and moisten the waste mass by means of recirculation of rainwater and water accumulation in lakes.

Project works

The project provides for redevelopment of the old landfill area and reshaping of the landfill body, planting of phytoremediation meadows for leachate treatment, in situ aeration fed by a photovoltaic plant to accelerate and complete waste stabilization, and in completion by establishing an extensive park (fig. 2).

The project envisages the carrying out of the following works.

Landfill stabilisation by in situ aeration. In the scenario of treatments available for use in regulating waste biological degradation processes, in situ aeration is an internationally acknowledged and applied technique. This system provides for the introduction of low-pressure air, concomitant removal of process gases and drainage of leachate present in the landfill (fig. 3).

The circulation of air inside the landfill promotes the onset of aerobic biodegradation of organic substances, accelerating the stabilization and settlement of waste, and drastically reducing the production of methane and other odorous substances, thus improving the quality of the leachate produced, and substantially lowering the environmental impact and post-management costs of the landfill.

These forms of intervention impinge directly on the source of the uncontrolled emissions of biogas and leachate, guaranteeing a definitive reclamation of the site and preventing the onset of further environmental issues in the future, years after the completion of works.

The plant will operate thanks to the energy produced by the photovoltaic panels situated on the top of the landfill, left side.

Landfill reshaping and landscaping. The landfill will

Fig. 2 – Sketch plan project (graphics: Studio Arcoplan).

Fig. 3 – Plan of the in situ aeration plant (graphics: Studio Arcoplan).

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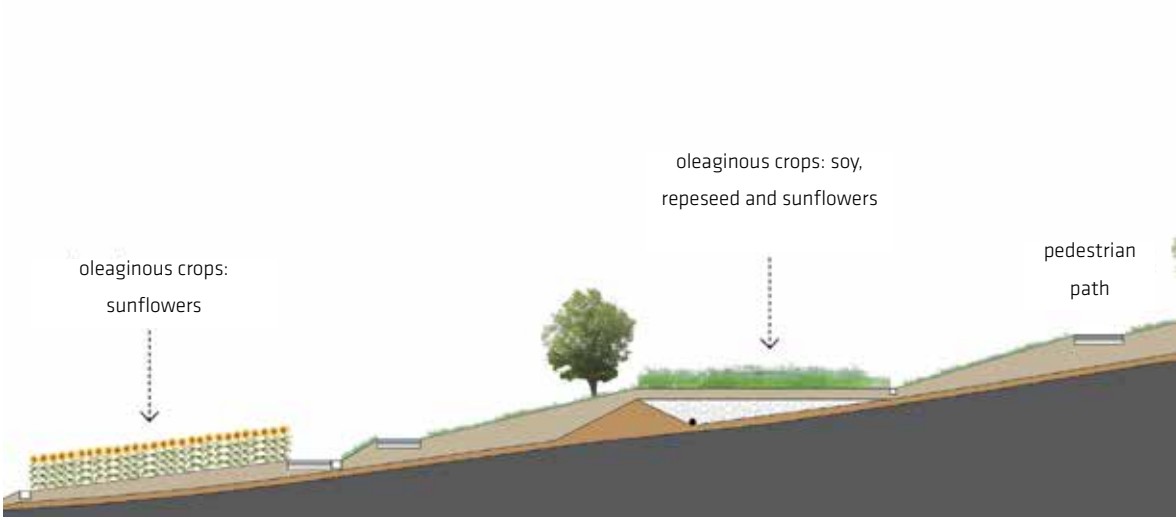
Fig. 1 – A general view of the landfill (photo: Studio Arcoplan).

be reshaped and recapped with a 30 cm layer of clay and a 50 cm layer of soil throughout the entire area. The capping is aimed at controlling the amount of leachate produced, allowing the infiltration of a limited amounts of water just to promote the biological waste degradation processes and enough to prevent waste mummification that often occurs when standard sealed capping is present.

Landscaping works will be undertaken using a series of cultivated and wooded terraces interspersed with a zigzag pathway. The anthropic and distinctive terracing will represent the key element aimed at achieving an area that is functionally and visually integrated with its surroundings, providing for the planting of the same crops on the surrounding plane (fig. 4).

The landscape design has been geared to the morphological organization of the area, taking into account those perspectives most readily visible from outside, and aims mainly to enhance the view of the landfill as seen by passers by on the main road. The terrace slopes will be planted in rows using largely indigenous species and lignocellulosic crops. The sections situated on the plane will be planted with oleaginous crops such as *Brassica napu* (rapeseed), *Helianthus annuus* (sunflower) and *Glycine max* (soya).

Landscaping of the area will be clearly visible from the main highway, thanks to the choice of species planted on the south-western slope featuring extensive blooms, and will provide a view of considerable magnitude throughout the spring and summer. In autumn and winter the scenario will be that of resting cultivated fields, in harmony with the surrounding local landscape.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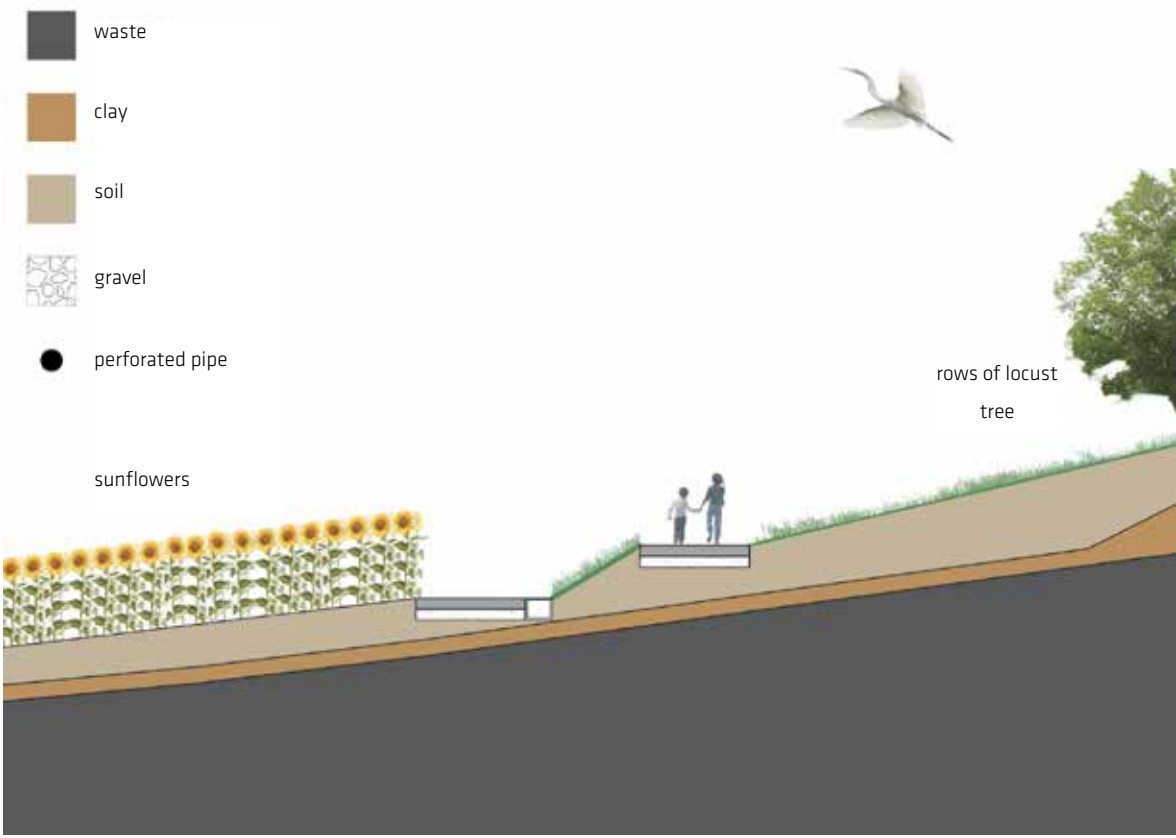
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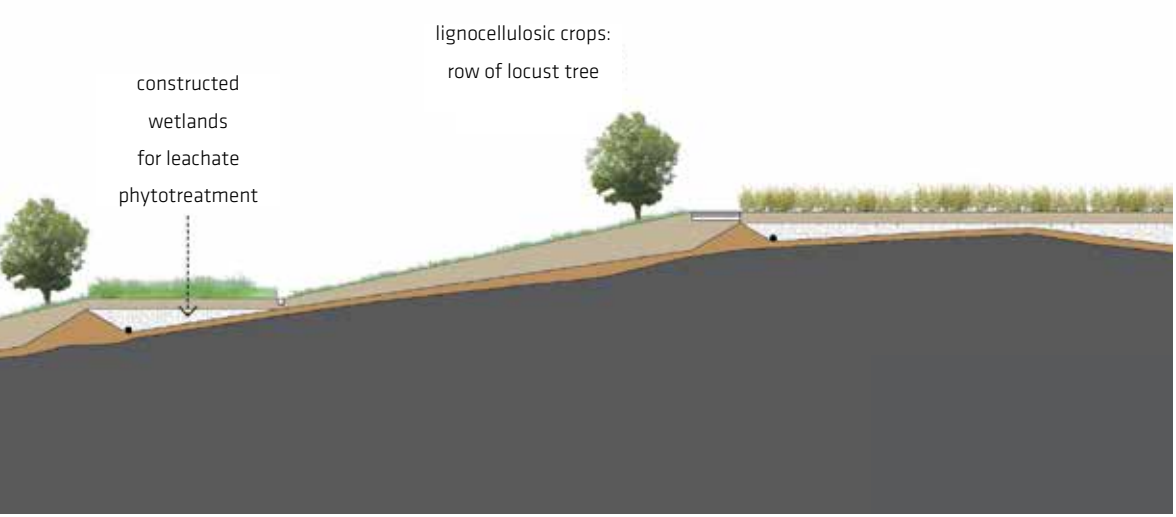

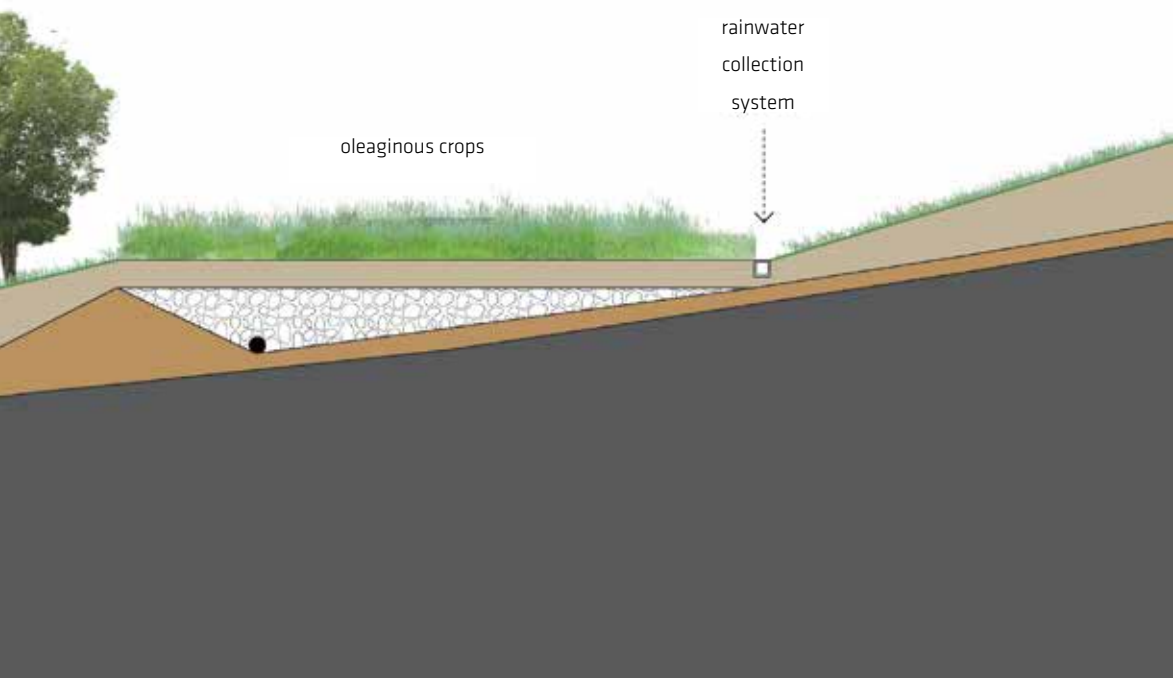

Fig. 4 – Cross section of the landfill: The reshaped morphology of the landscape (graphics: Studio Arcoplan).
Fig. 5 – Detail of the phytoremediation zones situated on the terraces (graphics: Studio Arcoplan).

Cultivation of energy crops and phytoremediation meadows. Energy requalification of the old landfill will be carried out by a series of interventions, including the use of energy crops on the landfill. Part of these crops will be irrigated using leachate produced by the landfill, thus implementing an *in situ* phytoremediation treatment. Thanks to the presence of the plants, the quantity of leachate will be notably reduced due to the effect of evapotranspiration. A pilot phytoremediation plant will be set up to test leachate irrigation of the energy crops prior to implementing full-scale operations.

The leachate irrigation system will be activated following the start up of *in situ* aeration. Leachate generated downstream of the *in situ* aeration plant, which considerably reduces the pollutant load, will however continue to represent a nutrient-rich (nitrogen, phosphorus, etc.) wastewater suitable for use in promoting plant growth due to the content of fertilizing elements, although also containing certain critical elements which will need to be administered with due caution. Therefore, both the amount of leachate to be used in irrigation, and the piezometric level inside the tanks, will be evaluated taking into account climatic conditions and results obtained from the pilot phytoremediation plant; this assessment will provide crucial information aimed at determining the method and times of irrigation, and monitoring plant resistance to increasing leachate loads.

Plants suited for use in the production of energy have been selected as energy crops for the project: their seeds will be used to obtain biodiesel, and the ligneous content applied in the production of thermal energy. Plants will be cultivated on soils that are partly compromised rather than on agricultural land, thus affording the dual opportunity of redeveloping a site the economic and social value of which has declined, and producing energy without resorting to use of valuable agricultural land.

In line with the landfill reshaping and capping project, the areas dedicated to the cultivation of energy crops for the production of biodiesel will be established on the south-western slope inside the green belt and on the top of the landfill.

The phytoremediation zones situated on the terraces comprise tanks waterproofed with a 30cm layer of clay on the bottom and sides and filled with a layer of non-woven fabric, a layer of gravel and a layer of topsoil, respectively (fig. 5).

Pilot phytoremediation plant. Leachate is a wastewater subjected to considerable changes in quantity and quality over time, even within the landfill. Accordingly, prior to commencing full-scale irrigation the times and methods to be applied need to be determined, taking into account the phytoremedia-

Fig. 6-9 – Leachate phytoremediation: Laboratory tests on energy crops

tion capacity of the chosen energy crops. These aspects will be gauged through use of a pilot phytoremediation plant (fig. 6-9).

The plant will comprise 4 waterproofed concrete tanks filled with a 50cm layer of inert material (gravel) and with an overlying 50cm layer of topsoil in which the roots will develop. This will extend over 100 m^2 in an area devoted to the setting up of plants. The plant will comprise a series of vertical phytoremediation modules for ammonia oxidation and horizontal modules for finishing; the modules may be run either in series or parallel in line with the most appropriate method of operation identified during the treatment simulation phase. Individual concrete modules will be constructed and filled with a 50cm layer of various loose materials covered by a 50cm layer of topsoil, to verify the most suitable combination in terms of plant development and depuration yield.

During the start-up phase, the plant will be fed with a specific percentage of leachate mixed with water; this percentage will be gradually increased according to the response of plant growth and yields obtained.

System for the collection of rain and lake waters. Reorganization of the water collection system is a work of major importance aimed at reducing water infiltration into the landfill body, thus limiting the vast flooding phenomena that currently occur in the presence of heavy rainfall.

All rainwater will be harvested and collected in two artificial basins (one of which outside the work area) linked to the overflow trenches adjacent to the landfill.

In particular, an additional area external to the landfill will be used to construct an artificial lake fed by the previously mentioned rainwater drainage system, with the aim of acting as a supply basin for the irrigation system, whilst also representing a recreational opportunity for the community.

Indeed, a re-naturalised lake considerably enhances a park environment and constitutes an attractive area for relaxation and observation all year-round. The surrounding areas will be densely planted using trees, shrubs and typical riparian vegetation (fig. 10).

Photovoltaic meadow on the landfill. The project moreover foresees the construction of a photovoltaic plant integrated with the morphological, functional and environmental characteristics of the site. The main objective is to make the complex of plants implicated in the environmental requalification of the area as energy autonomous as possible. Accordingly, the most convenient plant compatible with both user load profile and with legal requirements relating to the use and promotion of electric power produced by renewable sources has been identified. The plant, with a nominal power of 200 kWp, will operate under a net energy metering system for

Fig. 10 – View of the re-naturalised lake (graphics: Studio Arcoplan).
Fig. 11 – Plan of the requalification project: 1. Cultivation of sunflowers; 2. Cultivation of energy crops and phytoremediation meadows; 3. Lignocellulosic crops planted in rows; 4. Pilot phytoremediation plant; 5. Photovoltaic meadow; 6. Artificial lake for water collection; 7. Park (cycle tracks, footpaths, thematic itineraries, etc.); 8. Re-naturalised lake (graphics: Studio Arcoplan).

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Fig. 12 – Areal view of the project area (graphics: Studio Arcoplan).

the first 7 years, and subsequently under a purchase and resale arrangement with the GSE; this should result in a full energy autonomy of the park, provide the possibility to power other Municipal uses, and ensure electric power for at least 20 years. The plant will be equipped with an innovative installation system using metal tensile structures aimed at supporting potential settlements and ground subsidence following *in situ* aeration.

Functional re-use of the area: the park

All activities and functions envisaged for the area have been conceived in synergy with the landscape design project and have been distributed, as shown in the general design plan, to ensure full accessibility to the area (fig. 11).

The usability of the Park has been designed to allow both visitors (even those taking part in a guided technical visit) and workers and maintenance vehicles ease of access. The Park will include cycle tracks and footpaths, thematic itineraries with observation points and staging posts, wooden benches and an exercise route (fig. 12).

The project envisages additional planting on the north side of the area using woodland trees interspersed with autochthonous shrubs featuring characteristics suited to ensuring rapid growth and ready integration with the surrounding environment. The following species have been selected for this purpose: *Carpinus betulus, Fraxinus, Tilia cordata, Populus alba, Ulmus minor, Acer campestre, Prunus avium, Sambucus nigra, Crataegus monogyna, Rosa canina, Ligustrum* and *Salix alba* (fig. 13).

The footpath linking the two lakes will be planted with lignocellulosic species such as *Miscanthus x Giganteus* and rows of *Salix alba* and *Robinia pseudoacacia*.

Conclusions

From a neglected suburban area to a place for socializing and undertaking leisure activities: transformation of the area into a park will provide local communities with additional green spaces in which to organise social, educational and leisure activities, thus contributing towards promoting an improved quality of life.

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Fig. 13 – Selected species for the greening project (graphics: Studio Arcoplan).

The achievement of this ambitious aim has been made possible thanks to the multidisciplinary approach that has characterized this complex project from the outset.

The need to integrate such a complex task in a town planning project focussing on the environment, the territory, the landscape and the municipal areas indeed dictated the need for an integrated project design and a multidisciplinary approach in which the technical aspects (conventionally dealt with by engineers and environmental experts) became the field of action for the architects as well. This gave rise to an interesting synergy with a professional figure of crucial importance in ensuring the successful outcome of this type of territorial transformation.

The project is undeniably unique, particularly due to the plurality of works undertaken in the area, which have frequently been carried out individually, but which have never before been designed for implementation together on the top of a landfill. In particular, for the first time a real-scale, as opposed to lab-scale, phytodepuration of leachate is proposed.

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LEGEND
Tree species
Shrub species
Rows of Robinia pseudoacacia
Miscanthus x giganteus
Robinia pseudoacacia
Salix alba
Glycine max
Brassica napus
Helianthus annus
Lawn
TREE SPECIES
01 Quercus robur
02 Carpinus betulus
03 Fraxinus
04 Tilia cordata
05 Populus alba
SHRUB SPECIES
06 Crataegus monogyna
07 Sambucus
08 Cornus mas
09 Ligustrum
LIGNOCELLULOSIC CROPS
10 Miscanthus giganteus
11 Robinia pseudoacacia
12 Salix alba
ENERGY CROPS
13 Helianthus annus
14 Brassica napus
15 Glycine max
AQUATIC SPECIES
16 Butomus umbellatus
17 Sagittaria sagittifolia
18 Nymphaea