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Environmental Science, Engineering and Management

20th International Trade Fair of Material & Energy Recovery and Sustainable Development, ECOMONDO,
8th-11th November, 2016, Rimini, Italy

Selected papers (1)

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Aims and Scope

Procedia Environmental Science, Engineering and Management (P - ESEM) is a journal focusing on publishing papers selected from high quality conference proceedings, with emphasis on relevant topics associated to environmental science and engineering, as well as to specific management issues in the area of environmental protection and monitoring.

P - ESEM facilitates rapid dissemination of knowledge in the interdisciplinary area of environmental science, engineering and management, so conference delegates can publish their papers in a dedicated issue. This journal will cover a wide range of related topics, such as: environmental chemistry; environmental biology; ecology geoscience; environmental physics; treatment processes of drinking water and wastewater; contaminant transport and environmental modeling; remediation technologies and biotechnologies; environmental evaluations, law and management; human health and ecological risk assessment; environmental sampling; pollution prevention; pollution control and monitoring etc.

We aim to carry important efforts based on an integrated approach in publishing papers with strong messages addressed to a broad international audience that advance our understanding of environmental principles. For readers, the journal reports generic, topical and innovative experimental and theoretical research on all environmental problems. The papers accepted for publication in *P – ESEM* are grouped on thematic areas, according to conference topics, and are required to meet certain criteria, in terms of originality and adequacy with journal subject and scope.

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GUEST EDITORS

Fabio Fava, born in 1963, is Full Professor of “Industrial & Environmental Biotechnology” at the School of Engineering of University of Bologna since 2005.

He coordinated the FP7 projects (collaborative projects) NAMASTE (on the integrated exploitation of citrus and cereal processing byproducts with the production of food ingredients and new food products) and BIOCLEAN (aiming at the development of biotechnological processes and strategies for the bioremediation and the tailored depolymerization of major oil-deriving plastics). He also coordinates/coordinated the Unit of the University of Bologna participating/participated in the FP7 projects (collaborative projects) ECOBIOCAP and ROUTES (on the production of microbial polymers from different organic waste and food processing effluents), MINOTAURUS and WATER4CROPS (on the intensified bioremediation of contaminated waste- and ground-water and the integrated valorization and decontamination of wastewater coming from the food processing industry and biorefinery), and ULIXES and KILL SPILL (on the development of strategies for intensifying the in situ bioremediation of marine sediments contaminated by (chlorinated)hydrocarbons and the isolation and industrial exploitation of microbes from such contaminated matrices). He also participated in the FP7 BIORICE addressed to produce added value bioactive ingredients (semi-purified digestates and small molecular weight peptides) starting from protein by-products contained in the processing water of the rice starch production stream. He is vice-chairman of the “Environmental Biotechnology” section of the European Federation of Biotechnology (EFB). He is the Representative of the Italian Ministry of Education, University and Research in the "Working Party on Biotechnology, Nanotechnology and Converging Technologies" at OECD (Organization for Economic Co-operation and Development), Paris, in the "European strategy for the Adriatic and Ionian Region" (EUSAIR) and in the "Western Mediterranean Initiative" (WEST MED). Further, he joined the "High Level Group on Key Enabling Technologies" and he is member of the "Expert Group on biobased products", both at the DG-GROW of European Commission (Brussels). Further, he is member of the Scientific Committee of the Joint Programming Initiative on Agriculture, Food Security and Climate Change (FACCE-JPI). Finally, he is the Italian Representative at the European Commission (Brussels) in the Horizon2020 Programme Committee of Societal Challenge 2: European Bioeconomy Challenges: Food Security, Sustainable Agriculture and Forestry, Marine, Maritime and inland water research" (DG RTD) and in the BLUEMED initiative (Chair of the Strategic Board) (DG RTD and DG MARE), and in the "State Representative Group" (as vice Chair) of the Public Private Partnership "Biobased Industry" (BBI JU) (Brussels).

Grazia Totaro, born in 1976, has a degree in Chemistry (University of Ferrara), a Master’s Degree in Science, Technology & Management with a specialization in Environmental Chemistry (University of Ferrara) and a PhD in Materials Engineering, about modification, characterization and applications of technopolymers (University of Bologna).

She worked at the R&D Centre of Basell Polyolefins in Ferrara for 2 years in the frame of a project addressed to the development of a novel methodology for qualitative and quantitative analysis of additives in polymers. She also worked at ARPA, Regional Agency for Environment in Ferrara, division Water Analysis. Then she started working at the school of Engineering of the University of Bologna for a Ph.D. in Materials Engineering (2007-2010). After that she had a scholarship "Spinner 2013" in cooperation with Reagens spa (San Giorgio di Piano) on novel PVC nanocomposites. Now she is post doc fellow at the same school on new polymer-based nanocomposites from renewable sources and inorganic fillers. She also worked at the laboratoire de Chimie et Biochimie Pharmacologique et Toxicologique (Université Réné Descartes) in Paris in 2001 and was visiting professor at the Ecole Nationale Superieure de Chimie (Université Blaise Pascal, Clermont Ferrand, FR) in 2012 and 2015.

Dr. Totaro has about 20 scientific papers and several participations at conferences and scientific schools. She collaborates on Ecomondo from 2013.

(http://en.ecomondo.com/)

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SYSTEM OF SELF-FINANCING STRATEGY FOR THE POLICIES AIMED AT THE ECO-INNOVATION IN THE PRODUCTIVE SECTORS*

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Italian National Institute for Environmental Protection and Research (ISPRA), Environmental economist, Sector "Economic valuation"

Abstract

The transition from a linear economy to a circular economy requires structural change in production processes, both in the strictly technical sense and in relation to the reorganization. There are many forms of national and European funding aimed at encouraging the shift. All international organizations aim to encourage new financial instruments in order to increase the attractiveness of private capital to sustainable development policies.

The UNEP (United Nations Environmental Programme) on October 2015 launched in Lima the "Global Report of the Inquiry on the Design of a Sustainable Financial System". With which it intends to advance systemic action to align the financial system with sustainable development. In particular, the proposed strategies consist of:

• Mobilization of investment to specific priorities in terms of financial inclusion, funding for infrastructure and funding for eco-innovation;

• Integration of sustainable development factors in the financial decision-making through the inclusion of variables related to market integrity, risk and resilience through even the extent of liability and enhancing reporting processes.

On April 29, 2016 the Conference on the Indian sustainable financial system was held in Mumbai. The report was presented by R. Gandhi whom promoted the Reserve Bank of India in the presence of the Federation of Indian Chambers of Commerce and Industry and the UNEP. This report highlights how India is introducing an innovative approach to attraction of private capital to the green economy. Specifically, it is highlighted that to achieve effective sustainable growth they should aim at a financial contribution for the development of green products, in favor of renewable energy, in favor of safeguarding water matrix and the definition of financial indicators "green" acts evaluation of progress and financial risks.

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In summary all international organizations are trying to formulate strategies to finance green policies to guide development towards sustainability.
This paper discusses a new method of self-financing potential of eco-oriented process system, we can call "Circular Financing". We'll see how through the involvement of the private sector, public sector and financial institutions and banks can turn a financial mechanism through which all stakeholders would benefit thus accelerating the process of innovation of production processes automatically, creating synergies of systems capable of putting the eco innovative production system to finance themselves.

Keywords: circular economy, innovative financial instrument, self financing, circular financing, co benefits

1. Introduction

For the productive sector the transition from linear economy to a circular type, and /or to the passage generally to forms of echo procedural innovation, requires large investments that often the private sector cannot cover with the self-financing. This is one of the reasons why the state intervenes in certain contexts conceding grant incentives to the private sector. A form of cooperation is also dictated by public-private partnerships (PPP), that is when an activity has repercussions, or there is a common interest, in both the private and public sector are formed dual agreements in which the State may finance, totally or partially, a private project (Garcia-Pozo et al., 2016).

There may be situations in which action brings benefits in both public and private spheres, through ***win win*** type strategies. Besides the PPP there are forms of cooperation between the private sector and public sector in which you can also enter the banks and lenders pushed by a return on invested capital greater or equal to the opportunity cost. Thus from a given action, project, policy could benefit both the public sector and the private sector, through the economic and environmental benefits, both the financial sector and credit through the financial benefit given by the return on capital (Albertario, 2015a, b, c).

In order to increase competitiveness in the market, the industrial sector reduces production costs, increases the flexibility of processes, reduces the environmental impact to eco tents. The innovative tools related to sustainability are many and various (eco design, procedural, organizational etc.) and require significant investment (Donida et al., 2015; Milano et al., 2015). Companies often fail to implement innovative eco processes through self-financing, so the lenders and banks may be involved. The methodology by which the lenders and banks agree to finance a project of any kind it, in our context eco innovation, is based more on the assessment of the return on investment and thus on the performance assessment (Sáez-Martínez et al., 2014). Often we use for this reason the calculation of the internal rate of return on investment (IRR).

IRR indicates the profitability of a potential investment, is a discount rate that brings the net present value (NPV) of the cash flows of a specific project to be zero. Banks and lenders decide to grant a loan for a eco-innovation project when the IRR is greater or equal than the opportunity cost of capital, an opportunity cost refers to a benefit that a person could have received, but gave up, to take another course of action. This methodology can be summarized in the following financial mathematics formula (Eq. 1):

$$NPV = \sum_{t=1}^{T} \left[\frac{F_{endogenous} + F_{exogenous}}{(1+r)^t} \right] - I_0 \qquad (1)$$

I_0 is the initial capital to invest at time 0 for the implementation of eco-innovation process. Placing the net present value (NPV) of zero and solving the equation you get the discount rate r, which is here the internal rate return (IRR) of the investment. This methodology leads to a kind of win-win strategy. The strategy is a ***win win*** situation of conflict resolution which aims to satisfy all of the contenders. In this context, the contenders are businesses and financial institutions or banks, this process brings benefits to both.

The cash flows may be endogenous to the production system or exogenous. The development of an innovative industrial eco project has repercussions on the territory system that can also influence the economic variables of the public sector. The exogenous cash flows are economic externalities of the private sector. For example innovation of circular economy leading to the re-use of industrial waste and urban waste, has positive effects both on the environment due to the lower soil used as a landfill, both economically and in terms of the relatively slaughter state budget of environmental management costs "of the landfill management expenses", item recognized in the State Budget. So the smaller the state outputs for the management of landfills in the short and long term, lead to future cash flows with a positive sign that should be included for a proper assessment of the IRR of the project financed (EPA, 2015).

An efficient management policy by the state, may be to consider that an industrial eco-innovation process can then:

- decrease the environmental management expenses in public accounting;
- increase the income derived and original, due to greater persistence of firms in the market and a consequent employment held (EPA, 2015).

From the point of view of costs, as mentioned, an eco-efficient industrial policy can lead to less chance of environmental damage and major accidents, lower waste management costs (e.g. landfill management and others). From the point of view of revenue, a more eco innovative industrial tools in the long run leads to greater persistence of enterprises, greater employment held, to greater investment attractiveness even by individuals outside the territory. Fig. 1 shows how an innovative eco industrial process could generate positive externalities on the public sector.

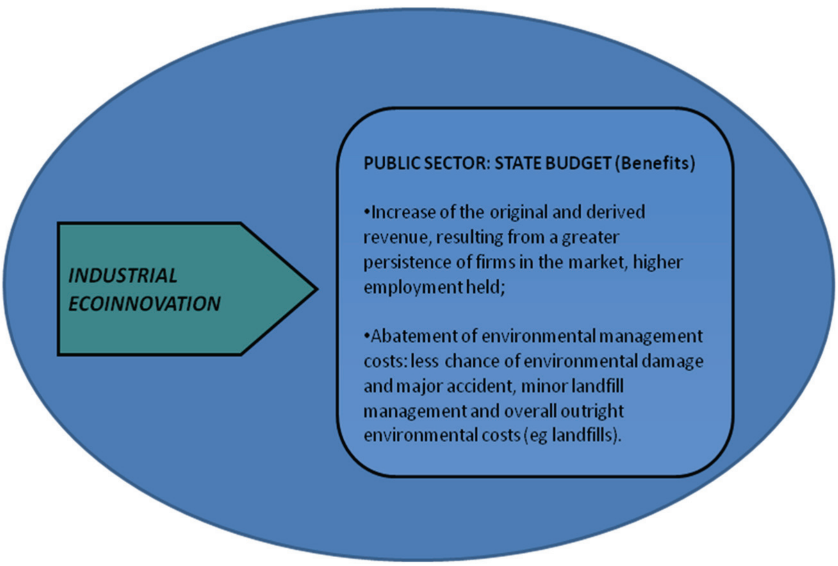

Fig. 1. Positive externalities generated by the private sector in public sector

2. Methodology

Evaluating more government revenues and higher potential output thus generated by the sum of eco-innovative industrial processes, the state with the lenders and banks may establish the agreements, thus creating system, as regards the granting of funds to finance the projects of eco-innovative investment self-powered by the sum of financial and economic benefits of the system.

An eco-innovation process can generate cash positive flows in the industrial system (***cash flows endogenous***) and external considering all the territory system in which the industry operates (***cash flows exogenous***) (Albertario, 2015, a, b, c)

For example Fig. 2 shows how, assuming a constant eco industrial innovation in the long term, going to evaluate the economic benefits over time on the General State Budget, we can suggest an intervention policy which transfers these benefits to businesses in the form of incentives also through the help of lenders and banks simultaneously (***win win strategies***) on one side anticipating cash flows exogenous eco innovation products national wide system by speeding up the process of national industrial innovation. Financial sector may grant loans in a manner advantageous driven by an internal rate of reasonable return on investment, greater than or equal to the opportunity cost. An ***opportunity cost*** refers to a benefit that a person could have received, but gave up, to take another course of action: $\boldsymbol{IRR \geq C_{opportunity}}$.

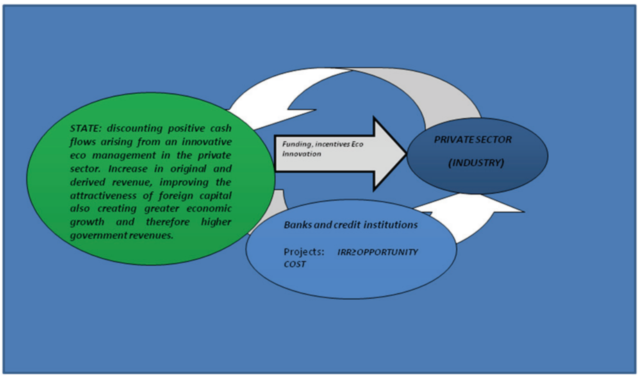

Fig. 2. Circular financial innovative system

So, watching Fig. 3 we can see how the Circular Financing mechanism works through the banks and lenders. These organizations aim at a return on invested capital, whose value must be greater than or equal to opportunity cost, anticipating the capital appreciation of reduced future expenses of state environmental eco-innovation management results, can accelerate the process of industrial modernization (UNEP, 2016a, b).

For example through this approach private sector implementing circular economy eco innovation tools can generate a reduction of costs for municipal waste management. In the State budget the positive cash flows discounted originating from the eco innovation in the years can be advanced (***incentives***) by lenders and Banks to private sector to accelerate the industrial eco innovation process. This methodology is shown in the Fig. 4.

We can represent what is described recovering the assessment generic formula of net present value and inserting the potential cash flows exogenous, will be expressed by Eq. (1). By solving the equation with a rate *r* higher return on opportunity cost that makes me NPV (net present value) of zero, a necessary condition, as explained previously. So that the lenders have a "fair" return on capital and can anticipate the capital needed to finance the environmentally innovative investments. I_0 is the initial investment for the private sector.

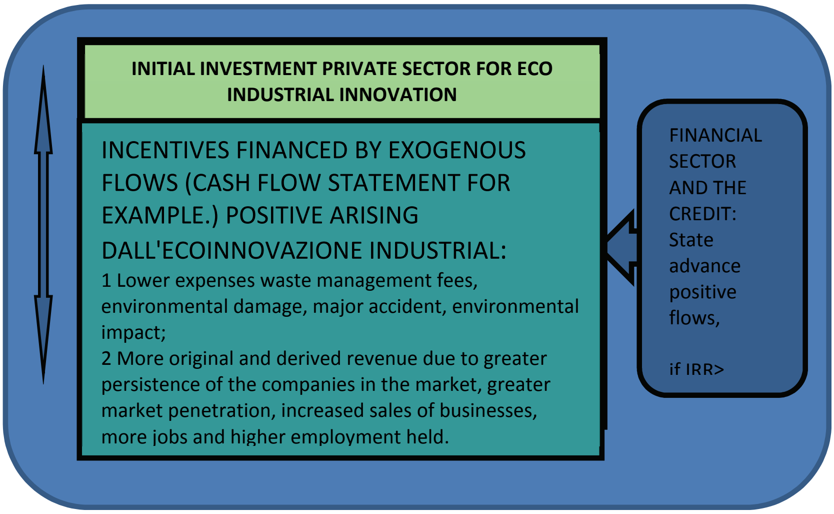

Fig. 3. Private finance increased public funding

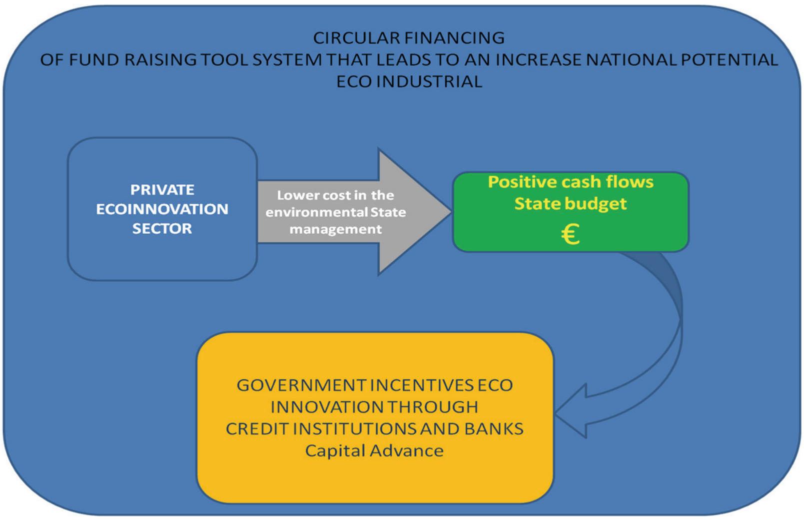

Fig. 4. Circular Financing methodology

Placing NPV zero the equation will be given by Eq. (2):

$$I_0 = \sum_{t=1}^{T} \frac{F_{endogenous} + F_{exogenous}}{(1+r)^t} \tag{2}$$

So cash flows exogenous can be paid advance by credit sector to the State, so State can be transferred to the private industrial sector (***incentives***) accelerating the eco innovation process (Pisano et al., 2015).

3. Concluding remarks

So we get to the situation, in some contexts, where the positive cash flows state budget (minor environmental management expenses, lower landfill management expenses due to a lower contribution of waste) paid in advance by lenders (driven by a fair return on capital) should finance the private sector by providing innovative eco tools.

In this way the State without additional statements can contribute substantially to eco innovation of the country. This leads in the medium and long term the industry to be more competitive, to substantially bring down the business risk, to have a more persistent employment rate, for a more attractive international (capital) in the strict sense and human capital thus leading to an increase in the medium and long term state revenue original and derived. The latter should further fuel to eco-innovation by implementing an automatic process of sustainable growth.

So the methodology exposed if implemented would lead to an innovative eco-intensive economic growth that would bring the European manufacturing sector (for example) to be more competitive in the long run because the innovative production process would be implemented in advance of an international (system) that does not adopt this financial strategy.

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RISK ANALYSIS AND FEASIBILITY STUDY FOR THE REUSE OF AN AREA PREVIOUSLY USED FOR REFINERY RESIDUES DISPOSAL*

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Abstract

Technip Italy S.p.A. has developed a FEED (Front End Engineering Design) project to increase the production capacity of a Refinery located in the Middle East. The project foresees the construction of new plants in an area of 55 ha close the refinery, which has been partially used in the past as disposal area of refinery residues (mainly oily waste).
The scope of Risk Analysis and Feasibility Study has been to combine the design requirements for the new refinery plants construction with the mitigation measures of environmental liabilities affecting the area. The feasibility study has been developed in three phases:

1) site assessment, based on existing soil and groundwater quality data, and conceptual site model reconstruction.
2) Site-specific risk analysis (according to ASTM standards and guidelines for Tier 2 analyses) elaborated in two site conditions: during construction phase and in the final operational phase.
3) Based on site risk analysis results, mitigation measures have been defined, both for construction and operational phase. Proposal of monitoring plan for soil vapors and groundwater quality.

As local environmental legislation does not provide specific guidance on contaminated sites management, site risk analysis - based on international standards - has been the decision process tool for selecting corrective actions.
A study on groundwater quality (inside and outside the site) is ongoing; a groundwater quality monitoring plan will be implemented during construction works.

Keywords: mitigation measures, refinery process residues, risk analysis

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*Selection and peer-review under responsibility of the ECOMONDO
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1. Introduction

Technip Italy S.p.A. has developed a FEED (Front End Engineering Design) project to increase the production capacity of a Refinery located in the Middle East. The project foresees the construction of new plants in an area of 55 ha close the refinery, which has been partially used in the past as disposal area of refinery residues (mainly oily waste). These residues were produced by thermal cracking process, containing 10÷20% of middle distillates (primarily olefins, paraffin and aromatics), the predominant compounds are PAHs (mainly benzo[a]pyrene), and secondarily VOCs and metals (Hu et al., 2013;).

In the 40's the site was used as a discharge area of refinery process residues. In the '90s the recovery and treatment operations started (mainly separation and recovery of the liquid phase), the volume of the refinery residues not mixed with soil has been estimated at about 1 million m^3. The groundwater level is about coincident with sea level and, due to the proximity to the sea (about 1 km), the quality is brackish to saline, the hydraulic gradient is very low. Shallow quaternary marine deposits are the first 0.0÷6.5 m b.g.l, overlapped on irregular bedrock of fractured limestone.

The thickness of soil locally mixed with refinery residues overlapping bedrock varies from 2 to 5 m in most of the area, reaching up to more than 6 m in a small portion, at the center of the site. The site now appears as a flat land, with topographic elevation in the range from +1.5 to +3 m above sea level (a.s.l.), broken up by a series of bunds, mainly constituted by filled sands, locally vegetated. The site is located in a lower area compared to the upper area where the refinery existing facilities are located. In most of the site the soil is soft with risk of sinking of for heavy vehicles: geotechnical soil improvement is required to make the site suitable for the construction of new refinery units (tanks, room controls buildings, internal roads, services…).

The project for the construction of new plants foresees that the final ground level of the site will be raised to the same level of the refinery existing facilities, by sandfilling with a maximum thickness of about 3.5 m (final ground level about 5 m a.s.l.)

The objectives of the study consist in:

- site assessment, based on existing soil and groundwater quality data, and conceptual site model reconstruction;
- evaluation of potential risk for site workers (during both construction phase and operational phase when the project will be completed);
- evaluation of possible mitigation measures appropriate for project realization.

2. Materials and methods

The study was developed in three main phases:

1. Analysis of available environmental data, deriving from past site characterization, and reconstruction of conceptual site model;
2. Site-specific risk analysis (according to ASTM standards and guidelines for Tier 2 analyses) elaborated in two site conditions: during construction phase and in the final operational phase;
3. Definition of mitigation measures, appropriate for the geotechnical soil improvement operations (construction phase) and for the operational phase.

The environmental quality of soil and groundwater has been reconstructed using the results of environmental investigations, carried out in the past and recently updated, during geotechnical investigation for soil improvement. Boreholes, trial pits, groundwater monitoring wells and relative soil and groundwater sampling have been realized on the site.

The site risk analysis has been developed taking as main reference the ASTM standards and guidelines, in particular ASTM Standards E2081-00 (2015) “Standard Guide for Risk Based Corrective Action” and E1379-95 (2015) “Standard Guide for Risk Based Corrective Action applied at Petroleum Release Sites”.

The basic assumptions of the study are:

- primary sources, as well as refinery process residues, are considered totally removed (the oily residues recover operation are ongoing and almost completed);
- transport mechanisms towards groundwater outside the site and surface waters are excluded;
- the exposed receptors are only the (industrial) workers, during the construction phase and during the operational phase according to the site use.

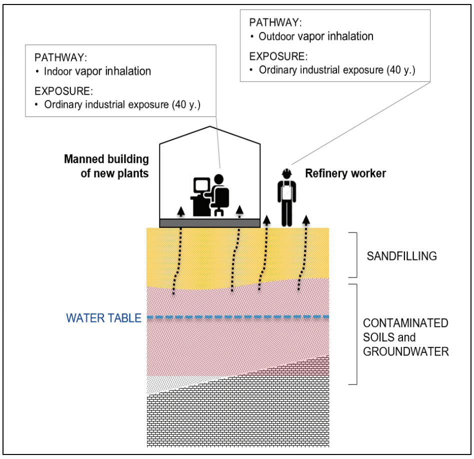
The screening level, for each substance (for soil and groundwater), has been conservatively taken as the minimum among the screening levels (or differently named equivalent thresholds) reported, for industrial sites, in the following guidelines (D’Aprile et al., 2007; Environment Agency, 2009; ESDAT, 2000; Water Boards, 2016; WHO, 2008):

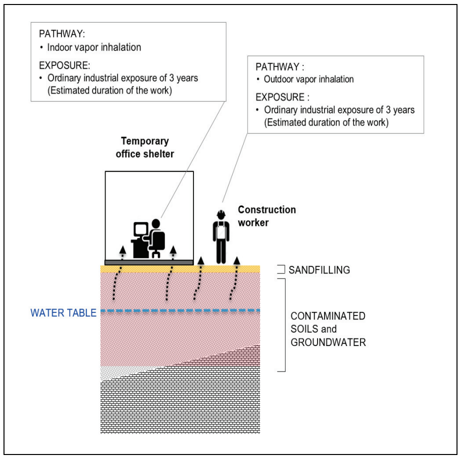
- US EPA Regional Screening Levels for Chemical Contaminants at Superfund Sites;
- UK Soil Guideline Values;
- Dutch Target and Intervention Values;
- Italian Soil and Groundwater Screening Levels;
- Beijing EPB Soil Screening Levels;
- US EPA Federal Water Quality MCLs;
- EU Drinking Water Standards.

The contaminants concentrations in the soil resulted quite significant in many cases, exceeding the screening levels adopted as reference in this study, especially for PAHs and some metals. Several contaminants have been found also in groundwater, where a larger variety of organic contaminants is present, although TPHs are the most important contaminants.

Contaminated soil and groundwater were identified as contamination sources and appropriate concentrations were select as reference concentrations for each contaminant: for groundwater they were taken equal to the maximum concentrations while for soil (where more data are available) to the maximum concentrations, in the Worst Case (WC), or to the mean concentrations, in the Most Favorable Case (MFC). The new refinery units will be largely unmanned. The locations where only refinery workers will operate are limited to three main buildings (gate and control rooms). During construction works, an area has been selected in the space available for future development, for the realization of site offices, covering almost 100,000 m^2. In this area a sandfilling, 60 cm thick is planned, before installing the construction offices (shelters laying on temporary slabs) distributed over the area without continuity.

The exposed receptors are only the workers, during the operational phase (see Fig. 1a) and during the construction phase (Fig. 1b); transport mechanisms towards groundwater and surface waters are excluded, according to the basic assumptions previously outlined. Due to the planned backfilling (and, additionally, slabs, where present) any direct contact between the exposed targets and the contamination sources is prevented and, therefore, being the risk analysis solely devoted to the protection of the site workers, the only active exposure pathways are indoor and outdoor vapor inhalation.





a) **b)**

Fig. 1. Receptors and exposure in the operational phase (a) and in the construction phase (b)

In conclusion, the potential receptors (targets) of soil and groundwater contamination and the pathways are:

- refinery workers, exposed to outdoor and indoor vapor inhalation, in the refinery area;
- construction workers, exposed to outdoor and indoor vapor inhalation, during the construction phase, in the construction office area.

For those receptors standards Reasonable Maximum Exposure parameters have been adopted, with the exception of:

- outdoor exposure frequency for refinery workers, taken equal to the maximum between 1h/d and 1m/y;
- exposure duration for construction workers, taken equal to 3 y.

According to the international practice, allowable risk levels, for each exposure pathway, have been set equal to the following values:

- carcinogenic risk:
  - individual contaminants: 10^{-6};
  - cumulate over all contaminants: 10^{-5};
- non carcinogenic risk (hazard index): 1 for individual contaminants and cumulate.

3. Results and discussion

Risk analysis calculations have been performed for all exposure pathways and receptors as previously identified, in both WC and MFC scenarios, leading to the following analyses:

- construction Phase, outdoor vapor inhalation and indoor vapor inhalation;
- operational phase, outdoor vapor inhalation and indoor vapor inhalation.

From the results of the risk analysis calculations, the following conclusions can be provided:

- the carcinogenic risk is always largely below the allowable level;
- the toxic risk largely exceed the allowable level for indoor exposure;
- the toxic risk remains borderline for outdoor exposure, taking into account that the outdoor risk depends more on the average source concentration rather than on the maximum

concentration and, additionally, that the source length has been set to a quite conservative value.

When largely exceeding allowable levels, the risk is controlled by semivolatile substances in the soil source, in particular naphthalene and aliphatic and aromatic TPH in the range C_{10}-C_{16}. However, the Johnson & Ettinger model used to represents the contaminant volatilization and the vapor diffusion in the risk analysis, although being the most widely used model in risk analysis studies worldwide, can significantly overestimate, in some cases, vapor fluxes from contaminated soil and groundwater.

Considering the results of the risk analyses, it is appropriate:

- performing vapor flux measurements to assess if a risk for vapor inhalation exists at the site (after sandfilling realization);
- defining corrective actions, to be implemented in the case the vapor inhalation risk is confirmed by the measurements.

For vapor measurements and safety measures design, the allowable fluxes of the contaminants controlling the risk at the site are key parameters and they have been calculated, taking into account that the risks are linearly dependent on the concentrations in the air at the point of exposure and these concentrations are a linear function of the vapor fluxes. Vapor fluxes can be, alternatively, directly measured using a flux chamber; or indirectly evaluated, from measurements of soil gas at different depths.

Mitigations measures, aimed at reducing the vapor fluxes from the subsoil to the interior of the buildings, consist in reducing the vapor permeability of the slabs, either by modifying their design or by introducing a new element having very low vapor permeability. Although the former approach can be, in principle, adopted, it may have major impacts on the slab construction and, therefore, it is proposed that the vapor permeability of the slabs is appropriately reduced, where necessary, by inserting in the slabs a plastic geomembrane, having appropriately low vapor permeability (Fig. 2a).

A maximum value of vapor permeability equal to 10^{-2} mc/smq/d, measured according to the ASTM Standards D1434, can be defined as target for plastic geomembranes to be used in the slabs, to appropriately prevent any risk of indoor vapor inhalation for the site workers, both in the operation and in the construction phases. In the case slabs with plastic geomembrane extend over large surfaces and are not widely spaced, a vapor collection system is recommended, to collect and properly discharge the vapors, which otherwise could accumulate below the slabs.

The actual need for this system has to be verified first on the basis of the slab extension and spacing and keeping in mind that this can be done after the vapor tight slab has been put in place.

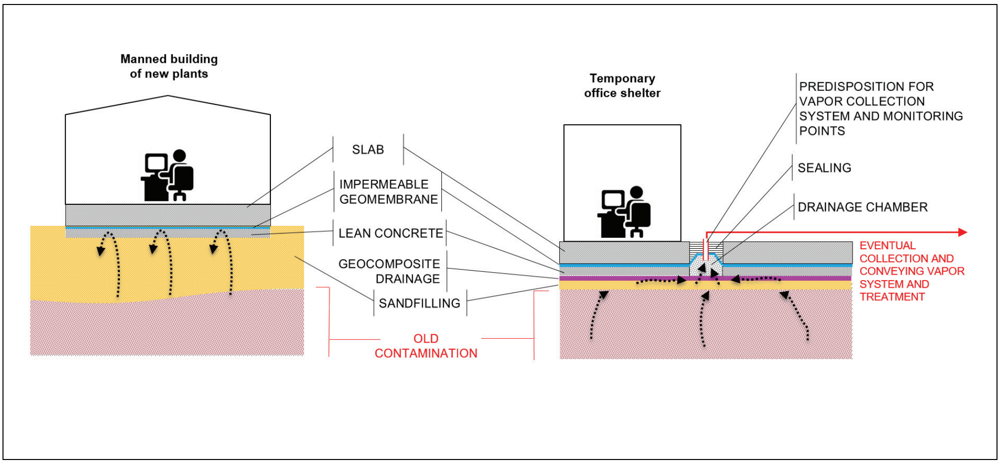
The vapor collection system may be composed of (Fig. 2b):

a) a draining geocomposite, where the vapors from the subsoil can be collected, to be put in place below the slab;

b) collection points, inside the geocomposite, which are small diameter pipes, appropriately spaced, welded/sealed to the geomembrane and connected to a network of collection pipes;

c) collection pipes, connected to activated carbon filters for treatment before air discharge, supplemented, if needed, by an air extractor.

Since parts a) and b) of the vapor collection system must be put in place below the slab (therefore before the slab is constructed), while the actual need of this system can be checked after the slab is realized. The vapor collection system has been recommend to be realized in any case, while part c) realized only if the need of the system is confirmed by appropriate measures.



a) **b)**

Fig. 2. Mitigation measures: a) Scheme of slabs of manned buildings with geomembrane at operational phase; b) Scheme of vapor collection system under temporary office shelter during construction phase

The construction of the new plants require interventions aimed at improving the geotechnical characteristics (bearing capacity) of soil, including stone column and mostly concrete poles implanted to the limestone bedrock. These operations involve the application of high pressures to the ground by vibration/air (especially for stone column) and through drilling fluids (concrete poles). These overpressures could favorite migration-dispersion of contaminants and cross-contamination of sandfilling, thereby changing the conceptual model assumed for the Risk Analysis. With the aim to test the possible effect of overpressure to the ground, it has been proposed the preparation of a field tests for the verification of the environmental status ante operam, post-operam and in-operam.

4. Concluding remarks

As local environmental legislation does not provide specific guidance on contaminated sites management, site specific risk analysis - based on international standards - has been the decision process tool for selecting corrective actions. Risk analysis has highlighted a potential toxicological risk for indoor exposure of workers: this risk can be mitigated by inserting in buildings floor slabs a geomembrane, impermeable to soil vapors (both for plant offices and for temporary construction offices). Also a toxicological risk for outdoor exposure of workers has been calculated with value close to the allowable limits: to verify this risk, it is necessary to perform vapor field measurements after site preparation.

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ENVIRONMENTAL DUE DILIGENCE FOR COMMERCIAL AND RESIDENTIAL REAL ESTATE*

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Abstract

Environmental Due Diligence (EDD) is a technical investigation used to support property acquisition, industrial Site concessions and corporate expansions or mergers. Its aim is to issue an opinion of compliance with respect to environmental law, calculate the costs of detected environmental liabilities and reduce the risks of legal litigations.
Although generally the environmental risk associated with commercial and residential real estate could be considered low, the potential liabilities, often associated with the historical activities conducted on site result significant.
In the present document, a model for the evaluation of potential risks and costs pertinent to environmental liabilities associated with commercial and residential real estate, was taken into account by adopting and adapting internationally recognized protocols.
The subject article also reports the most significant and frequent liabilities associated with commercial and residential real estate, identified analyzing Italian and European Portfolios in the last 15 years.

Keywords: commercial residential real estate, Environmental Due Diligence, Italian and European Portfolio

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1. Introduction

Originally, EDDs were mainly linked to the industrial field, but have lately begun to be considered also for commercial and residential real estate (Flyvbjerg, 2013; Rizzotti and Greco, 2013; Rosenbloom, 2016). Only recently has been understood the gravity of not identified or properly evaluated environmental liabilities, since they can affect the real value of properties, generate administrative pending suits and limitations to the site use. An EDD should not be limited to determine the economic costs of environmental liabilities, but should include a detailed evaluation of the associated potential risks, such as legal litigations, prosecution for crimes, Site or service interdiction and reputational damage (De Schutter et al., 2012; Forte, 2011, Grecu et al., 2014; Milano et al., 2015).

The first two objectives of this article are to outline the basic structure of an EDD for commercial and residential real estate and highlight the importance of this type of investigation, as an efficient means to obtain a neutral and internationally recognized overview of potential environmental non-compliances and liabilities. The third objective is to present the most significant and frequent liabilities associated with commercial and residential real estate on the basis of a study carried out on major Italian and European real estate portfolios starting from the year 2000.

In fact, the aim of an EDD is to issue an opinion of compliance in respect of environmental law. It consists of identifying the potential risks and costs associated with current and past activities that could have been, or currently are, causing a potential impact on the environment.

The three main goals of an EDD for commercial and residential real estate are:

- the verification of all current or past activities associated with any soil contamination, which could cause or have caused economic liabilities a/o Site use limitations;
- the verification of the presence of onsite hazardous substances a/o substances subject to restrictions;
- the verification of the legal compliance at the time of the transaction, which could imply responsibility for the new owner.

2. Material and methods

Preliminary activities for the assessment of potential liabilities associated with soil, subsoil and groundwater, are ruled at international level by standards defined by ASTM (*American Society for Testing and Materials*), which issued ASTM E1527-05 and ASTM 1528-06 protocols for the execution of EDDs. These protocols, which are globally recognized by financial service companies involved in property transactions, provide a comparison with similar environmental investigation and assure that assumptions made at the time of the transaction are unlikely contested. The above reported protocols are limited to the assessment of potential liabilities associated with handling and storage of petroleum products and chemicals, resulting into a subsoil impairment; in the common use the EDD includes the survey of restricted substances and the preliminary assessment of the compliance with the environmental legislation.

The EDD consists of two phases of survey: a non-invasive *(Phase I),* limited to documents and database review and visual assessment and an invasive one *(Phase II*), which could include subsoil investigation and material testing.

2.1. Phase I

EDD-Phase I aims at identifying potential environmental liabilities, providing a preliminary opinion of compliance in respect of environmental law, at establishing the need to perform additional investigation (Phase II), estimating the costs of environmental liabilities. An EDD-Phase I usually consists of three activities: Desktop Study, Dataroom and Site Inspection.

2.1.1. Desktop Study

"Desktop Study" is the retrieval of information required to obtain a local territorial and environmental overview of the property and Site vicinity. The Desktop study consists of a review of documents, such as topographic maps, geological maps, aerial photos of historical archives, etc., and anonymous interviews with public bodies.

The Desktop study includes the environmental setting of the target Site and the surrounding areas, specifically:

- Vulnerability to potential contamination (type of soil, depth of groundwater, presence of lake, wet lands etc.);
- Environmental sensitivity, in terms of potential targets of a potential contamination, such as water wells, residential areas, wildlife protected areas;
- Potential Source(s) of contamination in the property and in the neighboring properties, such as industrial and craft activities, contamination notifications, ongoing or past remediation activities, environmental incidents or background contamination in soils or groundwater.

Finally, the Desktop study also includes the vulnerability to natural disasters such as earthquake and floods and the presence of Radon.

2.1.2. Dataroom

By the term "Dataroom", we mean the available documents pertinent to the target Site. It consists of a documentation analysis in order to obtain information on environmental matters. The most significant environmental information consists of:

- Activities conducted onsite prior to the Site development
- Construction materials (backfilling material, building materials, potential presence of restricted substances, such as Asbestos, polychlorinated biphenyl-PCB)
- Actual and historical activities conducted onsite (crafting actives, commercial activities, such as dry cleaner, photoshop, car repair)
- Building plant and utilities, such as air conditioning and heating plant, electrical cabinet, wastewater management, chemical storage, etc.

It is crucial to keep track of the provided documentation, highlight the lack of documentation, inaccuracy or incorrectness and evaluate an estimate of the potential associated liabilities. It is also important that the documentation is made available before the inspection in order to acquire all preliminary available information.

2.1.3. Site inspection

During the inspection, the consistency with the information obtained in the course of the Dataroom Study is assessed and integrated with visual evidence and interviews to the onsite personnel. In this way, additional information related to past or ongoing activities, the conservation status of the real estate and the presence of possible contamination sources is gathered.

The Site inspection includes the survey of potential restricted substances such as Asbestos, Mineral Man-Made fibers, equipment and machinery containing PCB or Ozone Depleting Substances (ODS).

Furthermore, the correct implementation of environmental procedures and requirements set out in previous authorizations is checked, such as chemical handling, storage and use, waste segregation and storage; wastewater management, etc.

Evidences of historical artifacts and utilities are also important such as vent pipes, manholes, valves associated with historical underground storage tanks abandoned onsite a/o removed supplying the former heating plant, stressed vegetation associated with subsoil impairment, buried waste, etc.

2.2. Phase II

EDD Phase II consists of direct investigations and may include detailed evaluations of major environmental issues, through sampling activities and qualitative or quantitative analyses. Its aim is to further investigate potential liabilities that emerged in Phase I and generally includes:

- Technical assessment of the potential sources of contamination, such as the tightness test of underground storage tanks and sewer systems;
- Subsoil investigation, including soil, groundwater and soil gas;
- Sampling and analysis of potential Asbestos Containing Materials (ACMs) and other restricted substances as PCB, Man Made Mineral Fibers, etc.

2.3. Evaluation of the potential environmental liabilities

The final output of an EDD process is the interpretation of data and information obtained from the Phase I and II activities, therefore the definition of environmental liabilities and critical issues that determine environmental risk.

For each legislative non-compliance a/o potential or ascertained environmental liability, the costs for the actions required to solve the issues are quantified.

Due to the typical restriction associated with transaction, mainly associated with restricted timeframe, EDD often presents limitations, such as:

- Limited historical information;
- Impossibility to complete Phase II activities, such as subsoil investigation, tightness test of the sewer system, etc.

Potential environmental costs are usually calculated by means of a risk assessment process which evaluates the potential hazard (source of subsoil contamination, potential presence of Asbestos and potential non-compliance), the vulnerability of the Site (presence of water wells, protected wildlife areas, groundwater depth) and the resulting issue (remediation of the soil, Asbestos removal, restriction in the use of the Site).

The costs are outlined on the basis of previous calculations performed on other portfolios and the professional experience of the experts who conduct the evaluation. In this context, the costs are appropriately adjusted to current market costs and specific characteristics of the portfolio.

The costs of each potential environmental liability are usually expressed as a range of costs from a "*Best Case Scenario*" to a "*Worst Case Scenario*" and a “*Likely Case Scenario*”, resulting from the average between the two scenarios. The uncertainty between the Worst and Best scenario is highly influenced by the data gap in terms of missing information and the correct execution of the Phase II activities, such as tightness test, subsoil investigation, Asbestos Survey.

3. Results and discussion: study of major Italian and European real estate portfolios

Below are summarized the main issues associated with commercial and residential real estate. The results were gathered by the Analyses of Environmental Due Diligence conducted on over 10,000 assets in 15 years. The environmental Due Diligence involved private and public Portfolio.

The main identified potential issues are associated with subsoil contamination and Asbestos. Subsoil contamination is rarely associated with current Site operations but mainly associated with the historical activities conducted at the Site or prior to the construction of the target building and off-site contamination sources.

Previous industrial and craft activities conducted on site may have resulted in soil and subsoil contamination. Extremely significant are the historical activities conducted prior to the '80s and '90s, when there was less sensitivity in regard to the environment, environmental law was not developed and the use of hazardous substances, such as PCB-PCTs, chlorinated solvents, etc., was common. Often central residential areas could have been interested by heavy industrial activities. Special attention is given to wastewater management, once commonly infiltrated into soil or into the groundwater; also civil sanitary water systems are taken into consideration: chemicals, surfactants, medicines, paints and small amounts of oils/solvents. It is also important to evaluate the development phases of the Site, since filling materials, consisting of foundry slag and Asbestos could be present.

An aspect not to be underestimated is the nearby activities, which could result into the contamination of the groundwater, which could lead the contamination to the property. Present or past nearby presence of industry or small craft shops, dry cleaners, gas stations, could imply subsoil contamination.

Although the "polluter pays" principle of the Environmental Code, should protect the innocent owner for any potential liabilities, contamination from off-site source or associated with historical activities could result into a limitation in the use of the asset. Some of the contamination identified in the analyzed building result not proper for the lease, due to the presence of vapor associated with contamination.

It is essential that at each transaction the potential presence of pre-existing soil, subsoil, and groundwater contamination is addressed. This will protect both parts from any liability related to contamination not associated to the property management period. Although there are forensic methods for the dating of a contamination, very rarely it can be established with certainty. Furthermore, when present potential source of contamination a/o restricted substance, it is important to protect the new owner from potential infringement, which could also result into criminal liabilities. For example in the case of an Underground Storage Tank which is not tight and releases contaminants into the subsoil, the new owner would be responsible for the pollution.

Another example, in case of presence of Asbestos, which is a carcinogenic material, the owner of the Site or the employer would be responsible for the condition of the workplace. Asbestos, widely used in the past as building and insulation material, is, due to its carcinogenic nature, one of the main environmental liabilities connected to real estate. If the property was built before the year in which the use of Asbestos was banned (1992 in Italy), it may be necessary to undertake a complete survey of Asbestos aimed at identifying the presence, the harmfulness, as possible release of airborne fibers in the environment could occur and determine risks to human health. The presence of ACMs is usually assessed on ceilings, insulation panels, canopies, pipe coatings, seals, insulation of boilers etc. A commonly recognized sources of contamination related to commercial and residential real estate are Underground Storage Tanks (USTs), usually associated with heating plant and emergency generator. These artifacts, even when inactive, are not always properly cleaned, often abandoned onsite. In Table 1 there are reported some results of the analyzed Portfolios, which included the evaluation of approximately 10,000 commercial and residential assets.

Other environmental liabilities include non compliance with permits (air emission, wastewater discharge etc.), water supply (presence of unauthorized water wells, quality of drinkable water) presence of restricted substances (Man-made Mineral Fibers, PCB, ODS/Greenhouse gases), other non-compliance associated with waste management, noise and Legionella. Among the analyzed assets was also recorded the presence of limitation to the use of a Site due to the presence of natural Radon gas, a carcinogenic substance.

Usually due to the time and cost limitation is not possible to properly investigate the potential environmental liabilities identified in the Phase I; in Table 2 it is reported the quantification of the environmental liabilities, performed on a restricted number of Site which undergone in a complete Phase II including the subsoil investigation and the Asbestos survey.

Table 1. Environmental liabilities identified after the evaluation of approximately 10,000 commercial and residential assets

Potential Liability 10,000 Assets	*Incidence of potential Environmental liability*	*Potential liability exceeding 100 k€*	*Potential liability exceeding 1,000 k€*
Subsoil impairment	44 %	44%	6%
Presence of ACM	62%	38%	3%
Other environmental liabilities	37%	3%	-

The Phase II was conducted on limited number of assets (452) ranked as high risk, based on the age of the building, the surface and the presence of recognized environmental concerns, such as previous industrial activities, failure of UST tightness test, potential presence of significant Amount of friable Asbestos.

Table 2. Quantification of the environmental liabilities, performed on a restricted number of Site in a complete Phase II including the subsoil investigation and the Asbestos survey

Identified Liability 452 Assets	*Incidence of Environmental liability*	*Identified liability exceeding 100 k€*	*Identified liability exceeding 1,000 k€*
Subsoil impairment	58%	32%	2%
Presence of ACM	82%	45%	1%
Other environmental liabilities	27%	1%	-

5. Conclusion

Through an EDD and the implementation of a study model applicable to large real estate portfolios, it is possible to economically quantify environmental liabilities connected to real estate. As described, it is also possible to estimate the costs of prevention/mitigation activities, utilizing an internationally recognized standard that considers both legal aspects and specific critical issues of the investigated Site.

The percentage of impacted sites, calculated on a very representative pool, indicates that EDD is definitely justified also in case of residential and commercial real estate.

With respect to the potential liabilities associated with subsoil contamination, a detailed research on historical activities prior to the Site development and operations conducted on site is deemed necessary. In case of identification of onsite a/o offsite sources of contamination, a baseline subsoil investigation is recommended.

The EDD can provide an objective and impartial full view of potential non-compliances or environmental liabilities ensuring a fair result for the involved parties during property acquisitions.

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CALABRIAN BIOGAS: FIRST EXPERIENCE USING LOCAL BIOMASS AND ORGANIC FRACTION SOLID WASTE (OFSW)*

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Abstract

This study was focused on the Calabria region of Italy and coordinated by Cortea, with the help also of local partners, and hosted by the city of Crotone through NET, environment and energy pole.
The research was focused on studying the availability of biomass in the Calabria region for the production of biogas, thanks to the great potential from agricultural activities, such as citrus fruit pulp, pomaces, olive cake and buffalo dung, using the technology of dry anaerobic digestion. The higher yield of biogas production was obtained using buffalo manure (0.88 sm^3/kg volatile substance, then citrus pulp (0.60 sm^3/kg VS).
A special mention for the biowaste, the organic fraction of municipal solid waste: the Calabria region has definitely untapped potential, thanks to large urban centers and a vast rural area. The use of this material arouses a lot of interest especially for the production of biogas via dry digestion.

Keywords: calabrian biomass, citrus pulp, dry digestion, OFSW, organic fraction solid waste

1. Introduction

The Calabria region offers a lot of biomass as a result of production processes especially from fruit industry and processing. Calabria provides many types of biomass such as citrus pulp, marc, olive pomace etc. typical of the Mediterranean region. The idea at the base of the proposal is to use and valorize, from the point of view of energy, the existing huge biomass quantity in the Calabria region that nowadays is not yet exploited or used in any way (Marziliano et al., 2016; Paiano and Lagioia, 2016). The natural valorization for this

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type of biological natural material is the digestion to produce biogas (Battista et al., 2013; De Luca et al., 2015; Siciliano et al., 2016). The produced biogas can be burned to produce heating, mechanical energy and so on. The project was financed by the Calabrian Region through the POR/FESR 2007/2013 (Regional operative plane) and done in collaboration with NET, the regional pole of energy innovation and environment.

The other important aspect, characteristic of the Calabria Region, from the point of view of the availability of biological material for biogas production by digestion is the low level of differentiated waste collection of urban solid waste in the region that offers a great potential quantity of organic fraction for digestion (OFSW) (Agovino et al., 2016; Paiano and Lagioia, 2016). The economic impacts in the region are significant due to the integration between different activities in the pursuit of common goals and interests for the region in particular:

- implementation of the agro-energy in the territory
- integrated rural and sustainable development in marginal areas
- environmental protection (measures against instability and soil erosion etc.)

The purpose of the study was to investigate the production of biogas in relation to the available biomass in Calabria. With regard specifically to the biogas production from animal, agricultural and agro-industrial waste, due to the fact that the material has a low moisture content, or is even solid or semisolid was adopted the dry technology without integration of process water with the great advantage of a modest amount of digestate at the end of fermentation.

Fermentation tests were conducted using dry anaerobic digestion technology with different types of biomass mixtures such as citrus pulp, olive pulp, grape pomace, buffalo manure used as inoculum. The use of this fermentation technique has many operational advantages, such as those related to the handling of the biomass, to the production and recycling of the percolate etc., but above all involves a large energy savings.

With the traditional methodology of wet digestion in fact, approximately 15-20% of the electricity produced is consumed to activate all the necessary mechanical agitation of the biomass for proper fermentation while in the case of dry fermentation, for the intrinsic characteristics of the process, this need not arise (Bacenetti and Fiala, 2015; Battista et al., 2013). Through a digester, in a laboratory scale, different biomass mixtures have been tested and the amount of biogas produced was detected. Using a portable analyzer the quality of the biogas produced was also evaluated.

The system of biogas production is innovative, primarily because conceived to small and medium scale, the system utilized is indeed designed for small - medium power scale suitable for companies and production units of agricultural waste and agro-industrial residues of medium size, secondarily presents reduced or zero environmental impact, low operating and investment costs.

2. Materials and methods

First of all a research was conducted on the availability of biomass on the Calabrian territory to identify the location and the type of biomass on land resources, the qualification and quantification of biomass potential of agricultural and forest of inter-area, a characterization of the different types of biomass under the agronomic and analytical profile, an identification of the productive potential of biomass. Subsequently some samples of different types of biomass, among those available, were recovered thanks to local companies.

Once characterized the biomass samples, the tests of digestion were conducted in a laboratory scale digester using standardized conditions. In this way the speed of conversion of each raw material into biogas was determined. For the territorial study of biomass available in Calabria was performed a survey, with identification and classification of local raw materials from agricultural and forest residues, energy crops and waste used for energy purposes such as the organic fraction of solid urban waste (OFSW).

Then different biomass samples were collected, among those most available such as citrus pulp, olive pomace, marc etc., for determining the chemical organic matter, nitrogen, phosphorus, potassium and other mineral compounds content and the physical characteristics (salinity, humidity, density, size etc.). Moreover microbial analysis were conducted to determine the total microbial populations such as flora, cellulolytic, hydrolytic, and other functional groups.

Once characterized the biomass samples the tests of digestion were conducted in a laboratory scale digester using standardized conditions. In this way the speed of conversion into biogas was investigated. The dry fermentation tests were conducted on a laboratory scale digester. Maximum weight 2.5 kg tested. The biomass to be tested is disposed inside the sealed digestion chamber. Through the fermentation process the production of biogas determines a pressure increase within the digestion chamber which is constantly maintained at the operating temperature set through a PLC control. The pressure can increase up to a set value at which intervenes the automated opening of the exhaust valve of the biogas, that is then reclosed to a lower limit value set to allow the repetition cycle.

The measuring system in the time of pressure variations and temperature from which can derive the amount of biogas produced. Inside the cylindrical digestion chamber a stainless steel drum is allocated within which the biomass to be tested is disposed. At the center of the basket, equipped with side racks for moisture and biogas passage, there is a hole that allows the passage of the measuring probe of the internal temperature of the digestion chamber.

Above the drum where the biomass is allocated, a perforated steel pipe, within which the leachate to always keep the walls of the wet digestion chamber is circulated. There is also the possibility, as seen in the figure, to instantly spray the biomass by acting on a control panel button. The screen display allows you to set the parameters and check the status of the system easily. The data is recorded on computer and or USB stick connected to the system. Normally, the biomass retention time for the complete anaerobic digestion is about 30 days (Lettinga, 1980).

Tests with different biomass were performed, particularly with citrus pulp, with marc and with buffalo dung. The tested mixture was formed always from 80% of biomass to be tested and 20% of buffalo manure inoculum for a total weight of 2.5 kg.

3. Results and discussion

This paper presents an important study regarding the conversion to biogas of the types of biomasses present in the Calabria Region especially from the point of view of the impacts on environment and on local economy. At first the results on the availability of biomass in the region, arising from preliminary study, have shown that for citrus fruit pulp strong provinces in terms of productions are those of Reggio Calabria, Cosenza and Catanzaro with special reference to that of oranges. Average annual production amounted between 90.000 tons and 7.000 tons. Overall for the Calabria region the availability of orange citrus fruit pulp is around 170.000 tons per year.

For olive pomace the trend is the same of citrus fruit pulp and the productions are between the 90.000 tons and 18.000 tons with total values for the region around 200.000 tons per year. The distribution of marc for the production distribution is almost uniform in the region with the exception of the province of Vibo Valentia. The productions are between the 20.000 tons and 1.300 tons with total values for the region around the 50.000 tons per year.

For woody biomass something different must be conducted according to the actual availability of the biomass through the transport and road link.

A macroscopic analysis has issued guidance on the logistical difficulties, which also reflect the production trends recorded earlier biomass, however, at microscopic level, it is necessary a detailed study at the retail level to determine the real potential and availability of biomass.

Average annual production stood between 100.000 m^3 per year and 40.000 m^3 per year. Overall for the Calabria region of timber availability in terms of cubic meters goes from 360.000 m^3 per year for broadleaf to 300.000 m^3 per year for conifers.

Finally, as regards the organic fraction of urban waste, margins of improvement are still large. For the province of Cosenza, the most virtuous, the fraction collection of biowaste is approximately 20.000 tons per year (in the Vicenza area, afferent to the center of Bassano del Grappa biogas OFSW (organic fraction solid waste), the value is about 40.000 tons per year against a catchment of 300.000 inhabitants).

Subsequently physical and chemical analyzes were performed. From the point of view of chemical analysis, "approximate and ultimate", of the elemental composition such as carbon and nitrogen (CN analysis), conducted by the elemental analyzer LECO CN628, equipment NET pole, the results are shown in Table 1. In Table 2 the results of the physical analysis of raw materials are shown.

Table 1. CN analysis results, dry matter basis

Biomass	*C (%)*	*N (%)*	*C/N*
Citrus pulp	45.00±9.83	1.91±0.20	23.90
Orange pulp	35.70±2.83	1.14±0.28	31.32
Buffalo litter	41.40±2.02	3.20±0.14	12.94
Olive pomace	54.00±1.41	1.79±0.16	30.17
Chicken droppings	36.60±1.45	3.68±0.11	9.95
Oil mill waste water	52.00±2.09	1.43±0.01	36.40
Cereal straw	44.20±3.40	1.02±0.16	43.33
Jatropha curcas (solid residue of squeezing)	43.60±0.41	4.36±0.30	10±0.7

Table 2. Physical analysis results

Biomass	*Humidity (%)*	*Dry substance (%)*	*Ash (%)*	*Volatile substance (%)*
Citrus pulp	78.1	21.9	19.1	80.9
Marc	77.0	22.9	18.8	78.0
Buffalo manure	85.5	14.5	32.2	67.8
Olive pomace	69.5	30.5	4.8	95.2

After the tests, dry fermentations in the laboratory scale digester were performed, as discussed previously. During the fermentation time, about 30 days, the temperature is set constant and the pressure on the camera is controlled. The increasing pressure means that biogas is forming. An example of the data detected by the monitoring system: in particular, here the temperature and pressure levels over time are reported. The almost constant trend of temperature after reaching the test temperature is reported, and the linear trend of the pressure up to the maximum of 25 mBar value at which it is expected the product gas outlet. For each pressure peak corresponds an opening of the exhaust valve. As example a sample of the temperature and pressure trend during the fermentation test is presented in Fig. 1.

The pressure increases until the max value of 25 mBar, which was set as a limit for the test, and then decreases due to the opening of a pressure valve. The valve is closed immediately by the PLC controller and the pressure, at cause of fermentation, can increase again. From different biomass obviously very different behaviors were obtained, with different biogas production between them in relation to the quantity of bacteria present in biomass (Figs. 2, 3). Table 3 shows the quantity of biogas for the different type of the biomass tested.

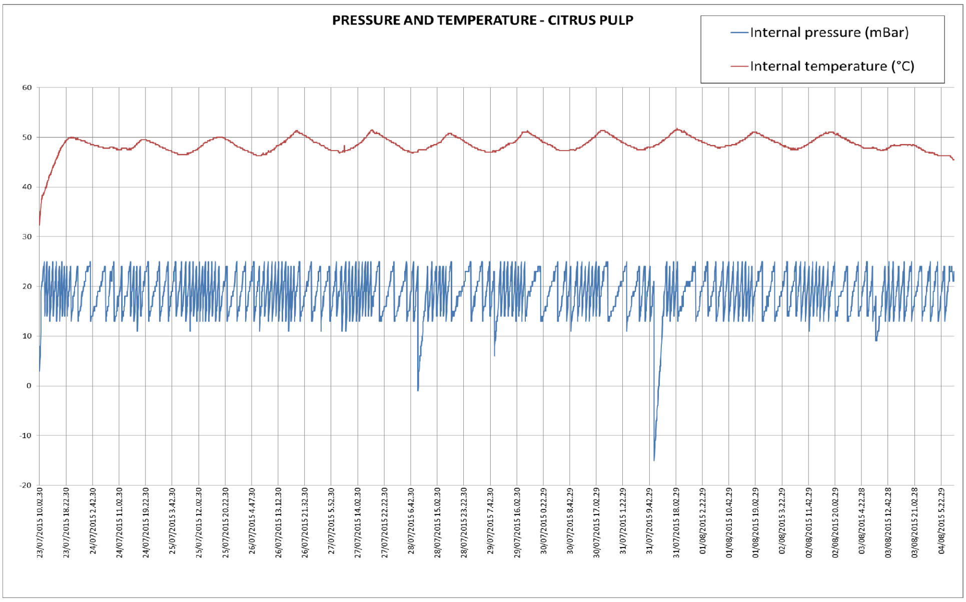

Fig. 1. P-T diagram of fermentation test

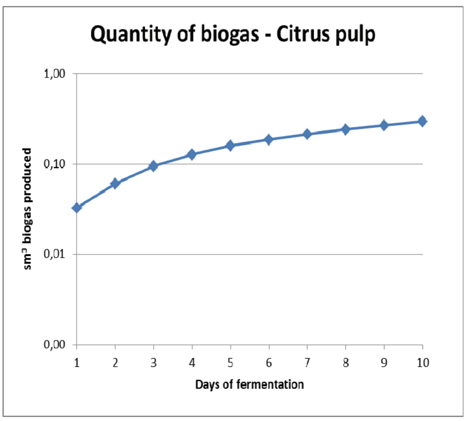

Fig. 2. Yield of biogas
(First 10 days, Citrus pulp)

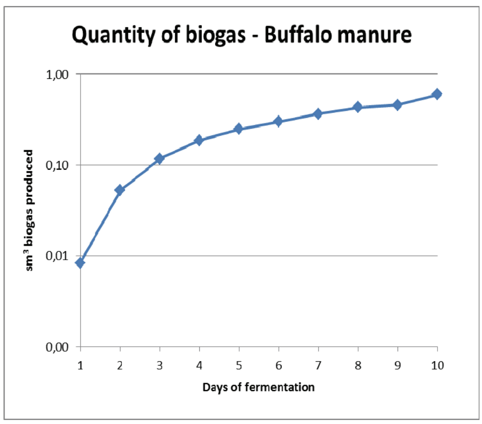

Fig. 3. Yield of biogas
(First 10 days, Buffalo manure)

Table 3. Yield of biogas at 10 days, per kg of dry biomass

Test no	Biomass tested	Mole of biogas	sm^3 biogas
1	Citrus pulp	15.62	0.35
2	Citrus pulp (oranges)	4.64	0.10
3	Marc	3.51	0.08
5	Buffalo manure	25.60	0.60

The short-term response is excellent for the citrus pulp but the results show that when mixed with orange peels the mixture is less productive with the increasing percentage of the oranges (Fig. 4). The marcs need much more time to trigger the fermentation whereas for the olive pomace it is well known, from the test results, that it contains toxic substances for anaerobic fermentation.

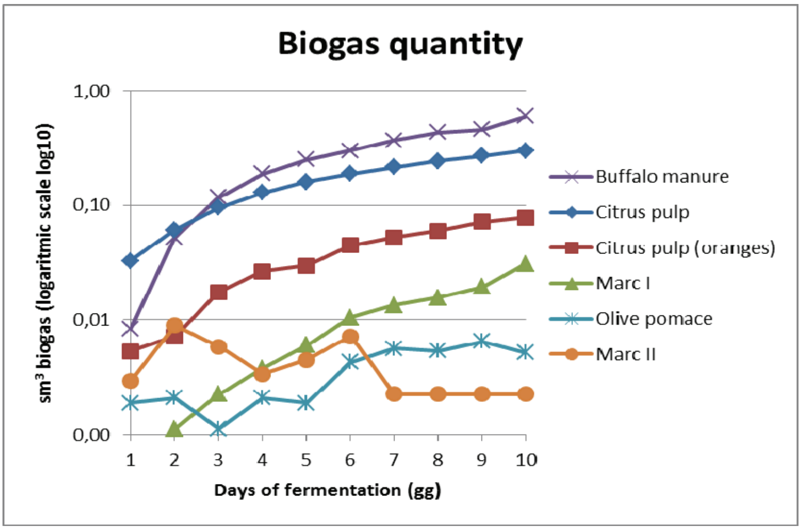

Fig. 4. Yield of biogas. First 10 days, per kg of dry biomass

Table 4 shows a summary of the experiments conducted and the amount of biogas produced at 10 days of fermentation compared to the dry substance, that part of the sample remaining after the removal of water. The fermenter records the variations of the pressure inside the chamber, the volume of the chamber is known therefore the volume of biogas produced is obtainable and normalized as a function of the temperature of the digestion chamber.

Table 4. Yields of biogas at 10 days per kg of dry biomass

Test	*Biomass*	*Mole of biogas*	*sm^3 of biogas*
1	Citrus pulp	15.62	0.35
2	Citrus pulp with oranges	4.64	0.10
3	Marc I	3.51	0.08
4	Buffalo manure	25.60	0.60
5	Marc II	1.80	0.10
6	Olive pomace	1.80	0.10

The trial results, in light of the potential of the region Calabria, are encouraging. The best results were offered by citrus pulp, of which the region has a great availability with biogas yields around 0.35 sm^3/kg referred to the dry biomass. Widely different results were recorded for the marc and the citrus fruit pulp of oranges and olive residues that offer, in addition to having more time to trigger anaerobic digestion, biogas values referred to the dry biomass trigger anaerobic digestion, biogas values are ranging from about 0.1 sm^3/kg to 0.35 sm^3/kg referred to the dry biomass (Fig. 5). From the point of view of the volatile substance, which constitutes about 70-80% of the biomass used in the tests, the biogas production is very variable depending on the type of biomass tested.

The values expressed from buffalo manure is around 240 sm^3 of biogas produced per organic matter ton as is. The values for the citrus fruit pulp are of the order of 120 sm^3 of biogas per organic matter ton as is while for the marc and the olive pomace the production value reduces of an order of magnitude to values ranging from 20 to 40 sm^3 biogas per ton.

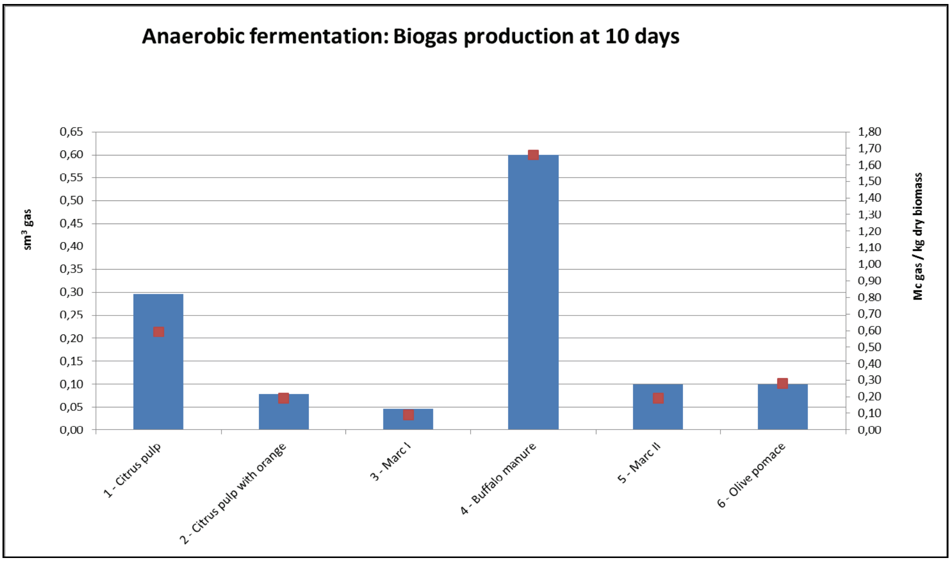

Fig. 5. Quantity of biogas per kg of dry biomass

Table 5 shows a summary of the experiments conducted and the amount of biogas produced at 10 days of fermentation compared to the volatile substance, the entire organic part of the sample.

Table 5. Yield of biogas at 10 days comparison per kg of dry and volatile substance

Test	*Biomass*	*Mole of biogas*	*sm^3 of biogas per kg dry biomass*	*sm^3 of biogas per kg volatile substance*
1	Citrus pulp	15,62	0,35	0,60
2	Citrus pulp with oranges	4,64	0,10	0,20
3	Marc I	3,51	0,08	0,09
4	Buffalo manure	25,60	0,60	0,88
5	Marc II	1,80	0,10	0,19
6	Olive pomace	1,80	0,10	0,28

The values obtained per ton of biomass in the case of buffalo dung are in line with those existing in the literature but the interesting thing, as the graph below shows, is that the values expressed by citrus pulp, if well mixed and with little presence of oranges, reach production values of all respect in the order of 120 sm^3 per ton of biomass as is (Fig. 6). The citrus pulp can be, given its great availability in the territory and the levels of productivity, an excellent resource for the production of energy from renewable sources.

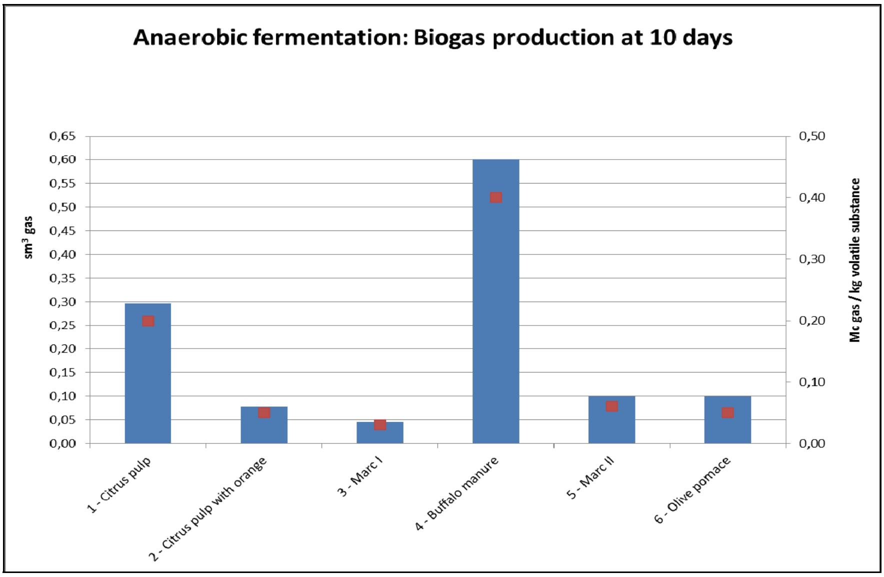

Fig. 6. Quantity of biogas per kg of volatile substance biomass

6. Concluding remarks

In the campaign tests the data were monitored and recorded and processing them properly quantity of biogas produced and moles per dry biomass were estimated.

As regards OFSW, the Calabria region offers great potential availability of organic fraction of solid urban waste for fermentation and the technology shown here, the dry digestion, is perfect for that purpose due to the fact that it don't provide the agitation of the material.

Future objectives and future step of the experiment on the dry digestion technology will be to investigate the production of leachate, related to the quantity and type of biomass used, its composition and its possible reuse.

Acknowledgements
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TWELVE YEARS OF QUALITY ASSURANCE SYSTEM ON COMPOST IN ITALY*

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Abstract

The development of separate collection of biowaste, mainly driven by foodwaste and garden waste collection, has been accompanied by the growth of a recycling industry that in 2014 counted as many as 298 facilities that have treated, through composting and anaerobic digestion, around 6 Mt of waste, with an estimation of 1.5Mt of compost produced.
According to the Italian legislation, a compost complying to the standards of the Law on Fertilizers represents the end-of-waste status for organic waste, which makes it freely marketable and actually utilised in several applications, ranging from organic fertilization in agriculture (roughly 80% of the market) to the production of growing media for domestic and professional purposes.

Keywords: compost, food waste, garden waste, organic fertilizers, Quality Assurance System

1. Introduction

A strong pressure is being made on EU countries in order to turn Europe into an actual recycling society. In this respect, significant provisions have been introduced by the Waste Framework Directive (EC Directive 98, 2008) requiring Member States to take measures to meet the goal of 50% recycling of household waste until 2020 (although the introduction of different methods for the calculation of this goal has created quite confusion in the system), and explicitly stressing the importance of biowaste separate collection and recycling (Guerini et al., 2015; Tatàno et al., 2015). It is worth mentioning that, according to the Circular Economy Package recently adopted by the European Commission, more

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ambitious targets for recycling (65% until 2030, coupled with a unique calculation method) are likely to be set, making it of utmost importance to provide each Member State with a robust and effective biowaste recycling chain (Cimpan et al., 2015; EEB, 2014; Ghinea et al., 2014).

Biowaste efficient recycling is also functional to the provisions of another milestone of EU regulation, represented by the Landfill Directive (EC Directive 31, 1999) which, in particular, demands a 65% minimum target for Biodegradable Waste diversion from landfill compared to the amount disposed of in 1995; needless to say that, once again, biowaste separate collection plays the leading role for meeting this goal (D_LGS 75, 2010; Da Ros et al., 2015; Di Maria et al., 2016).

2. Quality compost in Italy

In Italy, ambitious MSW separate collection targets were introduced in advance with respect to EU legislation, since the national Waste Framework Act (D_LGS 152, 2006) required Municipalities/District Areas to reach at least 65% separate collection until the end of 2012. Even though at national level this goal hasn't been met so far, in many areas of the Country MSW management performances have reached absolute excellence levels (significant waste production reduction and separate collection above 80%), and this accounts in particular for a biowaste management sector which has grown rapidly over the last 20 years, and representing today the main waste fraction separately collected and recycled in Italy.

According to the official data provided by the Italian Environment Agency (ISPRA), in 2014 as many as 298 biowaste management facilities were in operation treating (Fig. 1), either through composting or anaerobic digestion technologies, around 6 Mt of waste, with an estimation of 1.5Mt of compost produced.

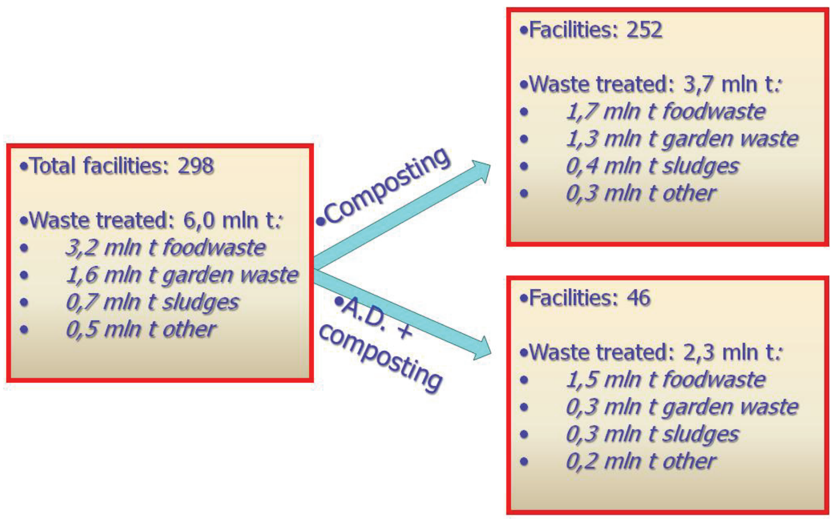

Fig. 1. Number of facilities in operation and amount of biowaste managed in Italy in 2014 (ISPRA, 2015)

In order to support the development of biowaste management sector, the Italian Composting and Biogas Association (CIC), which unites public and private companies, local authorities and others involved in the production of compost, as well as organizations which do not make compost but have an interest in the composting process (producers of machinery and equipment, producers of fertilizers, research bodies etc.) has undertaken actions aimed at qualifying the activity of biowaste recycling companies. For this reason, CIC has introduced in Italy in 2003 the first voluntary programme for the assessment of compost quality addressed to its associated companies, anticipated in 2001 by a viability study coordinated by the Technical Committee of the association. Thereafter a specific Quality Committee was established which drafted a series of rules to regulate the programme. These rules establish the frequency and types of product analyses required to achieve conformity with the Quality criteria laid down.

The assessment program scheme is voluntary and the concept of quality is based upon "acceptable risk". The standards applied in the rules of CIC's product assessment scheme are a useful instrument both for the producer of quality compost products, as a way of monitoring the quality standards achieved, and for the consumer, who can verify the quality of the compost used.

The Italian standards for End of Waste compost are set by the national Law on Fertilizers (D_LGS 75, 2010) and can be divided into agronomical parameters (pH, moisture content, organic Carbon and Nitrogen etc...), environmental parameters (heavy metals, physical impurities) and sanitization parameters (*Salmonella* spp., *E. coli*).

Two main types of compost are recognized as "end of waste" for biowaste; these are classified according to the types of biowaste used for their production: Green Compost (GC) is produced from garden waste and other vegetable waste only, while Mixed Compost (MC), derives from garden and foodwaste (Table 1).

Table 1. Quality standard for Green Compost (GC) and Mixed Compost (MC) according to the Italian legislation (D_LGS 75, 2010)

Parameter	***m.u.***	***Green compost (GC)***	***Mixed Compost (MC)***
Moisture content	% f.m.	≤50	≤50
pH		6-8,5	6-8,8
Organic C	% d.m.	≥20	≥20
HA+FA	% d.m.	≥2,5	≥7
Organic N	%Ntot (d.m.)	≥80	≥80
C/N		≤50	≤25
Cu	mg/kg d.m.	≤230	≤230
Zn	mg/kg d.m.	≤500	≤500
Pb	mg/kg d.m.	≤140	≤140
Cd	mg/kg d.m.	≤1,5	≤1,5
Ni	mg/kg d.m.	≤100	≤100
Hg	mg/kg d.m.	≤1,5	≤1,5
CrVI	mg/kg d.m.	≤0,5	≤0,5
Tl	mg/kg d.m.	≤2*	≤2*
Impurities (Plastic, glass and metals ≥ 2 mm)	%d.m.	≤0,5	≤0,5
Impurities (stones) ≥ 5 mm	%d.m.	≤5	≤5
Salmonellae	MPN/25g	Absent	Absent
E.coli	CFU/g	≤1.000	≤1.000
Germination index (30% dilution)	%	≥ 60	≥ 60

**For algae containing compost*

The compost samples taken from the plants joining the CIC quality assurance system are analyzed by two laboratories licensed for the European Ecolabel Certification of Organic soil improvers and substrates. Each lot/bag of compost sold by these plants has the right to use the Quality Compost CIC label.

3. The spread of CIC Label

Starting in 2004 with just 12 companies joining the programme, by the end of 2015, 43 plants were appointed by CIC, and 50 products were provided with the CIC quality label (Fig. 2).

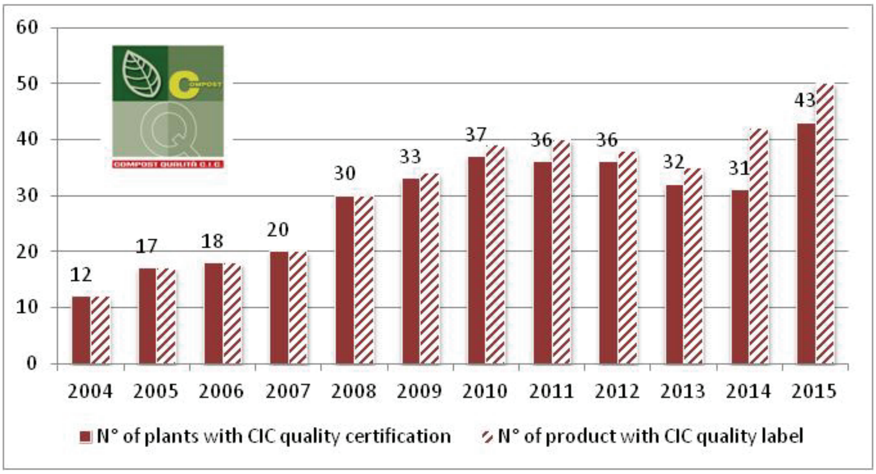

Fig. 2. Profile of number of plants and products provided with CIC quality label over time (CIC, 2015)

By the end 2015 the amount of compost certified represents about 490.000 tonnes, equal to 32% of Italy's total compost production. Most of the certified products are referred to MC (39 products, around 420.000 tonnes of compost produced), against 11 GC products, with some 70.000 tonnes of compost produced (CIC, 2015).

4. Comparison among different types of compost

Since 2003, over 2.500 samples of compost were taken and analyzed within the CIC QAS system. A focus was made on the quality of compost between 2013 and 2015; this period was chosen since the consolidation, over the last years, of the rate of CIC labeled compost generated by anaerobic digestion processes followed by composting, making it interesting to point out potential peculiarities of this "new" type of compost. For this reason, MC was divided in two categories, depending on its being generated from plane composting processes (MC-C) or integrated anaerobic-aerobic processes (MC-AD). The analyses performed on the certified products in the period considered, obtained from 557 compost samples, were elaborated independently for GC (94 samples), MC-C (324 samples) and MC-AD (139 samples).

In Tables 2, 3, the average features of GC, MC-C and MC-AD over the 2013-2015 period are summarized. Besides the parameters foreseen by the Italian regulation, nutrients content, conductivity and salinity are included in the dataset. As far as nutrients content is concerned, a general trend in the increase of organic Carbon from 2013 to 2015 can be observed in all types of compost; MC-C has the highest organic Carbon content, followed by GC and MC-AD. Total Nitrogen is present in comparable concentrations in MC-C and MC-AD (between 2 and 2.6 mg/kg d.m.); GC has a poorer N content (1.6-1.8 mg/kg d.m.) but, on the other hand, the highest relative content of organic N (95-98%), followed by MC-C (91-94%) and MC-AD (87.3-91.6%).

Table 2. Green Compost (GC) quality from 2013 to 2015 (For each parameter, average value is followed by standard deviation

	GC		
	2013	***2014***	***2015***
pH	8.2±0.4	7.9±0.5	7.6±0.5
Conductivity dS/m	1.3±1.0	1.2±0.4	1.5±0.8
Moisture content (%)	36.0±7.1	35.0±8.0	34.9±9.5
Organic C (% dm)	25.0±3.9	23.8±3.4	25.4±3.8
Humic and fulvic acids (%dm)	9.5±2.0	9.1±1.5	9.0±1.1
Organic N (% tot N)	98.3±2.9	95.1±4.7	94.9±3.7
Total N (% dm)	1.7±0.3	1.8±0.4	1.8±0.4
Cd (mg/kg dm)	0.6±0.2	0.4±0.1	0.4±0.2
Cr VI (mg/kg dm)	b.d.l.*	b.d.l.*	b.d.l.*
Hg (mg/kg dm)	0.3±0.3	0.2±0.2	0.2±0.1
Ni (mg/kg dm)	18.1±6.5	18.8±8.3	18.2±7.8
Pb (mg/kg dm)	36.7±16.8	40.9±24.8	36.9±23.3
Cu (mg/kg dm)	64.6±18.7	80.0±34.8	68.1±24.5
Zn (mg/kg dm)	161.0±44.6	164.2±40.6	164.0±48.8
Germination index (dil. 30%) (%)	102.0±15.0	90.3±18.2	89.3±18.1
P (% d.m.)	0.6±0.1	0.6±0.1	1.0±0.9
K (% d.m.)	1.3±0.2	1.2±0.1	1.4±0.2
Salinity (meq/100g)	22.3±7.9	24.5±14.1	26.8±14.1

**below detection limit*

Table 3. Mixed composta from plane composting (MC-C) and integrated anaerobic-aerobic processes (MC-AD) quality from 2013 to 2015. For each parameter, average value is followed by standard deviation

	MC-C			*MC-AD*		
	2013	***2014***	***2015***	***2013***	***2014***	***2015***
pH	8.0±0.7	7.8±0.8	7.7±0.7	8.4±0.5	7.9±0.6	8.1±0.6
Conductivity dS/m	2.9±1.1	3.6±1.2	4.0±1.1	2.6±1.1	3.1±1.0	3.6±1.0
Moisture content (%)	29.1±10.3	28.5±10.9	21.5±9.4	30.6±8.4	27.2±8.9	27.8±8.5
Organic C (% dm)	25.1±4.0	25.9±4.7	26.9±3.7	22.0±2.7	24.0±4.8	24.0±3.8
Humic and fulvic acids (%dm)	9.8±2.1	9.5±1.6	9.7±1.2	8.1±1.2	8.6±1.4	8.9±1.0
Organic N (% tot N)	94.0±4.9	91.0±5.0	91.3±3.7	91.6±4.4	87.3±3.1	89.2±3.3
Total N (% dm)	2.2±0.3	2.5±0.3	2.3±0.3	2.1±0.3	2.3±0.6	2.4±0.7
Cd (mg/kg dm)	0.7±0.2	0.5±0.2	0.5±0.2	0.7±0.3	0.4±0.2	0.6±0.3
Cr VI (mg/kg dm)	b.d.l.*	b.d.l.*	b.d.l.*	b.d.l.*	b.d.l.*	b.d.l.*
Hg (mg/kg dm)	0.3±0.2	0.3±0.2	0.2±0.1	0.4±0.3	0.2±0.1	0.3±0.2
Ni (mg/kg dm)	16.2±7.0	16.3±9.9	15.9±6.1	21.5±11.5	16.4±10.2	16.6±12.1
Pb (mg/kg dm)	42.7±18.8	39.018.5	39.622.2	39.4±13.6	39.7±21.2	44.3±24.7
Cu (mg/kg dm)	89.2±30.2	88.8±28.5	85.9±26.8	104.8±31.0	88.6±30.3	101.3±29.0
Zn (mg/kg dm)	232.2±89.3	209.2±70.3	227.1±72.0	232.9±56.0	217.8±71.4	258.9±75.9
Germination index (dil. 30%) (%)	90.0±21.7	86.4±19.9	76.9±18.8	100.0±19.6	80.5±10.8	78.3±13.2
P (% d.m.)	2.0±0.5	1.3±0.4	1.4±0.8	1.4±0.7	1.5±0.7	1.7±0.5
K (% d.m.)	1.6±0.5	1.4±0.5	1.5±0.4	1.5±0.4	1.3±0.3	1.6±0.3
Salinity (meq/100g)	51.0±16.9	61.5±19.9	65.5±19.8	48.6±26.3	55.0±21.9	63.3±18.7

**below detection limit*

While no clear differences can be observed in K content, a poorer P content characterizes GC (0.6-1mg/kg d.m.) compared to MC (1.3-1.7 mg/kg d.m. with a peak of 2.0 mg/kg d.m. on MC-C in 2013). These features can be due ~~to~~ several reasons. On the one side, the characteristics in the composition of the starting mixture undergoing the biological transformation (poorer in P and higher in C/N ratio for vegetable waste originating GC) account for the lower P and total N content in GC; on the other side, the fact that anaerobic digestion is in general more effective in consuming putrescible organic matter than plane composting processes accounts for the lower organic C and higher rate of mineralized nitrogen observed in MC-AD.

Taking into account the other parameters of agronomic interest, a far lower salinity in GC (22.3-26.8 meq/100g) compared to MC (48.6-65.5 meq/100g) can be noticed, confirmed by the same trend of conductivity; this can be explained by the high salt contents of animal tissues (not present in the starting ingredients of GC). A progressive decrease of pH can be observed in all compost types (from 8-8.4 in 2013 to 7.6-8.1), with a slightly higher pH in MC-AD, probably due to the higher ammonia content characterizing digestate.

All heavy metals are found in concentrations far below the limits given by the Italian standards for all the types of compost; on this respect, it must be emphasized that, in Italy, compost can be produced by source segregated organic waste only, thus avoiding any possible contamination. As expected, no clear evolutions between 2013 and 2015 can be found, nor differences among the different types of compost, apart from Cu and Zn, which are systematically lower in GC compost than in MC; as discussed for other parameters, the higher presence of Cu and Zn can be connected to the higher concentration in foodwaste than in garden waste. Even though to a lesser extent, Cu and Zn tend to be more concentrated in MC-AD than in MC-C. This observation could be related to qualitative differences in the organic matter deriving from anaerobic processes compared to aerobic ones, or to differences in segregation of dry matter and metals during the mechanical separation between solid and liquid phase of digestate. This aspect, anyway, deserves further in depth analyses.

Although sensibly over the minimum given by the national standard, Germination index has shown a decrease from 2013 to 2015; in general, GC shows the highest values (from 102% down to 89.3% in 2015), while lower average values were observed for M-AD (from 100% down to 78.3%) and M-C (from 90% to 76.9%). Germination index is related to several factors, ranging from compost maturity (evolution of the organic fraction) to the concentration of salts (this can explain the higher values of GC, characterized by a relatively low salts content).

6. Concluding remarks

The development of the CIC label among compost producers over the last 12 years not only has brought the market to increase its confidence on the compliance of compost to the national standards, but even makes it possible to consolidate the knowledge on the features of different types of compost.

This kind of information can be used to address the product to specific fields of application, ranging from professional applications in pots, to horticulture, to agricultural sectors.

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PURE OXYGEN-BASED MUNICIPAL SOLID WASTE (MSW) BIO-STABILIZATION: ENERGY, ENGINEERING, ENVIRONMENTAL AND PROCESS SAFETY ASPECTS*

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Abstract

Today, in Italy, mechanical-biological treatment plant (MBT) using pure oxygen are few and with limited knowledge of the functioning. With the intent of strengthening the state of knowledge, this contribution deepens the main energy, engineering, environmental and process safety aspects of a pure oxygen-based full-scale bio-stabilization system treating unsorted municipal solid waste. The activities were conducted at the Massafra MBT plant (Apulia Region, Southern Italy) with a treatment capacity of 220,000 tons per year. After the assessment of the energy consumption related to the conventional aeration system, representing, in this way the "baseline scenario", the study discussed the main design aspects for a safe operation of the pure oxygen system.

Keywords: bio-stabilization, mechanical-biological treatment, municipal solid waste, pure-oxygen

1. Introduction

Bio-stabilization represents the biological process implemented in mechanical-biological treatment (MBT) plant generally based on mechanical and biological processes. The scope is to achieve the stabilization of the organic matter present in the solid waste (De Feo et al., 2012; Sirini et al., 2009).

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The feeding is composed by unsorted municipal solid waste (UMSW) or the residual fraction from separate waste collection. Generally, in this condition the feeding cannot be used for the production of compost given the presence of other fractions in addition to the organic one. The mechanical treatment involves screening of all incoming waste in order to separate the different merchandise fractions. Usually, the mechanical section consists of (i) reception and storage, (ii) opening of the bags by means of "open-bag", (iii) screening and (iv) iron removal (De Feo et al., 2012; Godio et al., 2015; Sirini et al., 2009). Instead, biostabilization is aimed at (i) stabilizing the organic matter by means of the mineralization of the more easily degradable components with final production of water and carbon dioxide and stabilized material, (ii) sanitizing the waste by means of temperatures not lower than 55°C and (iii) reduce the volume and mass of the treated materials with weight loss of 20-30% due to evaporation (Arvanitoyannis and Ladas, 2008; Di Maria et al., 2014).

In terms of technological solutions, currently in Italy and Europe, it is possible to identify two types of MBT plant: (i) treatment separated flow, (ii) single-stream treatment (De Feo et al., 2012; Sirini et al., 2009). However, the main output of a bio-stabilization system is the SRF (Solid Recovered Fuel) characterized by high calorific value (Nasrullah et al., 2014a; 2014b). The state-of-the-art suggests the use of air for biological treatment of waste. In fact, air represents the suitable solution in the case of an ordinary functioning of the MBT plant (De Feo et al., 2012). However, some frequently emergencies such as the overload could suggest the need to reduce the times of the biological treatment in order to obtain a greater volume for the treatment of additional feeding.

In this context is held the collaboration between the Department of Civil, Environmental, Land, Building and Chemistry (DICATECh) of the Technical University of Bari, C.I.S.A. SpA, a leader in the field of waste management operating in Taranto (Apulia Region, Southern Italy) and SIAD SpA (Italian Society for acetylene and derivatives) of Bergamo. The intent is to provide and put into operation the first Italian prototype plant which uses pure oxygen to develop aerobic processes.

In details, the article deepens the main energy, engineering, environmental and process safety aspects of a pure oxygen-based full-scale bio-stabilization system treating UMSW. To best of our knowledge, just a few documented experiences are reported in the literature so as shown in Table 1.

2. Materials and methods

The activities were carried out at the Massafra MBT plant managed by CISA Spa and characterized by a treatment capacity of 220,000 tons/year. Table 2 and Fig. 1 show the main data and treatment phases of the MBT plant under investigation.

Considering the framework of the experimentation, the main steps were the following: (i) plant characterization and data input collection, (ii) assessment of energy consumption of all the equipment’s, (iii) integrated design of the pure oxygen system considering energy, engineering, environmental and process safety aspects.

For the first step, three operation cycles of the biocell shown in Fig. 2 have been considered.

3. Results and discussion

3.1. Analysis of the energy consumption of the conventional aeration system

Table 3 shows the results of the monitoring of the energy consumption with reference to the three cycles of functioning of a single biocell. Considering a contact time of 8 days, energy performance has been as follows: (i) biocell blower = 2352.13 kWh; (ii) biofilter blower = 1280.69 kWh; (iii) sewage pump = 12.4 kWh; (iv) biofilter water pump = 39.3 kWh; (v) hot humidifier pump = 6.1 kWh.

The consumption estimation has been used to design the pure oxygen system as well as to represent the so-called "baseline scenario". Results have shown how the blower of the tunnel (the aeration system visible in Fig. 1f) is the most energy-intensive machinery.

Table 1. Overview on the use of pure oxygen for the bio-stabilization of the organic fraction of municipal solid waste (OFMSW)(Source: SIAD)

No	***Country***	***Waste composition [%]***		***Heap Characteristics***	***Conventional aeration***		***Pure oxygen aeration***	
		OFMSW	***Wood***		***Contact time [days]***	***IRDp[(a)] [mgO₂/kgVS/h]***	***Contact time [days]***	***IRDp[(a)] [mgO₂/kgVS/h]***
1	Piedmont Italy	60	40	Height = 2m; Weight = 50 tons	15	800	8	< 600
2	Piedmont Italy	60	40	Height = 2.5m; Weight = 60 tons	15	750	5	< 600
3	LombardyItaly[(b)]	100	0	Weight = 100 tons	-	-	5	600
4	Emilia-Romagna, Italy[(c)]	75	25	Height = 3m; Weight = 150 tons	-	-	5-6	-

[(a)]: IRDp = respirometric Index; [(b)]: Inlet IRDp value of 2800 $mgO_2/kgVS/h$; [(c)]: The process was more efficient compared to conventional aeration and was completed in 5-6 days

Table 2. Main parameters of the MBT plant under investigation

Main characteristics of the CISA Spa plant: Pre-selection and bio-stabilization; RDF production; Associated landfill	
Entrance in operation	July 2014
Days of conferral	365 days per year
Working days for the RDF production	6 days per weak
Eligible quantities	220.000 tons/year of MSW and 50.000 tons/year of residual dry fraction from ATO/TA3
Eligible CER codes	160103
	190501; 191212;191203; 191204; 191210;
	200140; 200203; 200301; 202302; 200303; 200307

3.2. Integrated design of the pure oxygen system

Fig. 3 shows the positioning and the main elements of the pure oxygen system. The storage (Fig. 3b, 3c) has the function to enter oxygen within the biocell by means of an atmospheric evaporator connected to the transport pipe.

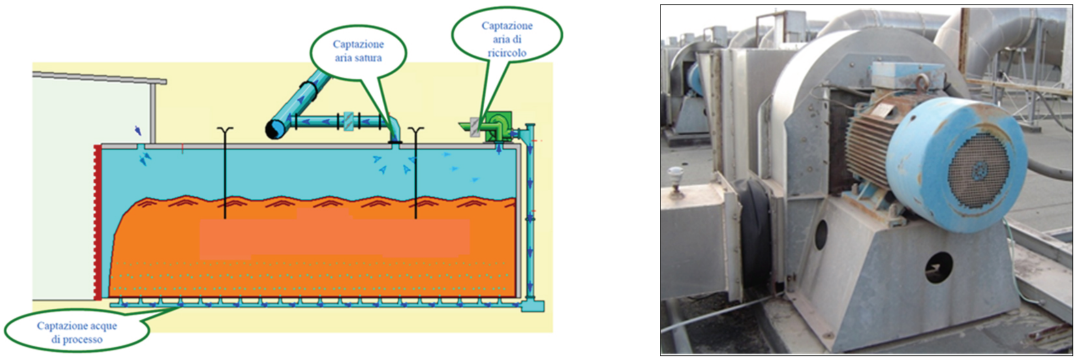
In detail, the storage and the liquid oxygen vaporization section consists of a cryogenic container with a total capacity of 12,000 liters designed to store liquid pure oxygen joined by a cold evaporator. The main characteristics of the liquid oxygen container are the following: volume = 12,000 liters; weigh = 13,692 kg; max operating pressure = 15 bar; operating pressure = 10 bar; design and construction are according to ISPESL/PED; safety devices according to Italian Law (DM, 1974).

Instead, the main characteristics of the air evaporator are as follows: max flow-rate = 310 Nm^3/h; heating fluid = air; model = VMP 310.

Fig. 1. CISA Spa MBT plant under investigation: (a) Acceptance and weighing of waste; (b) Waste storage in the reception area; (c) Primary shredder; (d) Iron separator; (e) Biocell; (f) Nozzles for blowing air on the floor; (g) Primary air pipe; (h) Biofilter

3.3. Identification of the main engineering, management, environmental and safety aspects

The design of the system described in the previous paragraph considered several aspects discussed below. From the engineering point of view, the system has been installed outdoors and on a base of concrete suitable to support the loads induced by the weight of the equipment and overload caused by wind, snow, seismic actions. The existing legislation has required a 40 cm thickness of the base and an elevation of about 10 cm above the existing forecourt. The base has a surface area of 23.76 m^2 (4.40m x 5.40 m). The plant area is surrounded by a bead in concrete with a thickness of 20 cm and 50 cm height. The bead has the purpose of protecting the equipment from possible impacts of vehicles in consequence of false maneuvers. On that bead, in order to prevent access to the system by unauthorized persons, a metal mesh fence has been realized using steel pallets with a height of 2.00 m.



(a) (b)

Fig. 2. Details of the biocell (a) and the blower (b) of the CISA Spa plant

Table 3. Results of the energy consumption monitoring with reference to the bio-stabilization process equipment

Treatment cycles	***Equipment***				
	Blower of the tunnel [kWh]	***Blower of the biofilter [kWh]***	***Pump into the wastewater basin [kWh]***	***Pump into the filtered water basin [kWh]***	***Pump into the dehumidifier basin [kWh]***
Cycle 1: from 23/11/15 to 01/12/15	2290.29	1325.47	12.50	39.94	1.23
Cycle 2: from 05/11/15 to 13/12/15	2493.10	1235.90	12.06	40.51	1.06
Cycle 3: from 06/01/16 to 14/01/16	2272.99	1865.54	11.57	37.54	0.88
Average values	2352.13	1280.69	12.04	39.33	1.06

The plant area is dedicated exclusively to the pure oxygen system and any storage of flammable materials and/or fuels were placed at distances greater than those provided by the Italian Law (Circular, 1964). In this regard, Fig. 3d shows how the distances provided for different categories of buildings and structures were respected.

Additional results involved the identification of the main design aspects such as (i) the safety valve on the container-dispenser cryogenic liquid oxygen, (ii) the reducer/pressure stabilizer also in the container-dispenser, (iii) the control and regulation instrumentation for pure oxygen flow and (iv) the system for the monitoring of the main pollutants parameters.

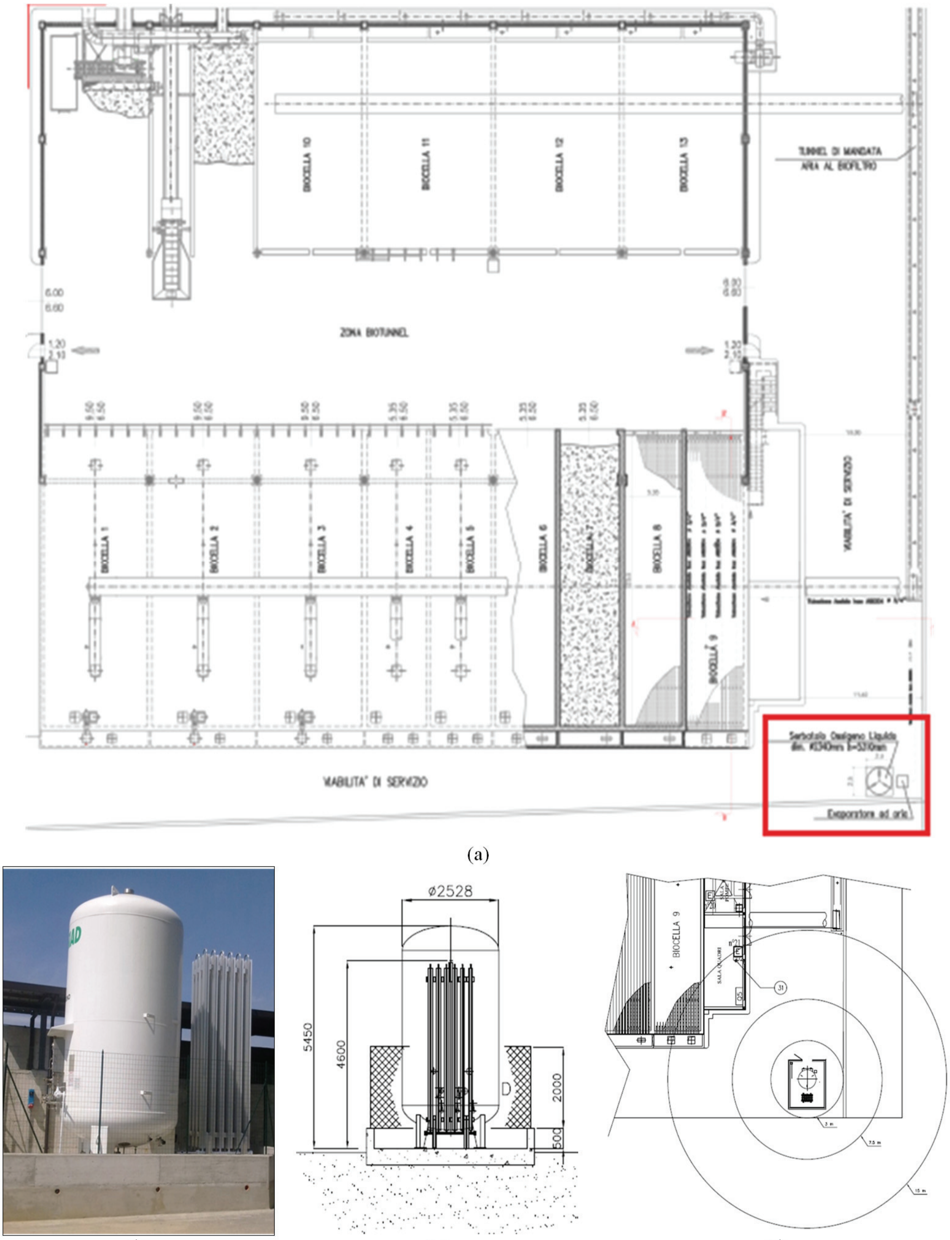


Fig. 3. Elements of the pure oxygen system installed at the biological section of the CISA Spa plant: (a) Location and (b-c) details of the storage and oxygen vaporization system; d) Safety distances (3 m; 7.5 m; 15 m)

Additionally, the installation of two pneumatic valves on the oxygen piping, internal to the biocell, was a necessary condition. The maximum speed of oxygen, under operating conditions, will have to be ≤ 4 m/s.

4. Concluding remarks

The experience conducted at the MBT plant of Massafra allowed identifying the key aspects for the safe design of a pure oxygen system. The design is to be considered "integrated" as several aspects such as energy, engineering, environmental and process safety should be taken into account.

Once the pure oxygen system is put into operation, the experimentation helps to identify the main process parameters useful also for an economic assessment of this unconventional system investigated.

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SETTING APPROPRIATE TECHNOLOGIES IN THE REMEDIATION OF BROWNFIELD CONTAMINATED WITH HYDROCARBONS: THE CASE STUDY OF THE EX-GASOMETER IN BARI, ITALY*

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Abstract

The contribution shows a case study concerning the remediation of a disused industrial plant (Ex-Gasometer) in the central area of the city of Bari (Apulia Region, Southern Italy). The Ex-Gasometer is an area declared "at risk" by local Authorities because of it is one of the most complex, extensive (about 20,000 m^2) and contaminated brownfields situated near a high population density urban area. The characterization highlighted high concentrations of heavy metals, organic pollutants and above all hydrocarbons both in groundwater and in soil. The contribution recognized and analyzed the main aspects that allowed the selection and the implementation of the most suitable remediation strategies for soils and groundwater decontamination. Furthermore, details of movable tensile structure as well as sampling procedures related to the monitoring of excavation fronts have been accurately described. In this way, the case study addressed is an example of how remediation plays an important role in the context of circular economy.

Keywords: brownfields, excavation faces, hydrocarbons, remediation

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1. Introduction

The US Environmental Protection Agency (EPA) defines a brownfield as "real property, the expansion, redevelopment, or reuse of which may be complicated by the presence or potential presence of a hazardous substance, pollutant, or contaminant" (US EPA, 2015). Brownfields are often abandoned, closed or under-used industrial or commercial facilities, such as an abandoned factory in a town's former industrial section.

Revitalization of unproductive brownfields has become an important issue for government institutions as well as for real estate developers, law firms, and banking and insurance interests. Furthermore, remediation and redevelopment of these brownfields is often the key to creating jobs, expanding the tax base, and revitalizing the economy of local communities, in the light of the circular economy principles (Ghisellini *et al.*, 2016).

Among contaminated sites, the gasometer brownfields are the most critical to be remediated. The critical aspects lay not only in the removal of pollutants but also in the fact that nowadays most of these plants are often located in densely populated areas (Altavilla et al., 2016). Thus, with the intent to strengthen the state of knowledge in such type of remediation, the aim of this study was to describe and discuss the principal aspects with reference to the ex-Gasometer area in Bari, Southern Italy.

2. Materials and methods

2.1 Background information

The Ex-Gasometer is located in the municipality of Bari, in the centre of town and at about 200 m from the sea. The Gasometer started its activities in 1865 to produce the distillation gas from hard coal.

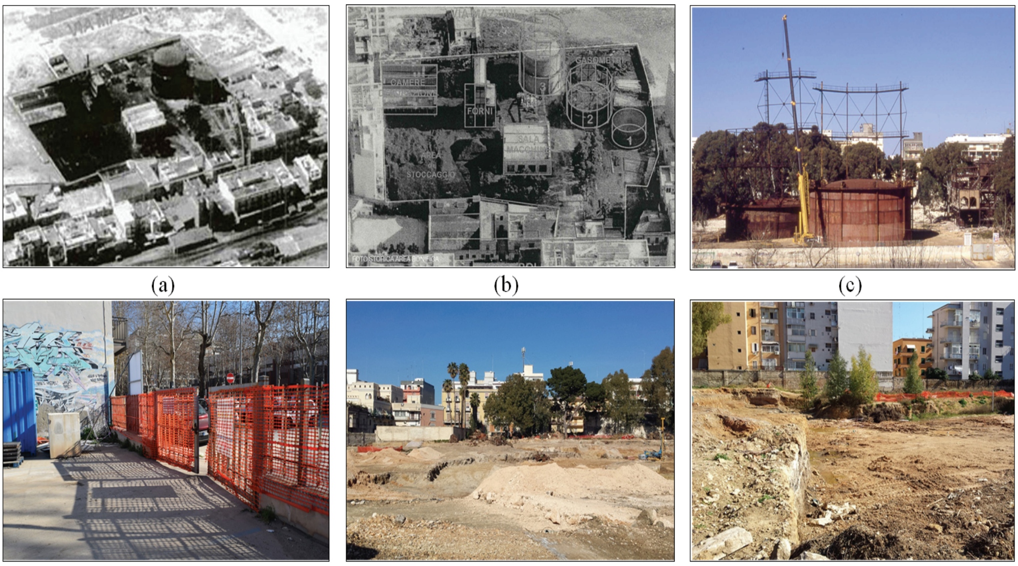
The activities were decommissioned in the mid-eighties. In 1999, the over ground structures were demolished and the whole area covered with a layer of breccias of about 15 cm. The covered area, with a surface of 20,000 m^2, had been partly used as a public car park (6,000 m^2) while the remainder was in state of abandonment (Fig. 1).

In the Ex-Gasometer area, the following structures were identified: (i) an area originally used for office space and housing for the guardian; (ii) an area occupied by the oven, gas cleaning rooms, engine rooms, tar distillation and workshops; (iii) an area occupied by 3 gasometers and; (iv) storage areas (Fig. 1a, 1b).

The characterization of the site revealed a contamination of soils by aromatic hydrocarbons (BTEX), heavy metals (Cd, Pb, Cr), light cyanides, phenols, light ($C \leq 12$) and heavy ($C > 12$) hydrocarbons. While, the contamination of groundwater concerned heavy metals (Cd, Pb, Fe), aromatic hydrocarbons (benzene, toluene and xylene), free cyanides, sulphates and light and heavy hydrocarbons. In this regard, Table 1 shows the compounds that exceeded the threshold established by Italian law (Decree 152, 2006).

Furthermore, the presence of a surface groundwater in the area under investigation has been detected, characterized by an average depth of 4 m from the ground level and a direction of SW-NE flow.

The hydro-geological characterization has allowed to define litho-stratigraphic succession of ground as reported: (i) surface coating; (ii) loose or weakly cemented soils (limestone); (iii) red clay, silt and clay; (iv) limestone.



(a) (b) (c) (d) (e) (f)

Fig. 1. Historical evolution of the ex-Gasometer area in Bari, Italy: (a-b) 1950; (c) 1999; (d-e-f) 2016

Table 1. Characterization of the contaminated site with the analysis with values above the threshold[(a)]

Matrix: Soil and subsoil			
Analyte	***Value [mg/kgSS]***	***Limit value[(a)]***	***Number of times exceeds the threshold***
Cadmium	3.74	2.0	1.87
Lead	3.168	100.0	31.68
Total chromium	162.8	150.0	1.08
Benzene	20.0	0.1	200.0
Toluene	16.0	0.5	32.0
Xylene	39.0	0.5	78.0
Light hydrocarbons (C < 12)	140.0	10.0	14.0
Heavy hydrocarbons (C > 12)	4600.0	50.0	92.0
Phenols	960.0	1.0	960.0
Matrix: Groundwater			
Analyte	***Value [μg/L]***	***Limit value[(a)]***	***Number of times exceeds the threshold***
Iron	470.0	200.0	2.35
Benzene	6890.0	1.0	6890.0
Toluene	2124.0	15.0	141.6
Xylene	926.0	10.0	92.6
Benzo perylene	0.04	0.01	4.0
Cyanides	120.0	50.0	2.4
Total hydrocarbons	241,126.0	350.0	688.9

[(a)]: *Threshold concentration of contamination according to the Italian Law DLgs 152/2006 (in Italian, CSC, concentrazione soglia di contaminazione)*

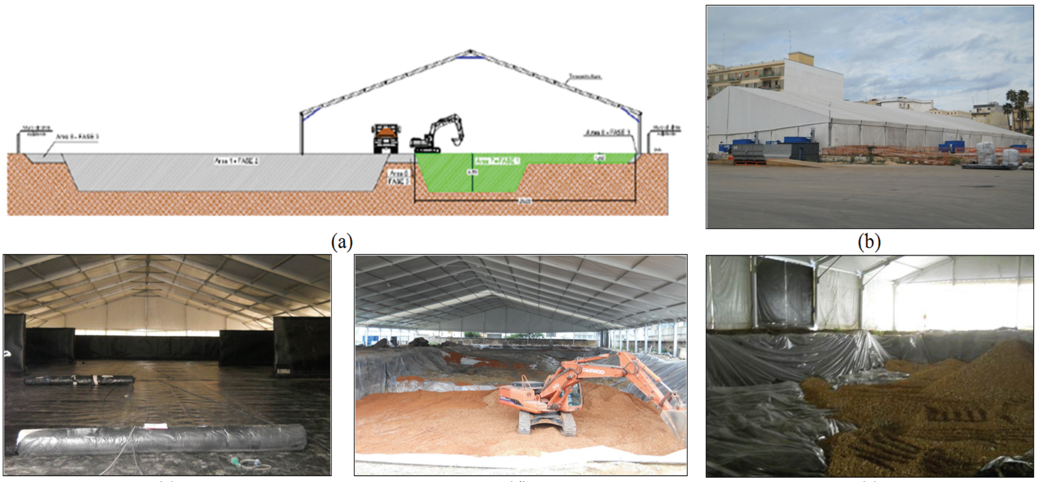
2.2. Framework of the experimentation

The goals of the remediation actions were the removal of pollutants in the surface and deep soils and in the groundwater so as to reduce pollution for achieving the threshold values established by the site-specific risk analysis (Wcisło et al., 2016).

More specifically, the goal of remediation for the surface soil matrix was the complete removal and disposal of soils that highlighted (i) exceedances of thresholds defined by the Italian Law (Decree 152, 2006) and (ii), the presence of products in free phase.

For the sub-soil matrix, the goal of remediation was the complete removal and disposal of unsaturated material in areas where product is present in free phase and in areas which showed exceedances of threshold values evaluated, in this case, by means of the site-specific risk analysis (unlike in the case of surface soil). Finally, for the groundwater matrix, the goal of remediation was the treatment of water in order to obtain concentrations below the thresholds evaluated, also in this case, by means of the site-specific risk analysis.

Based on the results of the site characterization, several strategies were identified. Considering the in-situ technologies, the following were considered: (i) Bioventing; (ii) Soil Vapor Extraction. Instead, the on-site technologies were as follows: (i) Biopile; (ii) Landfarming; (iii) Soil Washing; (iv) Bioaugmentation; (v) Thermal desorption. Finally, excavation and landfilling was the only off-site option.



(a) (b) (c) (d) (e)

Fig. 2. Excavation method: (a) Realization of a movable tensile structure;
(b) View of the tensile structure (c) containing the storage boxes for the soils at different hazard;
(e) Soils deposited on a HDPE bottom

The site-specific conditions highlighted the unsuitability of the in-situ and on-site technologies. Therefore, the excavation and landfilling, performed in controlled conditions by means of the realization of a movable tensile structure, was the most suitable solution. In this regard, Fig. 2 shows some details of the excavation that took place in the indoor environment. Having identified the soil fractions with different hazard, these were stored in special boxes constructed within the fixed tensile structure as visible in Fig. 2c-2e. The excavations activities were divided into 6 stages in order to optimize the installation and moving of the tensile structure. Fig. 3 shows and describes (see the caption) details of the six above excavation operations. Furthermore, in the case of soil mixed with asbestos, the soil was packed into big bags and sent directly to disposal facilities. In order to verify the outcome of the reclamation, sampling in accordance with UNI EN ISO 10:802 guideline were executed. The main steps are shown in Fig. 4.

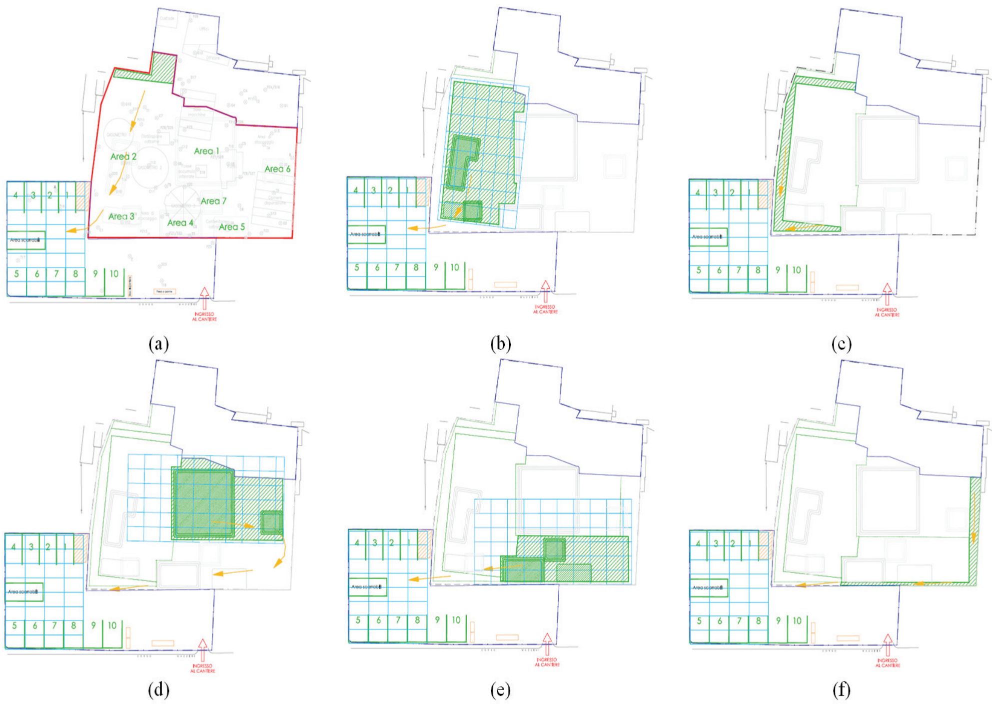


Fig. 3. Order of the operating steps within the soil excavation: (a) Excavation without tensile structure until 1 m from ground level for an area of about 350 m^2 (Phase 1); (b) Excavation under tensile structure until 1 m from ground level for an area of about 3400 m^2 (Phase 2); (c) Excavation under tensile structure of parts closer to the walls and remained in relief to support the structure of about 800 m^2 (Phase 3); (d) Excavation under tensile structure of the central zone until 4 m from ground level with the removal of a sunken bathtub (Phase 4); (e) Excavation under tensile structure until 1 m from ground level for an area of about 2047 m^2 (Phase 5); (f) Excavation without tensile structure until 1 m from ground level of the closest parts of the walls with a surface of about 724 m^2 (Phase 6).

The “quartering” method consists in a mixing and reduction in volume of the primary sample until reaching the volume necessary to carry out the laboratory sample. The test material is distributed uniformly in a heap or a “cake” with height corresponding to about a quarter of the radius thereof.

The cake is divided into four parts of equal size. While the two opposite quarters of the material is discarded, the remaining is mixed and distributed in a new cake. The sample thus obtained is divided into aliquots using the following procedure: a portion of the homogeneous mass is taken and distributed evenly into the containers. This operation is repeated for the other portions until the desired amount of material for each aliquot is obtained.

The final sample is ready to be transported to the laboratory for analysis on soils. With reference to groundwater, the best solution was the combination of pump and treats (P&T) and pressurized air tower system (PAT). The goal was to withdraw groundwater and then treat them by means of granular activated carbon (GAC) able to exert a selective action in respect of specific pollutants such as phenols (De Gisi et al., 2016). Subsequently, the outlet flow is treated in the PAT system with the scope of achieving the super saturation of water.

Fig. 4. Main steps of the excavation faces verification: (a) Sampling from the excavation; (b) Sieving; (c-h) "Quartering method" by mixing of soil subsamples; (i-j) Final sampling; (k) Samples of soil ready for analysis; (l) Transport to the laboratory.

The final step was the reintroduction of treated water in the aquifer, upstream of the contaminated area (from the hydraulic point of view), so as to favour the natural in-situ biological processes in respect of the hydrocarbons (Agnello *et al.,* 2016). Fig. 5 shows the operating layout of the technologies mentioned.

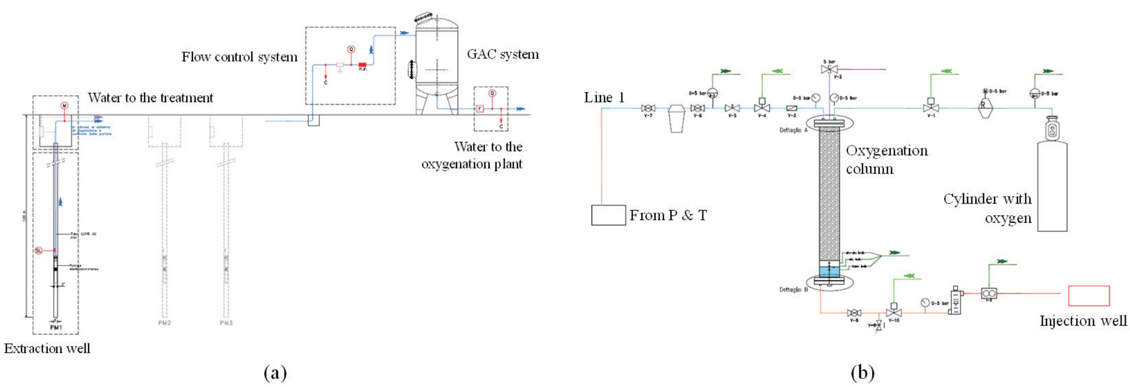


Fig. 5. Groundwater decontamination: (a) Pump and treat (P & T) system by means of granular activated carbons (GAC); (b) Pressurized oxygenation system or Pressurized Air Tower (PAT) and subsequent injection of the treated water into the aquifer

3. Results and discussion

3.1. Soil remediation

Soils remediation has provided for the execution of preliminary operations as visible in Fig. 6. In detail, the removal of part of the concrete structures remaining was carried out as well as the removal of any explosive devices (Fig. 6a) and the material containing asbestos (Fig. 6b, 6c).

Asbestos, after being removed in the indoor environment, was added in special big bags as visible in Figure 6c, ensuring a safe disposal. Finally, Table 2 shows the results of the excavation faces verification. It is observed how results show the achievement of remediation targets.

(a) (b) (c)

Fig. 6. Preliminary operations: (a) Explosive devices removal; (b) Removal of soils containing asbestos; (c) Big bags of asbestos.

Table 2. Results related to the verification of the excavation faces (in the columns, the sampling points; in the raw, the analytes to be monitored; in the last column, the thresholds provided by risk analysis)

		FRONTI SCAVO PROGETTO DI COMPLETAMENTO										
		P1NDX	P1W	P1NSX	P1S	P30E1	P30E2	F1	F1BIS	F1TER	F1QUATER	CSR
Data di campionamento		15/12/2015	15/12/2015	15/12/2015	15/12/2015	15/12/2015	15/12/2015	15/12/2015	15/12/2015	15/12/2015	15/12/2015	
Parametro	UM											
fenolo	mg/kg	< 0,05	< 0,05	< 0,05	< 0,05	< 0,05	0,08	< 0,05	< 0,05	< 0,05	< 0,05	1.600
2-clorofenolo	mg/kg	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	28
2,4-diclorofenolo	mg/kg	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	15
Metilfenolo (o,m,p,)	mg/kg	< 0,010	< 0,010	< 0,010	< 0,010	< 0,010	0,100	< 0,010	< 0,010	< 0,010	0,050	10
Pentaclorofenolo	mg/kg	< 0,005	< 0,005	< 0,005	< 0,005	< 0,005	< 0,005	< 0,005	< 0,005	< 0,005	< 0,005	3
Benzo (a) Antracene	mg/kg	1,10	1,17	0,25	0,72	0,91	11,15	0,04	0,01	2,58	3,12	100
Benzo (a) Pirene	mg/kg	1,25	1,19	0,21	0,69	1,31	26,42	0,03	0,01	2,14	4,24	29
Benzo (b) Fluorantene	mg/kg	0,85	0,99	0,18	0,56	0,94	20,33	0,03	0,01	2,11	2,91	600
Benzo (k) Fluorantene	mg/kg	0,37	0,40	0,07	0,23	0,42	7,07	0,01	< 0,01	1,09	1,47	1.000
Benzo (g,h,i) Perilene	mg/kg	1,09	0,94	0,13	0,53	0,86	16,43	0,04	0,01	1,87	3,02	1.000
Crisene	mg/kg	1,15	1,32	0,25	0,85	1,00	12,99	0,04	0,01	2,51	3,40	1.000
Dibenzo (a,h) antracene	mg/kg	0,39	0,29	0,04	0,16	0,36	5,22	0,01	< 0,01	0,47	0,92	90
Indenopirene	mg/kg	0,83	0,70	0,12	0,38	0,66	14,83	0,03	0,01	1,18	2,14	1.000
Pirene	mg/kg	1,05	1,54	0,45	1,37	1,02	13,23	0,06	0,02	3,56	4,44	1.000
Benzene	mg/kg	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	0,12
Toluene	mg/kg	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	6,90
Xileni	mg/kg	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	< 0,01	1
Idrocarburi (C< 12)	mg/kg	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	500
Idrocarburi (C >12)	mg/kg	77	29	25	35	139	1211	17	5	131	108	10.000
Cianuri (liberi)	mg/kg	< 0,1	< 0,1	< 0,1	< 0,1	< 0,1	< 0,1	< 0,1	< 0,1	< 0,1	< 0,1	110
Amianto	mg/kg	< 100	< 100	< 100	< 100	< 100	< 100	< 100	< 100	< 100	< 100	(CSC) 1.000

3.2. Groundwater decontamination

Fig. 7 shows the results of the groundwater decontamination by means of the combined P&T and PAT system. It is observed that the GAC treatment showed an excellent removal capacity in respect of organic pollutants such as phenols. In contrast, the removal efficiency was low for other compounds such as heavy metals.

Still, considering the wide area shown in Fig. 7 (See the right part of the Figure), it is observed that the groundwater below the site of the ex-Gasometer was slightly polluted when compared to that found in the past, and above all, for some analytes, cleaner than the values found at points outside the site.

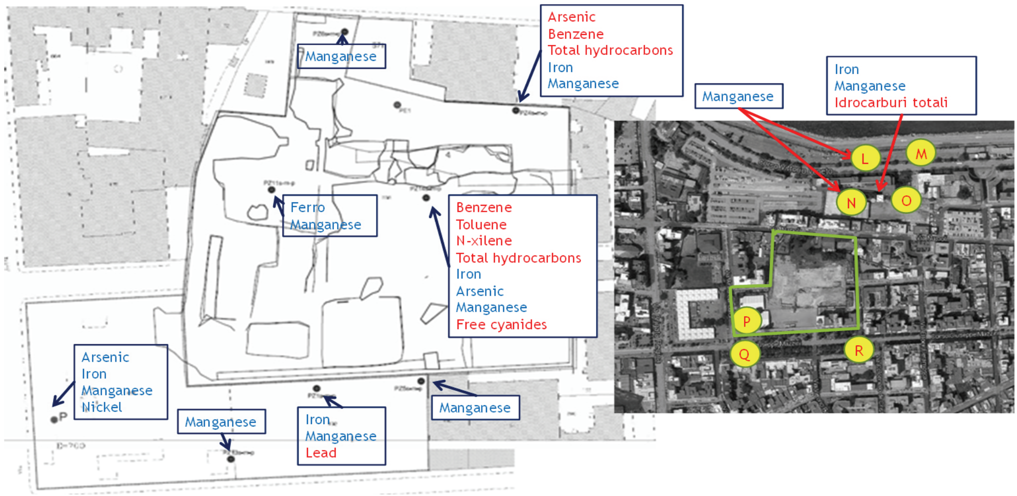


Fig. 7. Results related to the groundwater decontamination (in red, the analytes with values higher than the remediation objectives due to the contaminated site; in blue, the analytes with values higher than the remediation objectives due to external actions to the site – natural background)

Therefore, the removal of the still operating sources of contamination (interesting soil and subsoil) has led to a noticeable improvement of groundwater, in line with the forecasts of the conceptual model of the site.

4. Concluding remarks

On the basis of as discussed, the main conclusions are summarized as follows: With reference to the entire reclamation, the formal procedures have enabled the achievement of cleanup targets and the declaration of compliance by the competent environmental authority (ARPA Puglia);

With reference to the soil and subsoil matrices, the excavation and disposal of soil with concentrations exceeding the thresholds as evaluated by means of the risk analysis procedure represented the best suitable technology option. However, in order to mitigate the impacts induced by the movement of powders, excavations have taken place in an indoor environment based on the installation of a movable tensile structure. The verification of the excavation faces, carried out according to the UNI EN ISO 10802 guideline, highlighted the achievement of cleanup targets.

With reference to the groundwater matrix, the combination of P&T and PAT system was effective for the removal of specific compounds such as phenols showing, however, limited action in relation to heavy metals. The removal of the polluted soil, representing the primary source of pollution, allowed an improvement of the quality of groundwater with values, for some analytes, better than those found in areas outside the site.

Finally, the case study addressed highlights how the reclamation of a disused area can generate a variety of small and large economies representing, in this way, an example of circular economy.

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