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

Selected papers (3)

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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.

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GRASSLAND RECOVERY IN A LANDFILL SITE IN ALTA MURGIA*

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Abstract

This study is focused on evaluating the early vegetation dynamics in a restored landfill site in Alta Murgia National Park. While testing the effectiveness of different sowing methods, our aim was to identify the role of natural dynamics in the early successional stage of herbaceous communities. For this purpose, plant data were collected in the restored area as well as in the surrounding grassland patch. Cover values of vascular plant species were recorded and used to compute species richness and diversity, as well as to investigate the variation in plant life forms and bio-ecological parameters. Although the artificially sown species were not successful in grassland recovery, due to unfavourable abiotic conditions and natural competition, over 75% of the native species found in the whole area were effectively colonizing the restored surfaces.
No significant differences in species richness and diversity were found among restored sites, while more species-rich communities were found on landfill margins. These results underline the role of adjacent plant assemblages in natural colonization of restored surfaces, also providing cues for the application of cost-effective methods for vegetation recovery, as well as for planning strategies for habitat conservation and monitoring.

Keywords: grassland restoration, habitat conservation, plant community, succession dynamics

1. Introduction

Semi-natural grasslands of the Western Palaearctic region are among the most species-rich habitats in the world, having accumulated a huge amount of biodiversity during millennia of low-intensity land use (Dengler et al., 2014; Wilson et al., 2012). Today, many of these grassland ecosystems of high conservation value are threatened by several pressures associated with human activities (Cousins and Eriksson, 2008). This is the case of the

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calcareous grasslands of Alta Murgia uplands, where several conservation issues related to anthropogenic activities remain unsolved (Perrino and Wagensommer, 2013). To date, grasslands cover ~29800 ha and represent what remains from the ~80000 ha existing at the beginning of the 20th century (Mairota et al. 2013).

Therefore, recovery of grasslands in human landscapes has become one of the cornerstones of biodiversity conservation policy in Europe (Eggenschwiler et al., 2009). A major aim of grassland restoration projects is to recover grassland species richness (Walker et al., 2004). To achieve these aim, the recovery of native perennial grass cover is often given high priority to rapidly provide ecosystem services of erosion control and recovery of traditional landscapes (Conrad and Tischew, 2011; Kirmer et al., 2011; Tropek et al., 2010). On the other hand, methods enabling the effective recovery of native grassland plant communities on newly created soil surfaces are not straightforward. In general, a compromise is required in order to facilitate natural grassland colonization without the need for expensive sowing techniques.

Moreover in this context, few studies have taken into account the restoration processes in Alta Murgia plateau, where dry grassland vegetations of conservation concern occur. Among the most interesting grassland plant communities occurring in this area, those belonging to the classes *Festuco-Brometea*, *Lygeo-Stipetea* and *Helianthemetea* are listed in Habitat Directive 92/43/EEC.

Our study was first focused on evaluating the early vegetation dynamics on restored landfill surfaces in the Alta Murgia National Park. In particular, while testing the effectiveness of different sowing methods, our aim was to identify the role of natural dynamics in the early successional stage of herbaceous communities.

2. Materials and methods

This study was carried out in a restored landfill site in the northwestern portion of Alta Murgia plateau, in Apulia region. The landfill, which has been abandoned since 1992, was restored during 2015 within a project in charge of the municipality of Minervino Murge (BT). After first steps of cleaning-up and waste removal aimed at permanently securing the dump, capping was carried out using several layers (clay, HDPE geomembrane, drainage geonet), then the site was covered with native fine-grained soil for vegetation recovery. With the aim of enabling grassland recovery, three different methods were used according to the soil morphology occurring in the area: 1) no seeding on flat surface; 2) seed sowing on steep surface stabilized with jute matting; 3) hydroseeding on sub-vertical surface of a reinforced soil wall. For both seeding methods, a four-species mix of non-native perennial grasses (*Lolium perenne*, *Festuca rubra*, *Poa pratense*, *Dactylis glomerata*) was spread in October 2015.

In order to investigate vegetation dynamics, plant data were collected in June 2016 in the three different restoration surfaces, as well as in the surrounding grassland patches within a 20m buffer. For each area, cover values of vascular plant species (%) were recorded and used to compute species richness (S) and Shannon's diversity (H') indices.

Species were classified according to main life form categories (Raunkiaer, 1934): phanerophytes (Phan), chamaephytes (Cham), perennial grasses (H grass), perennial forbs (H forb), biennials (Bien), annual grasses (T grass), annual forbs (T forb) and geophytes (Geo). Specific Ellenberg-Pignatti's Indicator Values (EIVs) (Pignatti et al., 2005) were also computed for each species assemblage. EIVs are based on ecological requirements and specific plant traits of adaptation to soil pH (R), moisture (U), nitrogen (N), light (L), temperature (T) and continentality (C).

3. Results and discussion

As a first result, no one of the grass species artificially sown for restoration purpose was observed in the areas, though their seedlings were previously found growing during winter observations. This result indicates a loss of vitality of selected grass species during spring, which may be explained by both the unfavourable local abiotic conditions and by the competition with spontaneous weeds. Perennial grass species are known to be less efficient in suppressing competitive weeds during the early colonizing stage, while sowing annual species would have been more suitable for this purpose (Miglécz et al., 2015). Moreover, as a rapid weed suppression is known to be feasible at higher sowing rate, additional hay transfer would have enhanced a more rapid suppression of weeds even at low density sowing (Török et al., 2012).

Among the overall number of 159 species found in the whole explored area, 121 species (76.6%) were effectively colonizing the restored surfaces. As expected, plant communities occurring within the restored areas are characterised by a high proportion of ruderal weed species, which are well adapted to quickly colonize newly created soil surfaces. In particular in these areas, the grass layer was primarily dominated by the biennial weed *Silybum marianum*, in association with the annual grasses *Lolium rigidum* and *Avena barbata*. High proportions of *Conium maculatum* and *Dasypyrum villosum* were respectively observed on the flat surface and on the reinforced soil wall. In contrast, adjacent semi-natural grasslands were dominated by both annual (*Aegilops geniculata*, *Dasypyrum villosum*) and perennial grasses (*Dactylis glomerata* subsp. *hispanica*), with high cover value of typical grassland forbs (e.g., *Trifolium stellatum*, *Thapsia garganica*, *Asphodeline lutea*).

When compared with adjacent grassland area, all restored surfaces (flat, slope, wall, margin) showed considerably higher percentage in annual grasses and biennials (Fig. 1). With regard to plant bio-ecological traits, a strong increase in nitrophily (N) value was found in all restored sites, thus indicating a larger amount of ruderal weeds (Fig. 2). These results support the general finding that, after soil disturbance, a wide set of weed species with effective dispersal in space or time can rapidly establish on newly created open soil surfaces (Bischoff et al., 2009).

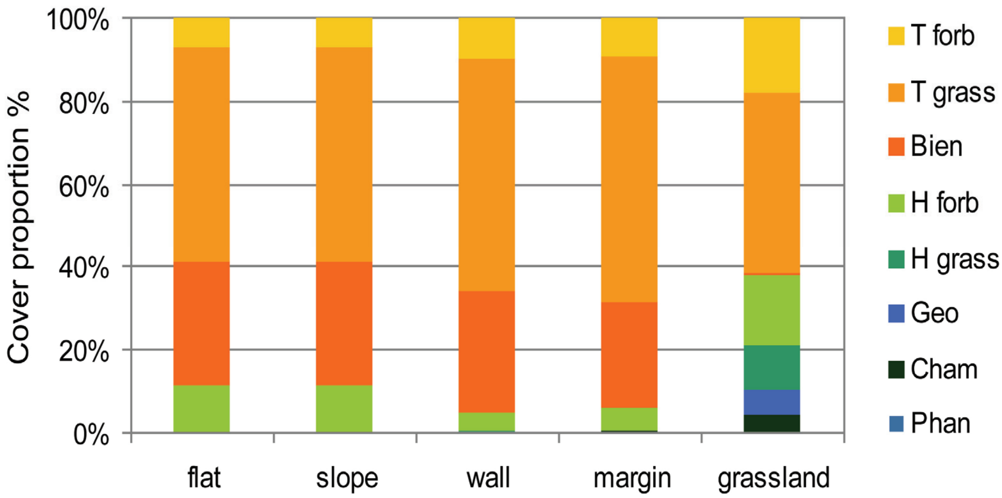

Fig. 1. Life form cover proportion (%) in the sampled areas

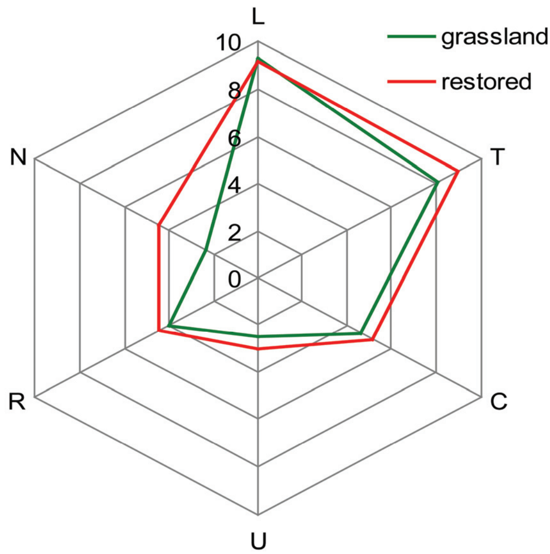

Fig. 2. Diagram of Ellenberg's bio-ecological values in the restored area (mean values measured in restored sites) and in the adjacent grassland patch

Despite the difference in soil morphology and restoration method, no significant variation in species richness and diversity was found among the three restored surfaces (Fig. 3). Indeed, while soil surface characteristics may have a role in driving species diversity in old restored communities, these may have no effect in recently restored ones (Deák et al., 2015). Vegetation composition on recently created surfaces could rather be driven by random species establishment processes, due to both local propagule banks and spatial dispersal (Rebele, 1992).

More species-rich communities were found at the margin between the landfill and the semi-natural grasslands (Fig. 3). This result indicates that the adjacent grassland community can act as an important source habitat from which species can colonize after restoration (Winsa et al., 2015).

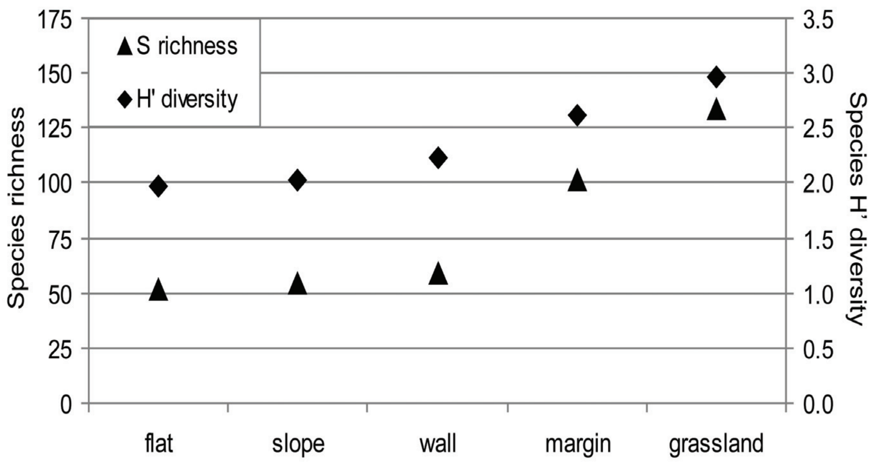

Fig. 3. Species richness (left Y axis) and diversity (right Y axis) in the sampled sites

In consideration of the natural instability of early stage ruderal plant assemblages, these results enable to envisage a quick natural evolution of studied herbaceous communities towards native grassland vegetation.

This preliminary study underline the predominant role of natural colonization by species from adjacent habitat patches, whose results are far superior to those of artificial sowing activities. This is specially important when assessing the feasibility of sowing high-diversity mixtures of native seeds, which tend to increase cost and time in many restoration projects. With reference to the study area, as well as to several dry landscapes in the Mediterranean, the application of more cost-effective sowing methods, e.g., hay transfer (Klimkowska et al., 2010; Török et al., 2012) is moreover suggested for restoration experiments.

6. Concluding remarks

The reported findings represent a starting point for monitoring restoration dynamics across time, which would provide a better understanding of successional processes in the poorly investigated study area.

This information is moreover needed for implementing cost-effective restoration actions in Mediterranean context, as well as for planning conservation strategies for habitat and species of European concern.

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CARBON FOOTPRINT EVALUATION OF AN ITALIAN MICRO-BREWERY*

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Abstract

In the last 20 years, the sector of the Italian beer has shown particular attention to environmental issues, reducing by about two-thirds the amount of water used in the production phase, more than a quarter of the energy consumption per hectoliter of product and approximately one fifth the amount of used glass. But the most important results were obtained for the amount of aluminum used in cans and for CO_2 emissions (about -40%). These successes are probably attributable to the awareness and the marketing strategies of brewing companies of larger size (mainly for the ever-increasing use of kegs, which accounts for more environmentally friendly distribution system) while significant margins of improvement remain for microbreweries that represent the real entrepreneurial phenomenon in the beer sector, in both numbers of plants in the area and growth rates. Therefore, in this study we analyze the case of a micro-brewery of Friuli Venezia Giulia (FVG) Region to understand what may be, for a small private organization, the strengths and weaknesses in the management of the greenhouse gasses emissions. A Life Cycle case study was performed to detect and quantify the organization's carbon footprint deriving from the overall activities of the brewery. Direct and indirect GHGs emissions from 3 high fermentation and 3 low fermentation beers production processes and packaging systems (0.33cL and 0.75cL glass bottles) were considered as well as the emissions related to plant management such as lighting, electric energy, workers mobility and waste treatment. Primary data were collected from a small brewer located in FVG region, secondary data were sourced from literature and databases included in the LCA SimaPro software used to calculate the CF applying the IPCC 2007 GWP 100a method. The organization is the reference unit for the analysis and the basis for defining the system boundaries, within these a carbon footprint of 58.2 t CO_{2eq} was obtained mainly due to direct emissions, i.e. Scope 1, that contribute for 57% to the total GHG emissions of the organization.

Keywords: beer, carbon footprint, LCA, microbrewery

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1. Introduction

During the last few decades the threat of climate change to sustainable development has grown to become a major concern not only among NGO and politicians but also among consumers and society in general. In many nations leaders are discussing ambitious reduction targets for greenhouse gases (GHG) emissions. In October 2014, for instance, the European Union (EU) set a reduction target of at least 40% by 2030 compared to 1990 across all sectors of the economy. A target to be delivered with the reductions in the Emission Trading System (ETS) sectors (industry and energy) and non-ETS sectors (transport, buildings, agriculture, waste, land-use as well as forestry) amounting to 43% and 30% respectively by 2030 compared to 2005 (European Council, 2014). Initially this target was supposed to be based on global projections in line with the medium term ambition of the 2015 Paris Agreement. The first multilateral agreement on climate change, adopted by the United Nations Framework Convention on Climate Change (UNFCCC) at the COP21, covering almost all of the world's emissions, which will replace the approach taken under the 1997 Kyoto Protocol. Recently a new EU Commission’s proposal for a Regulation on binding annual GHG emissions reductions by Member States from 2021 to 2030 has been defined. The aim of such proposal is to set national reduction targets (the ‘minimum contributions’) ranging from 0% to -40% below 2005 levels and to implement EU commitments under the Paris Agreement. In particular, the long-term goal is to keep the global temperature increase “well below 2°C above pre-industrial levels and to pursue efforts to keep it to below 1.5°C” (European Commission, 2016). According to the Intergovernmental Panel on Climate Change (IPCC), keeping global warming likely below 2°C above pre-industrial temperatures is an important goal to limit some climate change risks, such as risks to unique and threatened systems and risks associated with extreme weather events (IPCC, 2014).

The Paris Agreement represents the response to a global call action for policymakers to define a new framework on climate change to report and verify the GHG emissions and consequently the achievements of the national climate plans. At the same time, this ‘global climate deal’ represents a clear market signal that the transition to a low-carbon economy is inevitable and that every economic sector must be part of the solution to the climate change challenges. That is true also for the food and drink manufacturers. The report from the IPCC in fact states that all aspect of food security will potentially be affected by climate change, including food production and quality, as a consequence of global temperature increases and a reduction of renewable surface water and groundwater resources which will intensify competition among sectors. The failure of climate change mitigation and adaptation together with water crises are considered among the most impactful risks for the coming years (ranking first and third respectively) also by experts and decision-makers in the World Economic Forum’s multi-stakeholder communities (WEF, 2016). Extreme weather events such as droughts and storms will have implications for collectivity but even for corporate and business organizations. Among these latter ones there are the Food and Beverage manufacturers and that explains why environmental sustainability and climate change management are increasingly important also for this sector (FoodDrinkEurope, 2015). The growing interest in the relationships among strategies, environmental performance and communication is undeniably reflected by the number of companies that have decided on the one hand to invest in green management, adopting systemic and integrated approaches, and on the other to disclose the evolution of environmental performance levels achieved against objectives and targets.

During the last 25 years, the Italian beer sector, too, has shown particular attention to environmental issues, reducing by about two-thirds the amount of water used in the production phase, more than a quarter of the energy consumption per hectoliter of product and approximately one fifth the amount of used glass. But the most important results were obtained for the amount of aluminum used in cans and for CO_2 emissions (about -40%) (Assobirra, 2015). These successes are probably attributable to the awareness and the marketing strategies of brewing companies of larger size (mainly for the ever-increasing use of kegs, which accounts for more environmentally friendly distribution system) while significant margins of improvement remain for microbreweries that represent the real entrepreneurial phenomenon in the beer sector, in both numbers of plants in the area and growth rates.

Recently, a considerable number of studies addressed to the issue of environmental impacts that could result from beer production, see for example (Amienyo and Azapagic, 2016; Bonamente et al, 2016; Cimini and Moresi, 2016; Cordella et al, 2008; De Marco et al, 2016; Koroneos et al, 2005). In this study we analyze the case of a micro-brewery of Friuli Venezia Giulia (FVG) Region to assess the strengths and weaknesses in the management of the GHG emissions in a small enterprise. A Life Cycle case study was performed to detect and quantify the organization's carbon footprint deriving from the overall activities of the brewery.

2. Objectives

The objective of this study is to detect and quantify the organization carbon footprint deriving from the overall activities of an Italian micro-brewery that produces 3 high fermentation and 3 low fermentation beers, mainly consumed in Italy. The purpose of the study is also to identify the processes responsible for the great majority of GHG emissions to propose targeted actions for decreasing such emissions and that could become a best practice to be shared across brewery industries.

This work is divided in four main parts:

- selection of case study: a micro-brewery located in the Province of Trieste, Friuli Venezia Giulia, a North East Italian Region particularly rich in craft breweries.
- assessment of the most recent European guidelines on the environmental performance of products and organizations and especially on measuring and reporting greenhouse gas emissions This paper can be of interest for the beer sector since, to the best of our knowledge, it evaluates the carbon footprint of a micro brewery for the first time.
- choice of system boundaries, considering only all processes directly involved in the activities of the organization and therefore properly quantifiable (from raw materials transport to local delivery of products to customers)
- determination of organization's carbon footprint and identification of the processes most responsible for greenhouse gas emissions.

3. Materials and methods

Carbon footprint. An organization carbon footprint (CF) is the indicator used to quantify the total amount of direct and indirect carbon dioxide (CO_2) and other greenhouse gas (GHG) emissions from all the organization activities, expressed as carbon dioxide equivalent (CO_{2eq}) (Baldo et al., 2009; Bonamente et al., 2016; Gao et al., 2014; Pandey et al., 2011).

In this study, the carbon footprint of a micro-brewery, located in the Province of Trieste (Italy), has been modeled taking into account two main standards: the greenhouse gas GHG Protocol, the internationally recognized standard for the corporate accounting and reporting of GHG emissions (WBCSD and WRI, 2004; WBCSD and WRI, 2009) and the ISO 14064-1 standard that defines how to manage GHG inventories at organization and company level (ISO, 2006). Both standards follow an approach based on life cycle methodology for the measurement of the GHGs emissions. Furthermore, two guidelines, aligned with the former standards, have been used: the UK ministerial guidance that defines general principles to help organizations to measure and report greenhouse gas emissions (DEFRA, 2009) and Beverage Industry Sector

Guidance for Greenhouse Gas Emissions Reporting (BIER, 2013). Carbon footprint calculation was based on the method: IPCC 2013, contained in the SimaPro software (PRè, 2016).

System boundaries. In this study, GHG emissions of a small brewery wholly owned by a single owner have been measured. Therefore, being a simple organizational structure and according to the above mention standards (GHG Protocol and ISO 14064 Standard), the organizational boundaries encompass all the activities that take place within the production site while the operational boundaries categorize the emissions resulting either directly or indirectly from the organization's operations, facilities, and sources. Operational boundaries (Fig. 1) have been established by classifying the emission-released activities under organization's control in three groups called scope by the GHG Protocol.

Scope 1: Direct emissions resulting from company owned and controlled assets. In this investigation, the following activities related to direct GHG emissions were identified: a) combustion of NG to generate hot water for plant heating and to generate steam boiler for beer processing; b) use of carbon dioxide during bottling and liquid decanting operations; c) must fermentation and partial conversion of sugar into carbon dioxide; d) use of a company-owned van for local distribution (Trieste Province) of beer bottles and kegs.

Scope 2: Indirect emissions from purchased electricity. One activity generating indirect emissions was considered: use of electricity for lighting the brewery's rooms and warehouse cooling (approximately 20%) and use of electricity for the of production equipment (approximately 80%).

Scope 3: All other indirect emissions resulting from the activities related to the organization. The following activities were taken into account: a) transport of malt, hop, yeast, coadjutants, primary and secondary packaging materials, corks, detergents from the distributor sites to the micro-brewery gate, b) workers' car commuting.

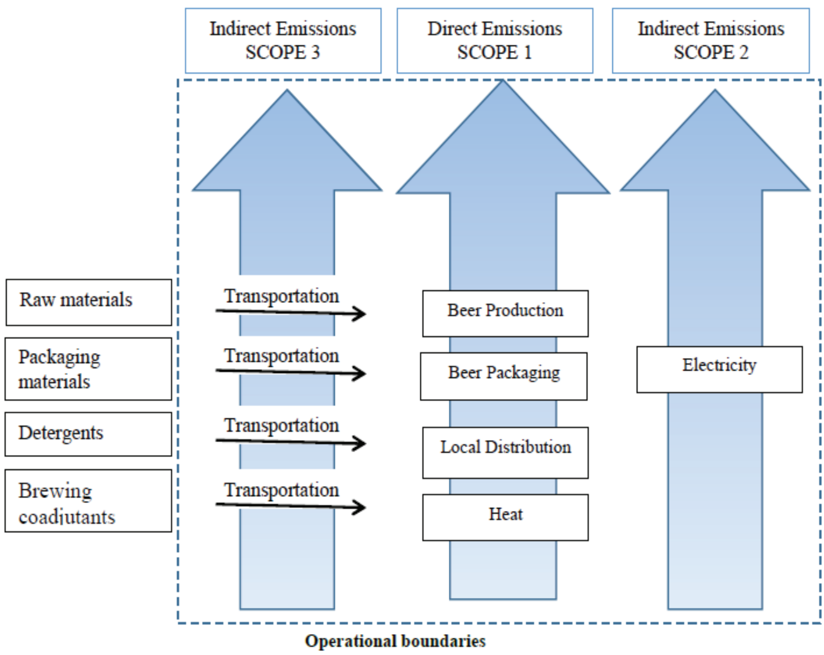

Fig. 1. Operational boundaries and activities within the scopes considered in the case study

Data collection. In order to collect proper data the organizational processes were established and the related activities responsible for greenhouse gas emissions identified. The primary data were gathered through personal interviews with the beer manufacturer and were referred to activities carried out in 2015 at the brewery. All data are referred to the total annual production equal to 57.95 m^3. Secondary data were obtained from EcoInvent 3 database included in the SimaPro 8.1 software.

Inventory Analysis. Primary data collected at the brewery and used to calculate the CF of the organization are summarized in Table 1. The data have been assigned to the different scopes previously described. In scope 1 the total natural gas consumption (8999 m^3) has been divided as follows: (i) 20% (3365 m^3) to supply a thermal boiler of 30 kW rated power, 86% yield and (ii) 80% (5634 m^3) to supply a steam generator of 175 kW rated power with a 90% yield. The carbon dioxide direct emissions from beer fermentation were calculated considering the degrees Plato (°P) (percentage of sugars in the wort before fermentation), the degree of attenuation (the percent of malt sugar converted to ethanol and CO_2) at 70%, the amount of wort produced for the different types of beer and the 10% of CO_2 that approximately remains in produced beer. Regarding local distribution, the organization delivers the 30% of total production (that is about 26.6 t, adding the beer and the primary packaging weight) in the Trieste Province by means of a van with an average load factor of 0.98 t (as modeled in SimaPro). From the data provided by the company on the mileage and the number of trips made, the average distance travelled has been calculated.

Table 1. Primary data for total annual beer production

Data for total annual beer production (57950 L)								
SCOPE 1			***SCOPE 2***			***SCOPE 3***		
Inputs	***Unit***	***Amount***	***Inputs***	***Unit***	***Amount***	***Inputs***	***Unit***	***Amount***
Natural Gas	**m^3**	**8999**	**Electric Energy**	**kWh**	**27383**	**Transportation**		
heat generation	m^3	3365				Transportation (16-32 t)	tkm	1523.6
steam generation	m^3	5634				Transportation (7.5-16 t)	tkm	168.6
CO_2						Transportation (3.5-7.5 t)	tkm	836.6
Beer fermentation	t	2.82						
Purchased	t	1.26						
Local Distribution (3.5-7.5 t)	tkm	9435						

In scope 2 the total annual organization consumption of electricity is reported.

In this case study, upstream activities identified as scope 3 by the GHG Protocol (i.e. raw materials, processed materials and packaging materials, coadjutants and processing aids) were not taken into account except the transportation of the overall materials from suppliers to the brewery. Data provided by the manufacturer on transport distance and annual material purchased were used to calculate the values of tkm as the weight of the transported materials multiplied by the average transport distance related to the three different vehicles type

Regarding brewery by-products 4.06 t per year, spent grains and surplus yeast were used as cattle feed in a farm very close to the brewery (about 1 km), considering the very low traveled distance emissions caused by this transportation as negligible.

4. Results and discussion

In order to estimate the CF of a micro-brewery the SimaPro 8 software was used to model the system and the IPCC2013 100a method was applied to calculate the CO_{2eq} emissions.

The percentage contribution of each of the three Scopes is reported in Fig. 2**.** As can be seen the direct emissions, i.e. Scope 1, contribute for 57% to the total GHG emissions of the organization, the EE indirect emissions, i.e. Scope 2, for 29.2% and the indirect emissions others, i.e. Scope 3, only for 13.4%. Regarding scope 3 it should be noted that only the materials' transportation has been considered and not their production that contributes to a significant extent to the GHG emissions (Amienyo and Azapagic, 2016; Pattara et al., 2012).

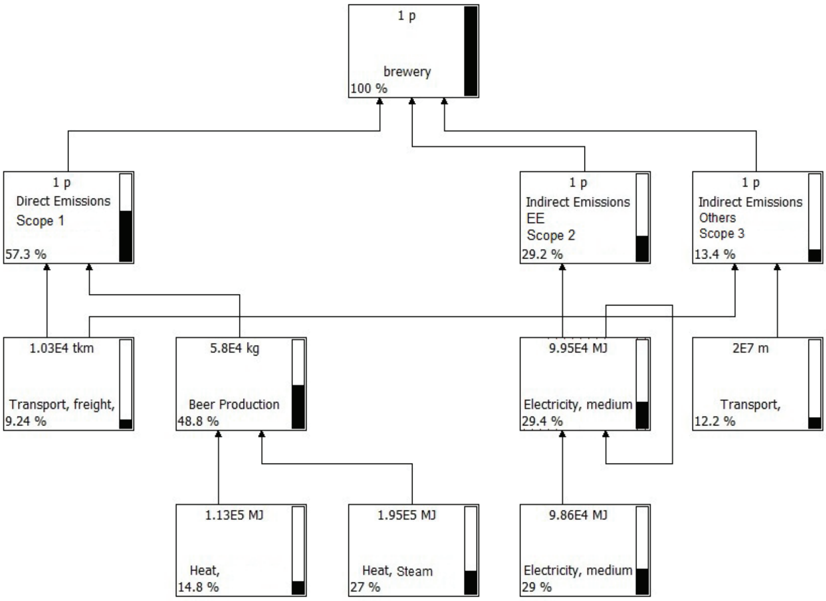

Fig. 2. Percentage contribution of different phases to the organization Carbon Footprint

Direct emissions are determined by two activities: local transport of beer and beer production that contribute for 9.24% and 48.8% respectively to the total GHG emissions of the organization. These values point out that in this specific case study, activities for beer production contribute to most of the greenhouse gas emissions and are mainly caused by the methane combustion for steam production (27%) and heat production (14.8%), while process CO_2 and biogenic carbon dioxide released during the fermentation account for 7% (Fig. 2).

Indirect emissions from electricity use amounts to about 30% of total GHG emissions and corresponds to 47 kWh hL^{-1}, a quite high value if compared with other case studies: 8 to 12 kWh hL^{-1} according to Olajire (2012), 8.61 kWh hL^{-1} according to (Cimini and Moresi, 2016).

To explain this result it must be considered that brewing is an energy intensive process and many factors can determine site specific variations due to differences in-product recipe and packaging type, the incoming temperature to the brewery of the brewing water and climatic variations (Olajire 2012), but above all the size of the organization: large, medium, small or even micro enterprise as in this study.

A more detailed analysis of the data allows to calculate the contribution, expressed in t CO_{2eq}, of different processes to the total emissions, the results are reported in Fig. 3. The consumption of natural gas for steam production used for wort boiling, water heating, and in the bottling hall is responsible for the major contribution to GHG emissions that is 12.17 t CO_{2eq}, followed by emissions from power generation plants (referred to Italian electric production) 7.38 t CO_{2eq} and further consumption of natural gas burned at the plant to obtain heat 6.71 t CO_{2eq}.

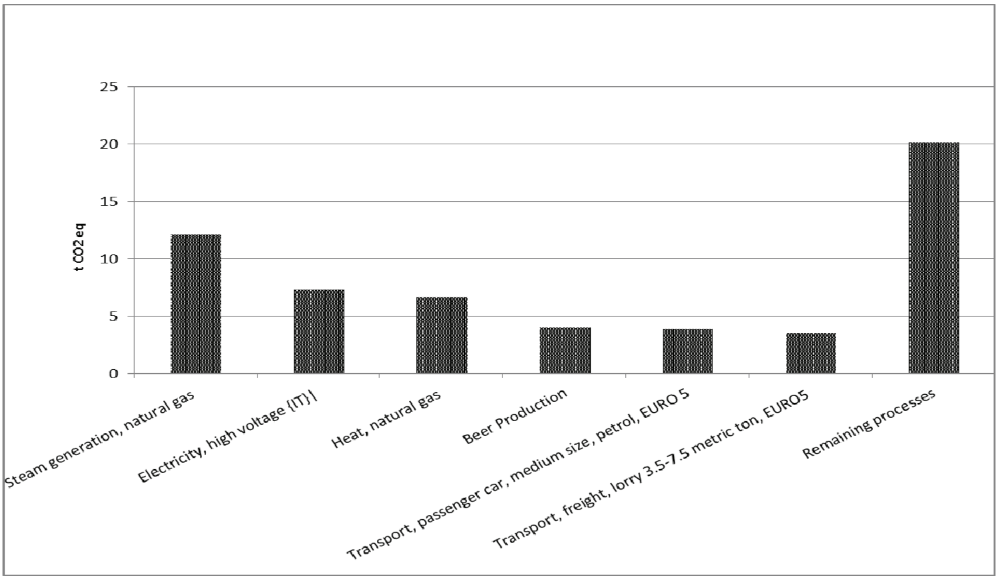

Fig. 3. Contribution of different processes to the organization Carbon Footprint

To the best of our knowledge, this study estimates the carbon footprint of a micro-brewery for the first time, therefore it is not possible to compare these preliminary results with others concerning the organization carbon footprint of similar craft breweries. However, by considering the value of 58.2 t CO_{2eq} and dividing it by the annual production 579.5 hL the value of 100 kg CO_{2eq} hL^{-1} is obtained, a higher rate than other ones concerning the product carbon footprint of industrial breweries, see for example (Cimini and Moresi, 2016).

It is worth noting that this high value of CF was obtained, even if only scope 1 and scope 2 (scope 3 partially) were taken into consideration in our study. Indeed we purposely analyzed only the stages where a small organization, as a micro-brewery, can more easily intervene to improve its environmental performances. Consequently, significant stages have been neglected, such as the national and overseas distribution, as well as the agricultural production of raw materials, that generally appeared as the most impacting stages. See for example (Pattara et al , 2012).It can be hypothesized that this high rate is attributable to shortcomings of optimization processes and economies of scale, present on the contrary in industrial breweries.

Within Scope 1 and Scope 2 energy consumption is the most critical hotspot since it accounts for nearly 70% of greenhouse gas emissions due to the use of electric energy and natural gas; it follows that to improve the organization environmental performance and to increase its value as well as reduce the resources consumption some improvement measures can be adopted. Actions could be taken on one hand for a better and more efficient management of operational activities by decreasing, for example, the amount of energy used per unit of beer produced or by recovering waste heat from the steam generation boiler; on the other hand by using electricity from renewable sources through the installation of a photovoltaic system and thermal energy collectors.

5. Concluding remarks

In this preliminary study the LCA methodology was applied to evaluate the carbon footprint of a small company and to identify the most impacting stages. From this investigation emerged the difficulty in obtaining accurate data from small companies. At the same time, the majority of European consumers, due to their growing interest in the climate change issue, is interested in a mandatory label indicating the carbon footprint of a product (European Commission 2009). In addition, considering the importance that the EU attributes to the Organization Environmental Footprint (OEF), it is desirable that the OEF Guide established by the JRC (JRC European Commission, 2012) will adequately take into account small companies' needs.

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EXPLOITING HYDRAULIC MODEL TO ENHANCE WATER NETWORK OPERATION, PERFORMANCE MONITORING AND CONTROL WITH FDD ALGORITHMS*

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Abstract

The paper presents the Fault Detection and Diagnosis (FDD) approach for water networks developed within the Waternomics project. In particular, the FDD system developed is based on the hydraulic modeling of the water network (done using the EPANET software) that is used to the train a Anomaly Detection With fast Incremental ClustEring (ADWICE) algorithm which in turns is applied to real time data of water flow and pressure monitored in the network to infer performance and detect leaks and operation anomalies. The developed FDD system is particularly useful when more than one parameter needs to be considered at the same time to determine if an anomaly or fault is in place in a complex water network. For a first evaluation, simulated training scenarios have been developed and tested for Linate airport (Milan - Italy) water network and the results are presented in this paper. WATERNOMICS is an EU FP7 research project and the key problem addressed is the lack of water information, management and decision support tools that present meaningful and personalized information about usage, price, and availability of water in an intuitive and interactive way to end users. On average water networks in EU have leakages and inefficiencies that results in 20-30% water losses. As such, new technologies and leakages detection methods are needed to solve this issue, to make the EU more sustainable and in this context the FDD method presented can be helpful.

Keywords: ADWICE, leak detection, model based FDD, water saving

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1. Introduction

The need for an efficient Water Management System (WMS) is strongly felt by water utilities, municipalities and in general by corporates that have to face every day with problems dealing with water usage and supply. Therefore, the basic idea to develop an automated system to implement the fault detection in the water network at an early stage is essential to manage the water resource in a sustainable way by avoiding both the waste of the natural resource and the waste of money. Whichever water network we consider the leakages exist; and they have to be localized and measured and solved.

This problem is more severe when we have to face cases in which large water network are implied and where, due the many variables coming into play, it could be very difficult to detect anomalies or fault in the system. In these cases we need to adopt more sophisticated fault detection techniques that are designed to cope with a larger features set and a Model based FDD could be appropriate. This is the case study addressed in the WATERNOMICS project at the Linate airport (Milan – Italy) water network where for the first time we are working toward putting together a hydraulic model simulation with an FDD algorithm (ADWICE) to detect abnormality in the operational phase of the water network. The automated FDD method introduced in this paper is suitable for large water networks for this reason the approach serves as a first step toward its implementation at Linate when sensor data becomes available.

The fault detection method proposed is made up of 5 phases described in the following Fig. 1.

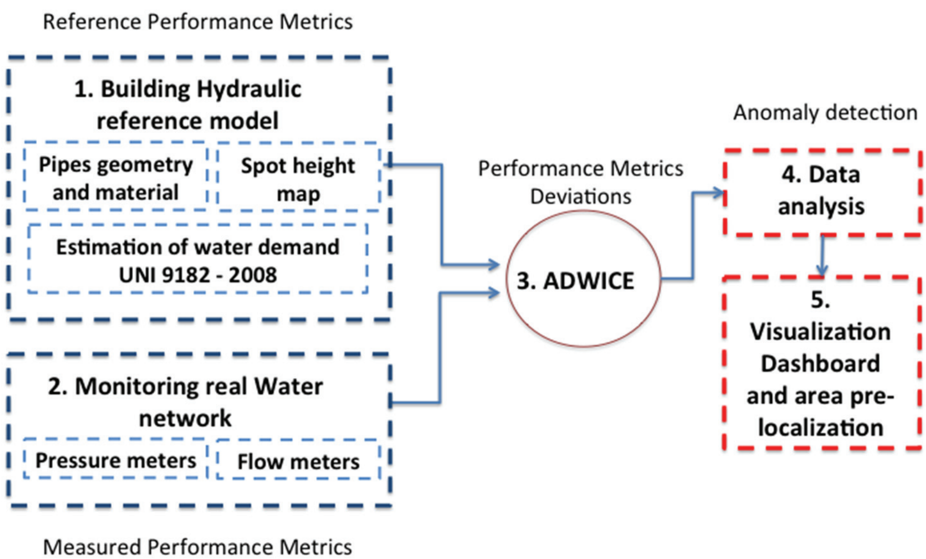

Fig. 1. Waternomics Model Based FDD Methodology

A short description of each phase is provided:

Phase 1 – Building Hydraulic reference model

In this phase, technical information is used to provide knowledge about the water network and for estimating the water demand. Information required to attain an accurate hydraulic model includes: pipe geometry, material types, age and an inventory of the buildings and their water equipment.

Phase 2 – Monitoring real water network

In this phase it is necessary to implement water meters installation in the network with the objective to get data to implement the training of the FDD algorithm ADWICE.

Phase 3 – ADWICE Algorithm

The FDD algorithm ADWICE (Anomaly Detection With fast Incremental ClustEring) is a clustering-based anomaly detector that has been developed in an earlier project targeting critical infrastructures protection. Originally designed to detect anomalies on network traffic sessions using features derived from TCP or UDP packets ADWICE has been adapted in this paper for the drinking water network and it is useful to determine if an anomaly or fault is in place in a complex water network. This class of algorithms is based on modeling the system selecting the best set of parameters that characterize the operational conditions (in our case the flow rate and the pressure) assuming normal operation, i.e. absence of problems (leaks, faults, etc.). This model is used as a comparison baseline with the operational values observed by the water sensors installed in the network in real time.

Phase 4 – Data analysis

If system under observation is not found to be operating in the modeled normal region and the deviation between the normality and the current situation exceeds a certain threshold, an anomaly is detected and an alarm is raised.

Phase 5 – Dashboard visualization

A notification event is raised through the Waternomics Platform to inform the users about the anomaly detected. The users will have the option to act immediately on the notification.

2. Water network modeling and ADWICE training

Water network information, as pipes geometry material and age, are necessary in this phase. This kind of information can be gathered both through design documents study and on site surveys. In Linate airport, 12 technical meetings have been held in order to get an accurate knowledge of the WDS (Water Distribution System) and its characteristics like the pumping stations system, the materials of the pipes, the spot height map of the pilot area and the depth of installation of pipelines. For estimating the water demand, an accurate survey of all the buildings within the pilot area was also conducted in order to develop, for each building, an inventory of the water equipment installed on each floor.

The UNI EN 9182/2008 was utilized in order to get, for each building, a corresponding water demand. The UNI EN 9182/2008 is an Italian law that defines design, installation, testing and management criteria for hot and cold water supply and it is generally used in the design and sizing of water pipes through the calculation of the estimated out flow rate. The water demand is estimated by conducting a *loading units* methodology. Loading Unit value is assumed conventionally according to the flow of a delivery point, taking into account its characteristics, its frequency of use and the simultaneous utilization of the other water appliances installed in the water distribution network inside the building. The method basically consists in assigning to each water equipment a load unit.

Figure 2 (extracted from UNI EN 9182/2008), has been used to assign the load units. The first column lists the appliances, the second is the typology of the water fixture, the third reports in order the Load unit for cold water, hot water and the total of hot plus cold water. As for example for the washbasin we have to consider the first line and assign the load unit corresponding to the total of hot plus cold water (2,00 U.L.).

Apparecchio	Alimentazione	Unità di carico		
		Acqua fredda	Acqua calda	Totale acqua calda + acqua fredda
Lavabo	Gruppo miscelatore	1,50	1,50	2,00
Bidet	Gruppo miscelatore	1,50	1,50	2,00
Vasca	Gruppo miscelatore	3,00	3,00	4,00
Doccia	Gruppo miscelatore	3,00	3,00	4,00
Vaso	Cassetta	5,00	-	5,00
Vaso	Passo rapido o flussometro	10,00	-	10,00
Orinatoio	Rubinetto a vela	0,75	-	0,75
Orinatoio	Passo rapido o flussometro	10,00	-	10,00
Lavello	Gruppo miscelatore	2,00	2,00	3,00
Lavatoio di cucina	Gruppo miscelatore	3,00	3,00	4,00
Pilozzo	Gruppo miscelatore	2,00	2,00	3,00
Vuotatoio	Cassetta	5,00	-	5,00
Vuotatoio	Passo rapido o flussometro	10,00	-	10,00
Lavabo a canale (per ogni posto)	Gruppo miscelatore	1,50	1,50	2,00
Lavapiedi	Gruppo miscelatore	1,50	1,50	2,00
Lavapadelle	Gruppo miscelatore	2,00	2,00	3,00
Lavabo clinico	Gruppo miscelatore	1,50	1,50	2,00
Beverino	Rubinetto a molla	0,75	-	0,75
Doccia di emergenza	Comando a pressione	3,00	-	3,00
Idrantino Ø 3/8"	Solo acqua fredda	2,00	-	2,00
Idrantino Ø 1/2"	Solo acqua fredda	4,00	-	4,00
Idrantino Ø 3/4"	Solo acqua fredda	6,00	-	6,00
Idrantino Ø 1"	Solo acqua fredda	10,00	-	10,00

Fig. 2. Unit Load methodology – image extracted from UNI EN 9182/2008

By knowing the loads units for each building, it is possible to obtain the estimated global water demand by applying the conversion presented in Figure 3 (extracted from UNI EN 9182/2008). These data are valid for public use buildings (offices, schools, hotels, restaurants).

Unità di carico UC	Portata l/s	Unità di carico UC	Portata l/s	Unità di carico UC	Portata l/s
6	0,30	120	3,65	1 250	15,50
8	0,40	140	3,90	1 500	17,50
10	0,50	160	4,25	1 750	18,80
12	0,60	180	4,60	2 000	20,50
14	0,68	200	4,95	2 250	22,00
16	0,78	225	5,35	2 500	23,50
18	0,85	250	5,75	2 750	24,50
20	0,93	275	6,10	3 000	26,00
25	1,13	300	6,45	3 500	28,00
30	1,30	400	7,80	4 000	30,50
35	1,46	500	9,00	4 500	32,50
40	1,62	600	10,00	5 000	34,50
50	1,90	700	11,00	6 000	38,00
60	2,20	800	11,90	7 000	41,00
70	2,40	900	12,90	8 000	44,00
80	2,65	1 000	13,80	9 000	47,00
90	2,90			10 000	50,00
100	3,15				

Fig. 3. Unit Load conversion – image extracted from UNI EN 9182/2008

The geometry of the pipes in the water network, the materials, the depth of installation, and the water demand calculated in accordance to UNI EN 9182/2008 are all input data for the EPANET software and for the development of the hydraulics model of the WDS. The outputs of the EPANET model that are helpful to implement the reference performance metrics are: pressure in the junctions (nodes) and flow in the pipes. Figure 4 shows the hydraulic model of the Linate Airport WDS.

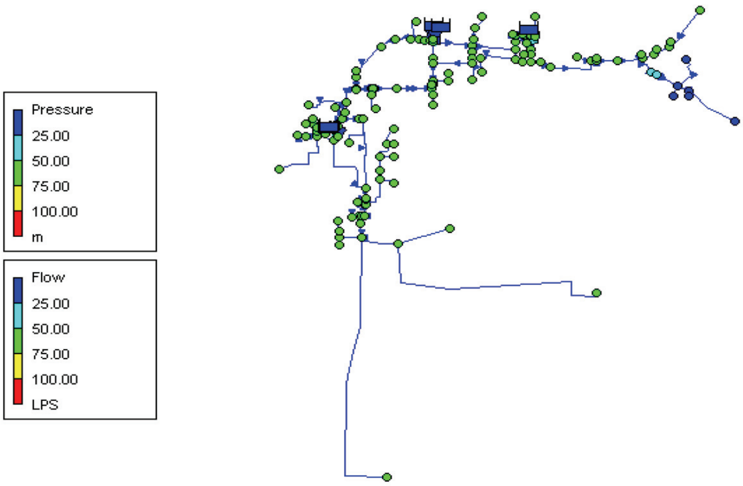

Fig. 4. Linate Airport water network model simulation with EPANET tool

The model is composed of 149 nodes and 159 links and simulates the entire water network of the Linate airport for a total length of about 10 km of water network. For the development of this hydraulic model a lot of information have been collected both with the documents made available by SEA (the airport operator) and also through physical surveys. To implement the simulation the Hazen-Williams formula has been used, while minor losses have been neglected.

The proposed model based FDD requires data from the meters installed in place in order to create a baseline through which to get the ADWICE algorithm trained and/or tested. Due the fact that in Linate airport the installation of the meters necessary to implement the algorithm trainer is on going, the problem has been solved by getting data from virtual scenarios created ad hoc to implement the algorithm trainer. With the objective to create realistic scenarios, a categorization of the Linate airport building was carried out. The categorization was implemented by considering the typical working time of each building. The homogeneous categories individuated for this are the following:

A. buildings with operation time from 6:00 am to 23:00 pm;
B. buildings with operation time from 8:00 am to 18:00 pm;
C. buildings with operation time 24/24 h.

For each category, a different water demand has been considered:

1) full water demand (100% demand pattern as identified before with UNI EN 9182/2008);
2) water demand corresponding to the 50% of the demand pattern identified with UNI EN 9182/2008);
3) water demand corresponding to the 0% of the demand pattern identified with UNI EN 9182/2008).

The combination of the above-mentioned categories and of the demand pattern has allowed us to consider 45 different scenarios summarized in Table 1.

In the second step, a list of buildings served from the water supply has been identified. The number of buildings served by the water network in Linate airport is 36 and they have been named utilizing a codification number. For each scenario, more instances starting from of it have been generated by scaling down the water demand of a building at a time with a factor ranging from 60% to 100% in steps of 10% of its estimated water demand, while keeping all the other buildings with the demand specified in the scenario.

Table 1. Categorization of the Linate Airport buildings and first 45 scenarios

	A	B	C		A	B	C		A	B	C
scenario 1	1	1	1	scenario 16	1	1	1	scenario 31	1	1	1
scenario 2	1	0,5	1	scenario 17	0,5	1	1	scenario 32	0,5	1	1
scenario 3	1	0,5	0,5	scenario 18	0,5	1	0,5	scenario 33	0,5	0,5	1
scenario 4	1	0	0,5	scenario 19	0	1	0,5	scenario 34	0	0,5	1
scenario 5	1	0,5	0	scenario 20	0,5	1	0	scenario 35	0,5	0	1
scenario 6	0,5	1	1	scenario 21	1	0,5	1	scenario 36	1	1	0,5
scenario 7	0,5	0,5	1	scenario 22	0,5	0,5	1	scenario 37	0,5	1	0,5
scenario 8	0,5	0,5	0,5	scenario 23	0,5	0,5	0,5	scenario 38	0,5	0,5	0,5
scenario 9	0,5	0	0,5	scenario 24	0	0,5	0,5	scenario 39	0	0,5	0,5
scenario 10	0,5	0,5	0	scenario 25	0,5	0,5	0	scenario 40	0,5	0	0,5
scenario 11	0	1	1	scenario 26	1	0	1	scenario 41	1	1	0
scenario 12	0	0,5	1	scenario 27	0,5	0	1	scenario 42	0,5	1	0
scenario 13	0	0,5	0,5	scenario 28	0,5	0	0,5	scenario 43	0,5	0,5	0
scenario 14	0	0	0,5	scenario 29	0	0	0,5	scenario 44	0	0,5	0
scenario 15	0	0,5	0	scenario 30	0,5	0	0	scenario 45	0,5	0	0

LEGEND	
1	100% Base demand
0,5	50% Base demand
0	0% Base demand

As results from this two steps categorization methodology we have obtained 8.100 scenarios (45 scenarios * 36 buildings * 5 scale factors) that are likely to be able to simulate, although not in-exhaustive way, a reasonable subset of the possible operating conditions that may occur in the water network and obtain an early feedback whether anomaly detection is feasible or not.

The simulation of the full set of possible operating conditions would be too complex from the computational point of view and would include too many unrealistic conditions (e.g. if we want all the possible combinations by varying the demand of each building from 0 to 100% in steps of 10% we should generate 11^36 scenarios, a huge number). Each of the 8.100 instances simulated with the EPANET model of the Linate Water network provided us with data, in terms of pressure at nodes and flow at links, that we used to train the ADWICE algorithm. The above procedure allowed to have available data for the water network prior to the installation of the meters and the real time measurements. Again, this dataset is not exhaustive and may not capture all the real operating conditions but it is valid for the purpose of evaluating the effectiveness of the anomaly detection algorithm. As described in the following section, a script that performs the 8.100 simulations in one single batch has been developed. The output is a CSV file where each line is the output of the simulation of an instance of a scenario and the columns are pressures and flows.

This file is given as input to ADWICE to build the normality model. ADWICE needed to be configured to work properly with this dataset: first, a feature selection procedure was performed, selecting only the most significant nodes and links that show more variation; the order of the features is also important and we gave more priority to one that shows the highest variance, than the second and so on. Finally, as any clustering algorithm, the dataset needs to be studied to get an idea of the proper amount of clusters to be set. If the number is too low we get a more general model, with big clusters trying to cover scattered points that are quite far away from each other. This model would generalize too much and fail considering as normal anomalous points that fall in areas that should not be covered by any clusters.

The other way round is not good either; if we let the algorithm create and use too many clusters we would over-fit the model to the training dataset creating little clusters around the given points. The algorithm would then correctly raise alarms with anomalous points falling outside those clusters, but would then raise also too many false alarms when normal behaviour generates points that are just away from the closest cluster.

ADWICE has a parameter that specifies the maximum amount of clusters it can use. This parameter is called **M**. Another important parameter is the threshold **E** it uses to accept new points outside the clusters. If E=1 it means no threshold, E=2 it means two times the size of the cluster etc. During training **E** is important to set how much a cluster can be stretched to embed the new point. During evaluation instead **E** is used to determine whether the algorithm should accept as normal or launch an alarm if the point is close (with a certain distance) to a cluster. To find a suitable range of values for M and E, we performed the following heuristic procedure:

- set a value of M and E and launch the training of the algorithm to create the normality model;
- check how many clusters it has use;
- Test the anomaly detection using the same (fault-free) dataset.

If the anomaly detector raises too many false alarms (we check the false positive rate FPR, which represents the percentage of good points wrongly classified as anomalies), we raise M and/or E. Once we stabilize the FPR, we check whether by increasing M the number of clusters used increases as well. If not, the model is over-fitted and we need to scale down M. This procedure gives an idea of possible values for M and E. Usually these are further tuned during the validation phase trying the algorithm with known faults to see how it performs in terms of alarm detection (measured as detection rate DR – the percentage of anomalies correctly classified as such). The final values of M and E are selected in order to get a good trade-off between false positive rate and detection rate.

3. Leakages scenarios development and ADWICE testing

In the same way, we generated "clean" scenarios that capture normal operating conditions for the WDS, to be able to test the effectiveness of the ADWICE as fault detector we need to develop some scenarios that contain leakages in the water network. In doing this, a methodology to simulate a leakage in the water network has been found and generally we can assume that the phenomenon of water leaks is governed by the relationship between the leakage rate (qi **) and pressure (pi):

$$q_i^{**} = c \cdot p_i^{\beta} \tag{1}$$

where: C is the coefficient of loss, β is the loss exponent.

It is evident that reducing pressures allows to decrease, exponentially, lost volumes.

a) **b)**

Fig.5. Water loss at high pressure a) and at low pressure b)

In the EPANET model, the leakages have been simulated by introducing a leakage through the emitter coefficient in some junctions. The introduction of the emitter allow to simulate the outflow rate depend on the pressure (Figure 5). In this way, 10 leakage scenarios have been implemented by introducing the emitter coefficient in some junctions as shown in Table 2.

Table 2. Leakages scenarios for Linate water network simulation

LEAKAGE SCENARIOS			Emitter coef.= 1					
SCENARIOS	NODE ID							
SP1	136							
SP2	136	126						
SP3	126	115	103					
SP4	126	115	103	111				
SP5	17	19	25	35	29	54	49	46
SP6	55	56	60	85	91	59	62	
SP7	75	73	100	93	63	74		
SP8	38	76	108	74	125	97		
SP9	1	4						
SP10	46	47	52	53				

With the same approach used to generate the normal dataset, we simulated a leakage at a time applying the emitter coefficient to the specified nodes. Each leakage is then produced in all the 8.100 scenarios as above. This gives us ten more files, one for each leakage scenarios, with 8.100 cases. To test the efficiency of the anomaly detection algorithm, we modified these files adding the 8.100 normal fault-free scenarios at the beginning of the files, letting the 8100 with the leakage be after these. This gives us the possibility to compute the accuracy of the algorithm (percentage of instances correctly classified either as alarms or not). EPANET is a Windows-based application and it allows modelling a water network and running a simulation from the graphical user interface (GUI). However, we need to simulate a high number of scenarios changing some input parameters (the demands at nodes) from one simulation to the other. To perform this task we created a C program that uses the libraries provided by the EPANET programmer's Toolkit. These libraries allow programmers to open network models, run simulations a retrieve the results from custom programs without the need of the EPANET GUI. Our script is structured as following:

- open the network input file which is exported from the model built using the GUI;
- read the scenarios configurations (scenario number, value of A, B, C) from a file. For each of them
  - for each building at a time;
  - for each scale factor between 60% and 100%;
- scale down the demands assigned to nodes according to their category (A, B, C);
- scale further down the demand assigned to the current building according to the current scale factor;
- add the leakage (if generating the validation dataset);
- run the simulation;
- write resulting pressures and nodes in a line in the input file.

4. Results and discussion

The Linate airport, given its large water network (about 10 Km), represents a good test site for the model based FDD. However, the lack of real measurement data represents an issue and it has been solved, as mentioned above, through the implementation of 8.100 virtual scenarios to simulate the WDS in a large variety of operational environments. The study will be much more detailed in future where, after to have installed the meters in Linate airport, real time measurements and data will be available. However, the results obtained with the virtual simulation of 8.100 operational scenarios give to us the hope for a good functioning of the Model based FDD methodology applied to the real case.

As an example, Table 3 reports the results of the validation of ADWICE with the leakage scenarios described above. As explained earlier, we had to tune the parameters M and E in order to get a trade-off between detection rate and false positive rate. In general, we want to have the minimum FPR and the maximum DR at the same time. In the test performed, we found that the lowest false positive rate we could obtain was as little as 0.01 (1%), but the detection rate was very low as well, being 30% on average. On the contrary, an 80% detection rate was achieved at the cost of a 10% false positive rate. Overall, we need to look at the accuracy, and the results presented in Table 3 provide the best average achieved. On average, the false positive rate is around 5%, the detection rate around 60% and the accuracy 80%. The results were obtained setting M=200 and E=3 for the training phase and E=1 for the validation phase.

Table 3. Results of the Model Based FDD Methodology

Scenario	False Positive Rate	Detection Rate	Accuracy
SP1	0.049	0.84	0.89
SP2	0.049	0.60	0.77
SP3	0.049	0.33	0.66
SP4	0.049	0.68	0.82
SP5	0.049	0.43	0.68
SP6	0.049	0.38	0.66
SP7	0.049	0.42	0.68
SP8	0.049	0.42	0.68
SP9	0.049	0.93	0.94
SP10	0.049	0.58	0.77

4. Concluding remarks

This paper aim is to introduce a model based FDD method helpful in leakages and faults detection in water networks. The method is based on the analysis of both pressure and flow variation produced by leakage in the WDS, for this reason this technique differs from the others we can find in the literature because it is not based on the transient analysis of the pressure waves but on the comparison of real pressure and flow data with their estimation using the simulation of the mathematical network model. For a first evaluation, simulated training scenarios have been developed and tested.

The results obtained in terms of False Positive Rate, Detection Rate and Accuracy, with the virtual simulation of 8.100 operational scenarios give to us the hope for a good functioning of the Model based FDD methodology applied to the real case. Next step is to test the method in a real case studio (Linate water network) by using the real time data gathered from the flow and pressure meters installed in the water network.

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APPLICABILITY OF DECENTRALIZED VERSUS CENTRALIZED DRINKING WATER PRODUCTION AND WASTEWATER TREATMENT IN AN OFFICE PARK AS EXAMPLE OF A SUSTAINBLE CIRCULAR ECONOMY IN AMSTERDAM, THE NETHERLANDS*

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Abstract

The Cleantech Playground is a testing ground for innovative clean technologies in Amsterdam, The Netherlands, which aims at closing the cycle as much as possible in a sustainable way. Here, the De Ceuvel is situated. This heavily polluted site features retrofitted houseboats as offices, placed on land, surrounded by soil-cleaning plants. In this Dutch Topsector Water Technology project Waternet, Metabolic, Advanced Waste Water Solutions and KWR Watercycle Research Institute worked together to investigate how local water-related loop closure fits in a sustainable circular economy. Water need has been reduced to a minimum by installing dry composting toilets and the absence of showers and washing machines. Therefore only five liter per capita per day is needed for drinking, food preparation and personal hygiene, compared to the current average of 25 liter in conventional offices and 128 liter in households in The Netherlands. The grey water is treated by biofilters including plants before infiltration. The water supply may pose a potential health risk. In this study, different approaches and technologies for water supply systems have been investigated with respect to hazards to health (with Quantitative Microbial Risk Assessment), sustainability (with Life Cycle Assessment), cost and legal issues. It is a challenge for decentralized systems to achieve the same level of safety as compared to centralized systems without increasing costs and the impact on the environment.

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Keywords: decentral vs. central, drinking water, grey water, Life Cycle Assessment, Quantitative Microbial Risk Assessment, waste water

1. Introduction

The number of (big) cities is growing worldwide, because of urbanization and population growth. Cities consume natural resources, like energy and raw materials, while waste is produced. The generation of waste is growing and an important issue. For more sustainable cities, it is necessary that water, food and energy from the available sources are produced as efficiently as possible. Renewable sources or reuse play an important role and as little as possible value should be destroyed in the system. The water cycle has a crucial role, from clean water production to treatment of wastewater, which contains essential nutrients for agriculture. The current water cycle is linearly arranged from a systemic perspective.

The circular economy is an economic system that is designed to maximize reusability of products and raw materials and to minimize value destruction. In the current linear system raw materials are converted into products to be destroyed after use. Self-sufficient neighborhoods with their own, decentralized water supply add to the image of the circular economy. Currently, in the Dutch water sector, several initiatives can be identified around the recovery and reuse of energy and raw materials (such as phosphate and cellulose).

This study was executed within the Dutch Top Sector Water. Within the various Top Sectors, end-users (often governmental), entrepreneurs and scientists work together in so-called Topconsortia for Knowledge and Innovation (TKI). This TKI project 'Loop-closure Cleantech Playground Amsterdam' is part of TKI Watertechnology and focuses on the water cycle of De Ceuvel in Amsterdam, The Netherlands. The project is a typical TKI Watertechnology collaboration with innovative water technology on the way to market launch in an innovative concept (closure of cycles in practice), with businesses interacting with public organizations and knowledge institutes. This offers advantages for all participating parties.

With this study a practical showcase of local loop-closure in the city is being created and assessed. The primary goal of this small-scale pilot project in Amsterdam, The Netherlands, is to achieve as much as possible cycle closure by applying innovative concepts and technological solutions. The performance, of in particular water-related technology, is monitored in this Dutch TKI project and critically evaluated in order to demonstrate the applicability in a sustainable circular economy.

This study combines innovative high-tech and low-tech installations and makes optimal use of waste materials. It involves the (future) users/residents in the building process and the concept monitoring/evaluation and technology. This is an example of a (future) possible sustainable circular economy. Local energy extraction (heat/electricity) and wastewater/organic waste treatment with nutrient recovery are applied. Research of the feasibility of local drinking water production, including legislation, institutional barriers and regulations, is part of the project. Several possible sources for local drinking water production were investigated; from rainwater and grey water, to local surface water.

Health risks (with Quantitative Microbial Risk Assessment (QMRA)), sustainability aspects (with Life Cycle Assessment (LCA)) and financial consequences have been extensively analyzed. Beside the study of technology performance and development of new solutions for metropolitan areas, human aspects and interactions between users and clean technologies are also studied, to understand how communities can adapt to new systems and changes. In this way, the project provides an ideal case for the circular re-development of metropolitan areas, through R&D activities in a real life environment.

2. Materials and methods

De Ceuvel in Amsterdam, The Netherlands, is a former shipyard that was not used for years. Nowadays completely renovated and insulated houseboats have been installed, which are used as offices for a group of creative initiators, for a 10 year period (Fig. 1). Due to the temporary nature and the highly contaminated soil no new underground infrastructure is constructed. The boats have no gas and no sewage system. Instead, each boat has a heat pump, solar panels, a dry composting toilet and a low-tech biofilter for grey water treatment. Offices are connected to the municipal power grid and drinking water supply, although clean technologies ensure that the use of these common utilities is significantly lower than in conventional offices.

In addition, at the De Ceuvel site a cafe is situated, where urine is collected separately. Centrally located on De Ceuvel is a composting plant, a struvite reactor and a greenhouse where vegetables are grown, potentially with the compost and struvite. The cafe has a conventional centralized sewer connection and water supply. This study focused on the water cycle of De Ceuvel in Amsterdam.

Fig. 1. For a 10 year period completely renovated and insulated houseboats have been installed for use as offices for a group of creative initiators at De Ceuvel in Amsterdam, The Netherlands

LCA was performed to compare sustainability aspects between the centralized and decentralized drinking water production at the De Ceuvel site. For the analyses of the LCA study the SimaPro 8 software has been used, combined with the EcoInvent 3.0 database.

For calculations the ReCiPe Endpoint V1.10 / Europe ReCiPe E/A was applied. If no data specific for The Netherlands were available in the EcoInvent 3.0 database, the following order was applied: RER (rest of Europe), Ch (Switzerland) and then RoW (Rest of the world). The drinking water production at Weesperkarspel (Waternet, Amsterdam) was model for a centralized drinking water production, and De Ceuvel was used as model for the decentralized drinking water production scenario. Data from Barrios et al. (2004) was used for centralized drinking water production. Much information regarding the processes involved in the decentralized scenario came from colleagues at KWR Watercycle Research Institute. Literature was consulted for data regarding usage of UV-lamp and membranes.

QMRA starts by monitoring (or estimating) levels of pathogens in the source water taking into account the variability of contamination due to seasonality or events like CSO (combined sewer overflow) due to heavy rainfall. Then the pathogens removal by drinking water treatment is estimated either by monitoring the indicator organisms removal by the treatment system, or by using process models published in scientific literature. This removal is expressed on a ^{10}log scale, e.g. 2 ^{10}log equals 99% removal. Because viruses are very small they are poorly removed by filtration, and they can survive some disinfection levels. Protozoa like *Cryptosporidium* are larger, but are not affected by chemical disinfection. Because the various pathogens pose different challenges to drinking water treatment, the risk is assessed for four index pathogens: enteroviruses, *Campylobacter* bacteria, *Cryptosporidium* and *Giardia*. For the study of the decentralized systems at De Ceuvel, literature reviews about treatment efficacy were used, since the systems were not built or in operation at the time of the study (Hijnen and Medema, 2010; KWR, 2015; LeChevallier and Au, 2004; Smeets et al., 2006). These reviews made clear that pathogen removal at full scale is generally less effective than at laboratory scale. Upscaling of technology, varying operational conditions and wearing of materials over time lead to less removal in practice than the potential removal reported in scientific literature. For the alternative systems at De Ceuvel both the potential removal (e.g. a newly installed system) and the expected removal (long term performance in practice) are estimated in the risk assessments.

De Ceuvel is actually a very specific situation with 15 offices, resulting in a very low water consumption, because of the installed composting toilets, but also because of the lack of showers. It is interesting to compare centralized and decentralized water systems in a residential neighborhood as well. Therefore the overall costs (i.e. not the consumer price, but the actual production and distribution costs) were compared at two different scales:

1. An office park with 15 offices, inspired from the De Ceuvel real case.
2. A residential neighborhood with 15 family homes.

From the beginning of this project, future users were invited to participate in construction activities at this Do-It-Yourself (DIY) eco-office park. Surveys were conducted during Summer 2014 and December 2014. Results from the survey are shown as indicators of the general opinion of De Ceuvel renters. While during Summer 2014, 8 companies (and users associated) answered the survey, the second survey has been filled by 10 companies. The difference in the number of answers is due to additional companies who settled on De Ceuvel after the summer.

Fig. 2. Grey water treatment in individual low-tech biofilters, consisting of two IBC containers filled with layers of gravel and coarse and fine sand, planted with reeds.

5. Results and discussion

A minimum amount of grey water is produced at the houseboats, since the boats are used as office, they do not have showers or washing machines. Only five liters per capita per day is needed for drinking, food preparation and personal hygiene, compared to the current average of 25 liters in conventional offices and 128 liters in households in The Netherlands (Pieterse-Quirijns *et al.* 2009). The grey water is treated in individual low-tech biofilters, consisting of two IBC containers filled with layers of gravel and coarse and fine sand, planted with reeds (Fig. 2). The effluent of the filters is monitored before it is infiltrated in the soil and complies with the individual wastewater treatment systems norms in The Netherlands (Table 1).

Table 1. Comparison of average monitored influent and effluent quality of grey water biofilters and Dutch standards (Wet Besluit lozen buiten inrichtingen, art. 3.6)

	COD (mg/L	***Total N (mg/L)***	***Total P (mg/L)***	***TSS (mg/L)***
Grey water influent	401	14	1.9	43
Grey water effluent	122	6.8	1.6	37
Standards	200	60	6	60

Composting toilets are being used in the boats. Through the application of composting toilets on De Ceuvel less waste water is produced, but the human feces have to be processed further. The users at De Ceuvel have to bring the fecal matter from their composting toilet periodically to a central composter (type Joraform). Possibilities for reuse of (parts of) compost have been investigated in this study. There is, certainly in the Netherlands, lack of experience in this field. Usually, *E. coli* is used as an indicator of pathogens in a given matrix. However, eggs of worms will survive longer in human feces than *E. coli*. Accordingly, other and/or more than one indicator species should be considered in order to guarantee a reliable safety standard. After 11 months of composting at De Ceuvel, the level of streptococci was reduced by log 1.9. This does not yet meet the WHO recommendation of log 6 reduction by composting.

Pure urine from a waterless urinal at Café De Ceuvel was used for nutrient recovery and tests with pharmaceutical micro-pollutants to investigate contamination of the produced fertilizers and food (tomatoes) grown with these recovered fertilizers (Fig. 3). Micro-pollutant uptake into the fertilizer streams was found to exhibit both high variability and uncertainty for the different pharmaceuticals, which reduced the accuracy by which trends could be identified. However, the concentration of pharmaceuticals in tomatoes was below detection limits (0.02 mg/kg) so the bioaccumulation was calculated at less than 0.03%. These levels were far below the acceptable daily intake (ADI), which is 1% of the minimum therapeutic dose (Hammerton 2016).

It is therefore possible that tomatoes produced using urine-derived struvite-sorbent fertilizers are safe for human consumption. However, although no bio-accumulation was detected in the tomatoes, this does not preclude bio-accumulation in other plant parts, for example the roots or leaves, which were not tested. Because nutrients and other molecules are taken up from soil by the roots, micro-pollutants are more likely to accumulate in root biomass than elsewhere. As humans do not generally consume tomato plant roots and leaves, this is unlikely to directly affect human health. However, this may pose a risk to human health for root crops, such as carrots or radishes, and leafy vegetables, such as lettuces.

Fig. 3. Nutrient recovery and tests with pharmaceutical micro-pollutants to investigate contamination of the produced struvite fertilizers

The goal of the performed LCA study was to compare the environmental impact of centralized and decentralized drinking water production, specific for the operational aspects. For De Ceuvel the following treatment scheme was assumed: 1) raw water intake, 2) ultra-filtration (UF), 3) nano-filtration (NF), 4) UV treatment and 5) remineralization. In this study only consumables for one year performance were taken into account. The goal of both systems is to produce drinking water according to Dutch quality standards. The production of drinking water corresponds to more Ecopoints in the decentralized (0.104) than centralized situation (0.0762), and the difference is approximately 25%. The difference between these two scenarios becomes more significant (60%) when also the distribution network is included in the calculation (Table 2).

The distribution network for the centralized scenario accounts for 37% of the environmental impact, for de decentralized scenario it is 64%. This major difference in impact of the distribution network is a result of the population density, which is relatively high in Amsterdam, while it is low at De Ceuvel. The parameters with the highest impact in the LCA in the centralized scenario were iron for coagulation, electricity for ozonization, sodium hydroxide (NaOH) and electricity for softening. The environmental impact is strongly affected by the energy origin. Improvements in energy demand or (green) energy supply can be implemented both at centralized and decentralized scale and as such there is no difference in environmental impact. The environmental impact was assessed per m^3 of drinking water. The fact that less drinking water is used at De Ceuvel does reduce the environmental impact of operations. The impact of infrastructure, especially distribution, is not affected by the use, since the momentary demand when opening a tap determines the design of this infrastructure.

Table 2. LCA results in Ecopoints for (de-)centralized drinking water production with and without the distribution network in the calculation

	Only drinking water production	***Drinking water production including distribution network***	***Drinking water production including half of the distribution network***
Centralized	0.0762	0.122	0.0991
Decentralized	0.104	0.291	0.198

Currently drinking water at De Ceuvel is supplied through the public centralized drinking water supply system of Waternet. Possibilities to implement local water collection and upgrading towards drinking water quality to achieve a locally closed water cycle were studied. At De Ceuvel, surface water, rainwater and grey water are potential water sources for local drinking water supply (Table 3). These sources are not protected against contamination with pathogens. The proposed treatment system should be capable of producing water that complies with the Dutch drinking water standards with respect to microbial safety with the maximum risk guideline value of 1 infection per 10,000 persons per year. Chemical contaminants may also be relevant for alternative water supply systems (Etchepare and Van der Hoek, 2015), however in this study the focus is on microbial contaminants since they pose an acute health risk. It is possible to produce safe drinking water in a decentralized system (Table 3).

Table 3. QMRA results with surface water, grey water and rain water as water sources for local drinking water supply

		Surface water	***Grey water***	***Rain water***
raw (organisms/L)	*Enterovirus*	0.75	10	0.01
	Campylobacter	453	1.6	24
	Cryptosporidium	3.3	1.2	0.19
	Giardia	3.5	1.2	1.1
total removal (log)	*Enterovirus*	9	5	4
	Campylobacter	10	5	4
	Cryptosporidium	5.5	5	4
	Giardia	5.5	5	4
risk (infections/person*year)	*Enterovirus*	$8.0*10^{-9}$	**$5.0*10^{-3}$**	**$1.2*10^{-4}$**
	Campylobacter	$2.6*10^{-6}$	**$8.8*10^{-4}$**	**$2.7*10^{-1}$**
	Cryptosporidium	$7.1*10^{-5}$	**$2.7*10^{-4}$**	**$9.8*10^{-4}$**
	Giardia	$4.0*10^{-5}$	$2.7*10^{-5}$	**$5.5*10^{-4}$**

The QMRA assumes constant performance of the treatment processes at the proposed level and sufficient operation and maintenance. This requires advanced treatment technologies and strict monitoring and maintenance. The latter will be challenging for consumers with limited knowledge of health risk and about the technologies (Harvey et al. 2015). Replacement of membranes or UV lamps that appear to be still functioning may be considered non-sustainable by end users, thus compromising safety. Monitoring, operation and maintenance would need to be performed by a specialized company, e.g. Waternet. The additional costs and environmental impact of this need to be taken into account when evaluating this option. Monitoring of pathogens in raw water, indicator removal and operational conditions to perform QMRA according to the guidelines would also require substantial resources. Even though the water treatment technology could produce safe water, current monitoring technology is not capable to guarantee continuous safety in an independently operated decentralized system.

Decentralized drinking water production is in theory allowed in The Netherlands when the following three priorities are fulfilled:

1. The drinking water needs a guaranty that it is safe for human consumption.
2. It needs to be produced in a sustainable manner.
3. It needs to be produced against acceptable costs.

However, to ensure that the drinking water quality is guaranteed, a comprehensive monitoring program is needed, which will increase the costs, so it becomes difficult to still produce at acceptable costs. Current quality monitoring regulations appear to make decentralized drinking water production 3 to 10 fold more expensive compared to centralized drinking water production (Fig. 4). Only when the costs for quality monitoring are reduced with about 90%, decentralized drinking water production might be economically more favorable compared to the current costs for centralized drinking water production.

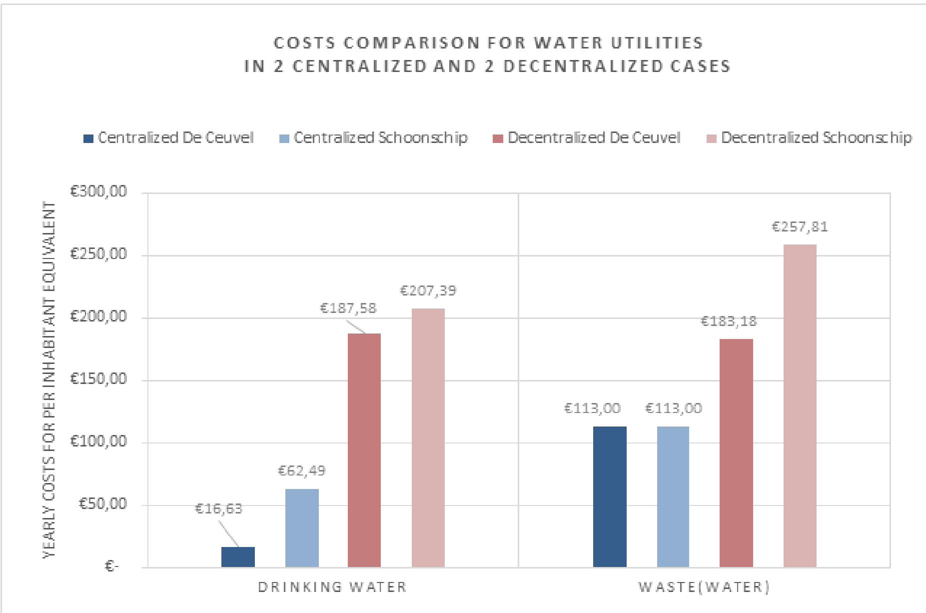

Fig. 4. Cost comparison between centralized and decentralized water facilities for an office park (15 offices 'De Ceuvel') and a residential neighborhood (15 family houses 'Schoonschip')

When labor costs for operation and maintenance are minimized by the deployment of volunteers in decentralized wastewater treatment, overall costs can be comparable with centralized treatment, but such a comparison is not completely fair and certainly not advisable from a risk point of view. Furthermore, in the current costs for centralized drinking water production and wastewater treatment in The Netherlands, several additional costs are included, like costs for environmental protection, research & development and additional taxes.

Finally, user behavior and satisfaction were investigated. It is clear that the occurrence of uncontrolled phenomena such as smells and flies are not acceptable for users. It breaches the comfort level of conventional solutions they are used to. When solutions for each of these issues are implemented, the users are as satisfied with the clean technologies as they are with conventional systems. The first outcome of their feedback is that grey water systems are well accepted among the community, since the removal of settling drums in Fall 2014. Furthermore, regular use of composting toilets is not recommended in the Netherlands, because of discomfort of the users, higher costs and the difficulty to safely reuse the compost. Taken into account the goal of the research at De Ceuvel (local loop-closure) and the lack of a sewer connection, the previous choice for composting toilets is understandable.

6. Concluding remarks

The low-tech biofilters installed on De Ceuvel site (grey water purification systems) ensure sufficient water effluent quality for it to be discharged into the ground without threatening the environment, based on Dutch regulation. Concerning toilet waste composting, results on biological indicators show that toilet waste needs to be composted for a longer period of time in order to ensure safe handling and reuse as a soil conditioner.

The long-term effects of using contaminated urine-derived struvite-sorbent fertilizers on soil quality should also be investigated. It may be necessary to carry out further research in order to determine the indirect risk of using contaminated plant biomass as a feedstock for other purposes, such as compost or animal feed. Further investigation should also be carried out into struvite-sorbent fertilizers for root crops, such as carrots or radishes, and leafy vegetables, such as lettuces. Besides a much larger crop trial, also a broader range of pharmaceuticals are necessary to test the robustness of the preliminary performed experiments.

In addition, feedback from users on De Ceuvel allows for a better understanding of which aspects of the clean technologies are problematic or satisfying. Composting toilets are not well accepted for most of the users. Technical improvements, user-friendly handling and better communication (e.g. operation guidelines) could improve the acceptance, but it is strongly recommended to use other sanitation solutions. Technically local loop-closure is feasible, but user acceptance and especially legislation issues might limit further application. The experiences on De Ceuvel already showed that it is not easy to apply local loop-closure in The Netherlands, but more research and experience with bigger, more representative projects, is needed.

Overall, aspects that could be beneficially applied or prevented in any future decentralized concept can be identified from this study. Decentralised drinking water treatment systems generally have a higher energy requirement per cubic meter of water produced due to the small scale. By reducing the amount of water used, the total use of energy and thus environmental impact will be reduced. When sufficient, sustainable energy is available the total environmental impact and total cost can remain low. For large scale systems, reduced water use has limited effect since its costs and environmental impact depend more on the fixed assets. In comparison with centralized drinking water production, the local drinking water production results in higher risks and costs. Therefore, decentralized drinking water production is not recommended.

Composting toilets are not well accepted by users, because of discomfort and the composting of faecal matter requires a long period of time, since after 11 months of composting *streptococci* reduction did not meet WHO recommendations. Application of composting toilets is therefore not recommended in urban areas. Nevertheless, separated collection of wastewater streams and treatment has potential and could support a circular economy, e.g. nutrient recovery & reuse. Low-tech treatment of limited amounts of grey water with biofiltration is possible. Legal and institutional aspects regarding local water treatment and loop-closure are under development and currently not always clear. Important issues regarding responsibilities, user-acceptance, health and safety risks, sustainability and cost reduction should be further clarified.

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PILOT PROJECT OF WASTE MANAGEMENT IN ZAMBIA: THE SUCCESSFUL REALITY OF KOINONIA, LUSAKA*

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Abstract

The quantity of wastes globally is increasing, not only in the industrialized states but also in the developing countries. According to the report UNEP 2010, this is attributable to a demographic growth, new urbanization and a general improvement of lifestyle.
Zambia can be considered an example of this situation, because is characterized by a significant economic and social development, but at the same time by strong economic inequalities. Referring to the waste management, the Zambian legislation is updated and conformed to the international guidelines for health and environment protection. However, the municipal solid waste management still appears fragmented, characterized by several critical issues and the capital, Lusaka, it is symbolic. The waste disposal is not performed as provided by the national law but according to costumes and habits deeply embedded in the population. In fact, the wastes are usually abandoned and accumulated on city streets, the methods of disposal are reduced exclusively to silting and uncontrolled incineration, even thought a dumpsite is placed in the district of Kafue and a more recent one in the district of Lusaka.
In this paper are presented the first results of a work conducted in collaboration with non-profit NGO Amani, for a project of international cooperation, facing the introduction of waste separation and recycling in the Koinonia community in Lusaka. The study has, as main objective, the creation of a municipal waste management model that was effective, lasting and exportable to other African countries. The analysis of the territory and community habits, along with the involvement of the local population, have led to the success of the project, currently under implementation and realization, for the differentiation of product classes of waste generated in the community with a view to recovery and recycling.

Keywords: Lusaka, municipal waste, recycling, waste management, waste disposal

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1. Introduction

The amount of waste is rising around the world, especially in developing countries, due to the simultaneous occurrence of several factors including the continuous increase of the population, changes in lifestyle and increasing urbanization. (Guerrero et al. 2013) The UN-habitat study of 2010, *"Solid waste management in the world's cities"* (Anand, 2010) shows how these countries not have real plans for the waste management and how so precarious and worrying conditions in terms of impact on health and environment persist. Moreover, the issue of public health becomes clear and worrying during the rainy season, when outbreaks of various diseases, such as cholera and dysentery, are generated in the majority of the most densely populated areas. These diseases then spread and propagate because of the poor sanitary conditions (Wilson et al., 2012). This year, in Zambia, about 1179 cases of cholera, with 31 confirmed deaths (8 were children) have been recorded (Unicef Zambia, 2016).

However, there is a wide legislation on environmental issues in Zambia. National environmental policies formulated by the Ministry of the Environment consider theoretically the effective management of waste as part of the environmental protection strategy and pollution control and especially the protection of public health. National environmental policies, by the Ministry of the Environment, consider, in principle, an effective management of waste as part of the environmental protection strategy and pollution control and especially the protection of public health (Anand, 2010). In specific, the waste management is regulated by the Parliament Act, 2004, thank to which have been instituted the Waste Management Unit at Lusaka City Council. In addition, there is the Environmental Management Act (GRZ, 2011) e l'Health Act (GRZ, 1978) which treats these issue. This is a high-quality and updated legislation. It defines a separate waste management, in order to recycle materials according to the different product categories, and landfill disposal of mixed waste. Moreover, it considers sanctions for irregular practices of waste disposal.

As reported in the Environmental Audit on Waste Management del 2007, in Lusaka the administration has contracted out garbage collection to private companies, which confer on the city dumpsite. (Chifungula, 2010) This landfill, located to the west to Chunga, does not operate disposal of waste according to appropriate safety standards for operators inside. Furthermore, all around the city are created irregular collection sites and uncontrolled incineration of waste, despite the laws. These happens because is not possible pay collection services by the majority of the population belonging to the lower classes.

In this situation, an informal economy of wastes has been established in which the different actors, mainly groups of poor citizens, collect and sell wastes to be recycled for their own gain to ensure their subsistence (Simpson and Gupt, 2010). To confirm this, the PDFs below in Fig. 1 shows how the regular collection system covers about 45% of the population and the amount of waste handled illegally are significant (Anand, 2010). Illegal actors also take care of the disposal of a large amount of waste (94,297 tons / year), even higher than the ones disposed in landfill (77,300 tons / year). Another interesting fact is the low quantity of recycled material, approximately 16,000 tons/year, compared to the amounts that would be potentially recyclable. The recyclable waste is not completely processed within the country but about 30% is transported to South Africa or Zimbabwe.

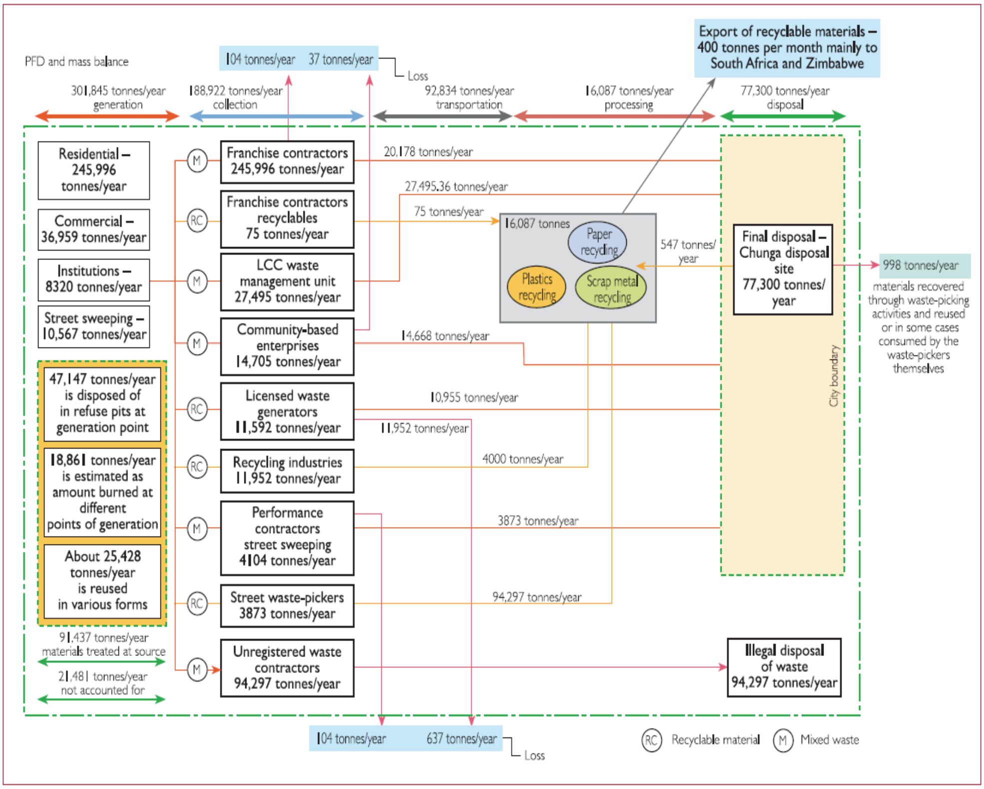

Fig. 1. PDF representing the situation of waste disposal in Zambia (Anand, 2010)

In dumpsite waste separation officers work in very poor health and hygiene conditions, which often stand side by side with members of the population, searching useful materials. These habits characterize all the inhabitants even those of the suburbs of Lusaka, as are the members of the Koinonia community, the place where the project reported in this memory started. In fact, the project moves just by the need to involve and educate people on the subject of wastes and to create a differentiated waste management system in partnership with the community, which could also be versatile and adaptable to other realities in Zambia and in the developing countries in general.

2. Experimental

2.1. Case study

The community of Koinonia, located in Lusaka province, in Chilanga district, at about 15 km from the center of the capital, is a community of life, founded in 1982 by Father Kizito, supported by the NGO Amani since 2000 with whom collaborated in the realization of some projects. The total area owned by the community covers an area of 100 acres, equivalent to 40.5 hectares, of which 8 hectares are the living quarters of the community and the remaining 32.5 correspond to the agricultural area, which is cultivated in most of part with corn, and includes the horticultural areas and some cultivation of moringa. The village consists of ten residential houses, the Mthunzi center for street children, a medical clinic, a school, a library, a theatre, a poultry and a piggery. There is also a joiner, a computer lab, a football pitch and a structure, recently completed, which should be used as a school of agriculture. The overall prospective is to create social entrepreneurship activities that could make, in the long terms, the community and the project sustainable and independent.

The resident people are one hundred and fifty, but there are variations during the week, until to have two hundred people, in public holydays. The resident population is itself divided into 10 households with 10 people each, plus 50/60 boys housed permanently at the Mthunzi center. The increase of people is due to the presence of the boys studying in other cities (borders) and children of the neighboring communities that participate weekly to community activities of Koinonia (home based). The community is self-managed throughout its administration. They elect every four years a president that coordinates the management of the community and chairs the weekly meeting of the Executive Committee, composed of five members (president, secretary, treasurer and two counselors). The support of ONG Amani for Africa is not only economical for the financing and maintenance of the facilities and activities, but also managerial and coordinative thanks to the presence of a reference person for many months a year, which works alongside the community.

The community of Koinonia, though on small-scale, represents a symbolic example of the general state of waste management in Zambia.

2.2. Waste management

In Koinonia, the population adopted the same method for the waste disposal, by silting and uncontrolled incineration, with consequences often harmful to the quality of air, soil and groundwater, resource from the entire community. Waste management included the use of storage pits, not far from the homes, where all members of the community collected wastes indiscriminately. Furthermore, the waste was abandoned all around the village, including horticultural areas (Fig. 2).

Fig. 2. Photographs emblematic of the situation in Koinonia. The first is a storage pit and the second are wastes abandoned

The necessity of a practical and applicable solution in a short time was the basis of the project. Daily habits of families were observed in order to identify the types of waste produced within the community and consider the potential for recycling of the materials according to the most appropriate collection plan. At the same time, some community members were involved to enable them to know and understand the dangers and the damage of these habits. The risks arising from the uncontrolled burning of waste for both health and the environment were then outlined. Moreover, there was a search for local companies operating in the recycling industry and a survey about which waste categories were recyclable and therefore exploitable by the community. There were evaluated the modes of transports and the distances to be covered to reach the above-mentioned companies. Finally the managers of the landfill were contacted in order to obtain information about the types of waste transferable on to the site, the mode of transport and the costs of disposing.

It was clear from the researches that:

- the perception of environmental and health risks to the community is negligible;
- the knowledge on waste, their characteristics and economic value is limited;
- wastes derive from the normal daily activities of the community, from the kitchen to work activities related to the use of machinery for cultivation, up to personal hygiene. The wastes are constituted by biodegradable organic material, paper material, packaging, plastic materials, glass containers, clothing and footwear, aluminum tins, chemical products for the hygiene and the coating, inert ceramic materials and waste resulting from the management of the green areas and allotments;
- the recycling of materials is carried out by private companies and the plastic material was a result the more profitable to recycle;
- the disposal of general waste should be made to the Kafue landfill, according to the authorities. This landfill is at south of the city, far away from the community so prohibitive for the cost of transport. However, it is possible to apply for permission to use of the landfill Chunga, far few kilometers from Koinonia and therefore more advantageous;
- the Chunga dumpsite is for urban waste, ensure the collection of waste if the quantities are sufficient to justify the use of special transport, and requires the payment of 140 Kwacha, for an individual waste dumping.

3. Results and discussion

The project starts from the assumption that the success itself arises from the awareness that all actors share the choices and make it their own, so that the project is a shared thought and an imposition of a few (Edema et al., 2012). Knowing the importance of community involvement, it has been planned activities practical and training. For example, have been organized meetings to propose a new plan for the waste management and therefore encourage the sharing in the community, as well as meeting between technical knowledge and the local intrinsic knowledge to optimize the recovery plan. The separation of wastes has been explained to the boys of Mthunzi center by simple and funny games.

The new collection plan for the community is based on the vision of a holistic management system that minimizes waste production, taking advantage of the circularity that is established between the animal world, nature and the human being in order to create an organization that promotes the symbiosis of the three environmental compartments. Organic waste from the kitchen activities have been identified as a source for feeding pigs, whose waste is regularly collected and used for fertilization of vegetable crops. In addition, significant amounts of green waste from the pruning and maintenance of the gardens, with non-edible organic waste for pigs, have been defined as secondary raw materials, useful for the production of compost. This compost is useful for nourish the crops of vegetables that complete then the circle for managing the biodegradable organic waste, inside the community. The non-degradable waste management is instead planned and organized on the basis of public and private facilities in the area. The collection plan is designed in two successive steps in order to make gradual the transition to a differentiated waste management:

- Step 1: Collection of organic waste, compost, plastic bottles, mixed waste;

- Step 2: Collection of organic waste, compost, plastic bottles, paper, glass, ferrous materials, aggregates, plastics.

Depending on the type of waste, it has been necessary to think solutions for a simple collection system that would meet the demands of families and the approval of people. For this reason, the collection is organized in a mixed system: Proximity and door to door.

Specifically, bio-waste and plastic bottles are collected through a door by door collection system, unlike relating to mixed waste and the production of compost for which were individuated special collection points. Regard to mixed waste, has been set up four collection points, each with a container of 0.25 m^3, located at strategic positions for the community, representative for the same user base of 40 people. By means of a collection system provided every two day, the four containers are emptied into a main container in a collection center located in the square in front of the poultry (only fenced area). Once filled, it will be transported by the trailer available and disposed of at the landfill site.

About the door by door collection, the community has established a specialized team consisting of three persons involved in the control of the correct differentiation and the withdrawal of waste. Each household has been provided with a specific container for biodegradable organic waste, and a container for the collection of plastic bottles (Fig. 3).

Fig. 3. Containers for the of plastic and organic waste at a community family

Organic waste, for reasons of climate and high perishability, they are transported daily from the piggery of the community, after the differentiation of non- edible organic waste which are destined to production of compost. The plastic bottles are transferred weekly to the single container of a ton at the collection center, as well as for the mixed waste (Fig. 4).

The introduction of this system began with the application of a " year zero ", some days in which were closed all the storage pits, collected all the waste left on the ground, with the final abandonment of the practice of ' incineration. It has also been called a trial period of one year, with monitoring and optimization of the first phase, trying to organize the second phase with additional information.

Fig. 4. Images of the station of collection. To the right, the bags for the collection of plastic bottles; left, the bags of mixed waste and a working collection team operator

4. Conclusions

The situation of the Koinonia community reflects the general reality of Zambia. The condition was very precarious and dangerous and in need of an intervention. Population health and the environment were at risk because of the negative habits and the limited knowledge of the population.

The project has radically changed the habits of the community, so a period of adjustment has been necessary to get used to the new management. Nevertheless, the project has achieved almost immediately the approval and commitment of the whole community. In the first period, the team has been instructed in the proper work. The monitoring has found several errors or doubts in the separation of waste, especially among compost and organic pet. In this way, these errors were correct and the collection was efficiently improved. This described is the preliminary intervention planned and initiated at the community of Koinonia for a trial period of one calendar year starting from October 2015.

It is evident that sometimes the engineers must leave behind the numbers, because in the world there are places where the response to the working of a project derives from the people involved rather than charts and tables built on databases that are difficult to find.

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CONTAMINATED MARINE SEDIMENTS: WASTE OR RESOURCE? AN OVERVIEW OF TREATMENT TECHNOLOGIES*

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Abstract

The continuous stream of sediments dredged, from harbors and waterways, is a considerable environmental issue recognized worldwide. Every year about 200 million of m^3 of sediments are dredged only in Europe, over half contaminated and expensive to dispose of. In a vision of sustainability and of circular economy, the proper management of such sediments plays an important role. Therefore, the aim of this study was to critically revise the remediation technologies currently adopted for the suitable reuse, recycling and recovery of contaminated marine sediments (CMS). First of all, the description of the common technologies for the complete removal and/or immobilization of pollutants was realized. Subsequently, potentially technical solutions for marine sediments reuse were discussed. Such re-use or recycling is in line with the European Waste Hierarchy and generates positive environmental impacts. Finally, the research proposes a new approach to the "sediment issue", an eco-sustainable management where the contaminated marine sediments are viewed as a useful resource.

Keywords: beneficial reuse, contaminated marine sediments, treatment technologies

1. Introduction

Sediments are dredged, from harbors and waterways, for maintenance of navigation, environmental remediation, or both. Every year about 200 million of m3 of sediments are dredged only in Europe, over half contaminated and expensive to dispose of (SedNet, 2011). In fact, contaminated dredged sediments are considered as waste materials and only less than 5% of these is being treated for ultimate beneficial re-use, at present.

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Until the early 90s, in most cases the dredged sediments were disposed of at deeper seas or deposited on land (the less expensive method). Fortunately, this tendency has been changing in recent years. Conventions for the protection of the marine environment and some new European regulations concerning waste have been introduced to set guidelines for a proper disposal of dredged material into the sea and to avoid the traditional perception of these contaminated materials as waste, considering them as a commercially exploitable resource. In fact, the Protocol of the London Convention (IMO, 2009), for disposal at sea, and the European Waste Framework Directives (EU Directive, 2008), for disposal on land, demand sustainable management of sediments and waste minimization.

There is a growing impetus for considering dredged sediments as a resource rather than a waste. However, whether a beneficial use is possible, the Contaminated Marine Sediments (CMS) should be treated. In fact, the re-use of contaminated materials is possible when these possesses technical characteristics appropriate for its specific utilization and are environmentally acceptable in accordance to end-of-waste criteria.

This report proposes a critically review of remediation technologies currently adopted for sustainable management of CMS. Recent developments in this area were assessed through a literature search, and promising technologies were identified.

2. Contaminated marine sediments treatment technologies

Different treatment technologies are well known by worldwide experiences of sustainable management to CMS. In this section, some of these technologies are presented, with special attention to new emerging technologies employed in relevant case studies to attend the reuse goals (technical characteristics and environmentally acceptable).

2.1. Landfarming

Landfarming treatment is a full-scale technology in which the soil, climate, and biological activity interact to degrade, transform, and immobilize the contaminants.

Contaminated sediments are spread over lined beds in the upper soil zone or in biotreatment cells, and regularly turned over or tilled to aerate the mixture. The conditions of the sediments are controlled to optimize the rate of contaminant degradation. These include: moisture content (by irrigation or spraying), aeration (by tilling soil with predetermined frequency, the soil is mixed and aerated), pH (buffered near to neutral pH through adding crushed limestone or agricultural lime) and the addition of other amendments such as soil bulking agents and nutrients.

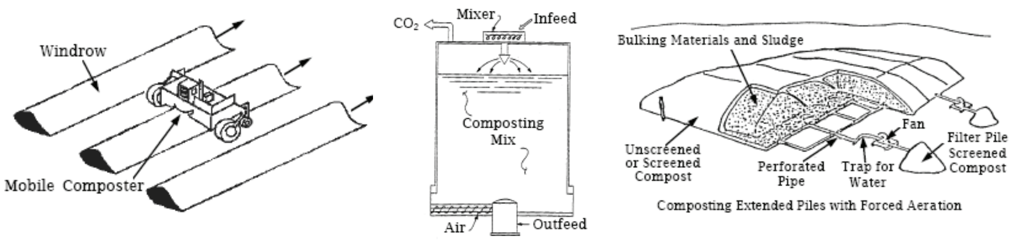
A landfarming treatment site should be managed correctly to prevent both on-site and off-site problems with ground water, surface water, air, or food chain contamination. Sufficient monitoring and environmental protections are required (NSW EPA, 2014).

2.2. Composting

Composting is a controlled biological process by which organic contaminants are broken down by indigenous microorganisms (under both aerobic and anaerobic conditions) to innocuous by-products, such as carbon dioxide and water. Maximum degradation efficiency is achieved through maintaining of thermophilic conditions (54 to 65 °C) and monitoring of water, oxygen, and nutrients.

Available composting techniques include: (i) aerated pile, where compost is formed into piles and aerated with blowers; (ii) windrowing, here compost is heaped in long piles known as windrows and periodically mixed with mobile equipment, such as a digger; (iii) closed reactor designs where compost is put into a reactor vessel where it is mixed and aerated (US ACE, 2014). These are shown in Fig. 1.

Volatilization of contaminants may be a concern during composting and may require controls, such as enclosures or air management system.



a) **b)** **c)**

Fig. 1. Composting techniques: (a) Windrow, (b) Closed reactor and (c) Aerated Static Pile. (US ACE, 2014)

2.3. Solidification/Stabilization

Chemical fixation and solidification, also commonly referred to as solidification/stabilization treatment (S/S), is a widely-used treatment process for the management and disposal of a broad range of waste materials, even those classified as hazardous.

The S/S techniques is based on adding chemical compounds to dredged material with two objectives: (i) chemical immobilization of the contaminants to reduce the leachability and bioavailability; (ii) stabilization to use the product as a construction material. This technique does not remove the contaminants from the dredged material, but they are transformed into a less mobile, and therefore less harmful species. In general, the target contaminant group for s/s treatment is mainly inorganic (Bortone and Palumbo, 2007).

The simplest form of treatment is with Portland cement. Further materials can be added, such as calcium aluminates, fly ashes, bentonite or other clays, phosphates, lime, oil residue and silicate fume. The additive used depends on the type of contaminants, water content and characteristics of the dredged material.

In the last years, innovative binders and mixtures (other than, or in combination with, cement) have been tested in pilot sites and in full scale, showing a significantly reduced of leachability of organics from stabilized contaminated sediment.

2.4. Sediments washing

Sediments washing is an effective technique to remove (by dissolving or suspending them in a water-based solution) a wide range of organic and inorganic contaminants from sediments.

The process involves some steps: a preliminary treatment for separation of metal parts (by magnetic belts), separation of the clay and silt particles from the sand fraction (using hydrocyclones and upstream classification), unit of gravel washing (coarse-fraction is cleaned by scrubbing and counter flow washing), sludge treatment (the sludge-fraction is further dewatered in a filter press) and process water treatment.

Surfactants, organic solvents, acids and bases or chelating agents may be used with water to effect separation of some contaminants. For example, the use of surfactants may be successful for removing organic compounds from sandy sediments.

One of the most promising sediment washing treatment using the BioGenesis technology (Fig. 2). The basic treatment train involve the separating the particles using high energy, mixing with oxidants, and finally separating the solids into organic and mineral fractions. The completely disaggregated mineral fractions are then mixed with suitable clean organic amendments, to create clean manufactured topsoil with the necessary nutrients added to promote plant growth. The organic and ultra-fine fractions, as well as the effluent, must be disposed of or treated off site.

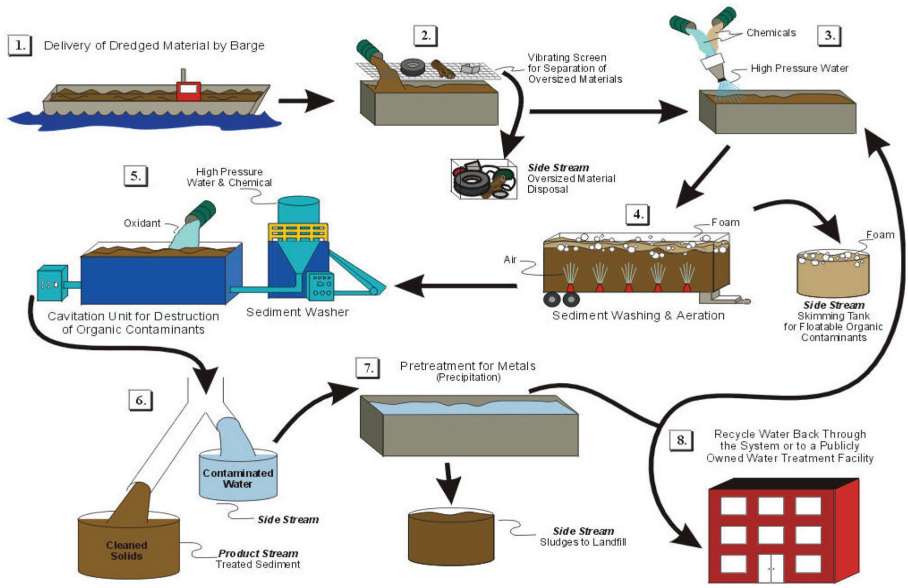


Fig. 2. BioGenesis sediment washing process (Stern et al., 2007)

2.4. Thermal desorption

Thermal desorption can be applied to treat sediments containing contaminants that can be volatized at temperatures below 650 °C (e.g. mineral oil, mono-aromates, PAHs, PCBs, cyanides, chlorinated solvents and TBT).

The most promising thermal processes utilize rotary kiln technology, which operates at temperatures of over 2,000 °C. The contaminants present in the material that enters the drum are volatilized at the working temperature and transferred into the gas phase. The processed and cleaned material is leaving the installation through a discharge system with water nozzles to cool it down and preventing dust formation. The gases leaving the rotary drum are treated by a system that includes a multicyclone separator, an oxidizer, an air-to air cooling chamber, baghouse and optional an acid gas scrubber (Bortone and Palumbo, 2007).

In general pretreatment is necessary. Dewatering methods should be used to reduce the moisture content of sediment before it enters a rotary kiln. Some thermal processes may require the separation of the sand fraction and washing with fresh water of sediments to remove salinity (US ACE, 2014).

2.5. Vitrification

Vitrification is an emerging technology that uses electricity to heat and destroy organic compounds and immobilize inorganic contaminants on sediments.

A typical unit consists of a reaction chamber divided into two sections: the upper section, from which it is introduces the feed material, containing gases and pyrolysis products, while the lower section contains a two-layer molten zone for the metal and siliceous components of the sediments.

Materials are vitrified by high electrical currents. Electrodes are inserts into sediments and a large current is applied, resulting in rapid heating of the solids and melted of the siliceous components. The product is a solid, glass-like material that is very resistant to leaching. Temperatures of about 1600 °C are typically achieved (US ACE, 2014).

In general, the technology requires extensive pre-processing of the dredged material. Salts must be removed from the sediment before of the vitrification, since some of them are volatilized during the melting process and provide problems corrosion of the system. Furthermore, the pretreatment process includes dewatering of the sediment to remove water prior to injection into the melting chamber, avoiding increasing costs with electrical power.

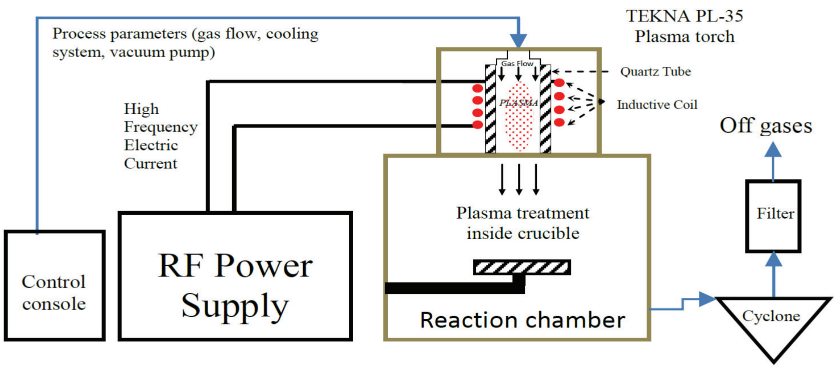


Fig. 3. Schematic illustration of the inductive plasma reactor system (Colombo et al., 2012)

3. Results and discussion

This paragraph provides information regarding potential alternatives of management of CMS using decontamination technologies. Relevant case studies, result from a literatures survey about the treatment technologies currently adopted for the sustainable reuse, recycling and recovery of CMS, are reported in Table 1.

The obtained results showed how, biological treatments have been used only in treating of marine sediments contaminated by organic compounds. For all biological treatments, there is as a rule of thumb: the greater the molecular weight (and the more rings with a PAH), the slower the degradation rate. Therefore, increases the time to complete remediation. For intensive land-farming is necessary a period of at least 1-2 years. Instead, passive landfarming may last several decades. As for other biological treatments, removal efficiency is dependent upon many factors, the most important is inorganic contaminant concentration.

Landfarming is considered as a promising technology (Harmsen et al., 2007) to remediate PAHs and mineral oil contaminated sediments, because provides an excellent opportunity to produce non-fossil fuel. Trees Fast-growing (willow and poplar) can be grown and harvested with regular cycle to produce usable wood biomass for a range of applications. This practice is called Short Rotation Coppice (SRC) and maximizes the social, economic and environmental benefits of reuse and remediation of sediments (Paulson et al., 2003). Several full-scale operations have been utilized.

Table 1. Summary of relevant case studies. Re-use is the use of material in same form (though cleaning or separation for re-use is acceptable); Recycling is the use of material in a different form after processing. Can be beneficial use, but materials changed (bricks, aggregate, etc.); Recovery of energy, biomass or other materials

Treatment	*Target contaminants*	*Scale*	*Processing*	*Product*	*References*
Solidification/Stabilization	Metals	Laboratory	Recycling	Cemented mortars	Couvidat et al., 2016
Solidification/Stabilization	Metals	Laboratory	Recycling	Fill material and blocks	Wang et al., 2015
Solidification/Stabilization	Metals	Laboratory	Recycling	Fill materia	Tang et al., 2015
Thermal pretreatment and S/S	Metals	Laboratory	Recycling	Fill material and bearing	Wang et al., 2015
Solidification/Stabilization	Metals	Laboratory and pilot	Recycling	Granular material	Achour et al., 2014
Sediment Washing + Vitrification	Hydrocarbons	Pilot	Recovery	Fill material and silicon	Magagnini et al. 2013
Phytotreatment processes	Hydrocarbons	Pilot	Recycling	Recycled land	Masciandaro et al., 2012
S/S + Thermal Desorption	Hydrocarbons	Laboratory	Recycling	Fine aggregates	Careghini et al., 2010
S/S + Thermal Desorption	Mercury and hydrocarbons	Laboratory	Recycling	Fine aggregates	Bonomo et al., 2009
Vitrification	Metals and hydrocarbons	Laboratory	Recovery	Silicon	Colombo et al., 2009
Landfarming	PAHs and mineral oil	Pilot	Recovery	Biomass for bioenergy	Harmsen et al., 2007
Stabilisation + Thermal Desorption	Metals	Laboratory	Recycling	Cement-based materials	Agostini et al., 2007
Stabilisation + Thermal Desorption	Metals	Laboratory	Recycling	Clay bricks	Zoubeir et al., 2007
Sediment washing	PAHs	Pilot	Re-use	Manufactured soil	Stern et al., 2007
Composting	PAHs and PCBs	Pilot	Re-use	Recycled land	US ACE, 2014
Composting	PAHs and PCBs	Pilot	Re-use	Recycled land	US ACE, 2014
Solidification/Stabilization	Metal	Pilot	Recycling	Fine aggregates	Wiley et al., 2002

The most studies shown in Table 1 are referred to S/S treatments. The fact that S/S has been so extensively utilized for management of CMS is testament to the effectiveness of the technology in terms of structural properties of dredged material and environmental compatibly. Use of S/S treatments to beneficial reuse of CMS appears to be well demonstrated for civil engineering applications. However, performance of this treatment is difficult to predict because of the complex interactions between organic contaminants and binding agents. For this reason, often S/S treatments are associated with thermal treatments.

The obtained results show as sediment washing is a physical/chemical treatment that can be applied to organic and inorganic contaminants. Contaminant reduction varies and depends on the sediment matrix, total organic carbon content, contaminant concentrations, contaminant type(s) and extent of treatment. Removal rates are typically in the 60 to 80% range for fine materials, with higher rates achievable on coarser grain fractions.

With this treatment is possible the separation of fine fraction (the most contaminated) to produce sandy material sufficiently decontaminated for beneficial reuse.

The public supports sediment washing due to low environmental impact, low emissions, beneficial products, and competitive costs at a commercial-scale level. Thermal technologies have been shown to be effective in destruction of organic contaminants and immobilization of metals. The most promising thermal treatments use technologies of the rotary kiln and the plasma torch. Though thermal technologies have proved highly successful from a strictly decontamination standpoint, from a logistical standpoint, kilns are expensive and difficult to realized (due to air pollution concerns) and prone to breakdowns that reduce reliability.

Thermal desorption plants are in operation at full scale in several countries (e.g. Belgium, The Netherlands, Germany). Proponents of rotary kiln technology suggest that costs for sediment treatment might be reduced by adding electronic waste, waste solvents/ oils, or tires to the input stream. Small-scale tests indicated that adding other waste streams does not negatively impact the quality of the final product. Unfortunately, adding other waste streams does reduce the processing rate of dredged material. Compensating for this requires additional kilns, which would further increase capital costs. Another way to lower processing costs without sacrificing processing capacity for dredged material might be to scavenge waste heat from the process and use it to generate electricity (cogeneration).

Plasma technology offers a great number of unique advantages to decontaminate marine sediments and to obtain a final recyclable product: (i) the high temperatures ($T \geq 104$ K) help to decompose all organic contaminants presented, encapsulating heavy metals and mineral phases into a stable glassy matrix, (ii) the use of electric energy to generate the plasma discharge allows to decreasing the gas flow produced, facilitating control and treatment of emission and giving the possibility of generating saleable products (Colombo et al., 2009)

4. Conclusion

Among the various technologies stated in this review, S/S remains the most widely used technology for beneficial reuse of CMS. However, this technique has certain drawbacks such as its limited application for organic contaminants.

Although thermal treatments are superior from decontamination standpoint, these techniques are not preferred. Compared with other conventional treatments, there is basic apprehension about construction of thermal plants. Equipment for pollution controls must be state-of-the-art to insure regulatory compliance and instill public acceptance/confidence.

Future research is needed to study the combined effect of two or more technologies or to develop an efficient innovative technology that is eco-friendly, affordable, scalable and easily available.

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A WEB-APP FOR IMPLEMENTING A 'CARBON FOOTPRINT CALCULATOR' FOR SMART WASTE MANAGEMENT SYSTEMS*

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Abstract

Nowadays, being "smart" is fundamental to achieve sustainable objectives and targets set by the European Union. Providing smartness to waste management systems deserves considerable attention. Indeed, it is a sector that has experienced remarkable organizational and technological progresses. Much more can be done to involve smart actors who cooperate in decision-making on public or social services. Stakeholders include also citizens whose behaviours strongly affect system performance. Consistently, in the frame of the European project "RES NOVAE", the authors developed a web-app named "Smart Waste - Carbon Footprint Calculator (SW-CFC)". SW-CFC is conceived to evaluate and monitor direct and avoided emissions of municipal solid waste management systems. The web-app has two different users profile: public decision makers and citizens. The public decision-makers can use the app to assess the carbon footprint of the *'status quo'* systems and to evaluate the impact of potential changes in different technical and organizational choices. On the other hand, the use of SW-CFC can stimulate citizens' consciousness leading their actions on right collection practice. By a short survey section, the app calculates and shows citizen' green attitudes and habits in terms of avoided emissions. Due to the formative and informative purpose of the app, the increase of social involvement is an expected result too.

Keywords: carbon footprint; smart city; waste

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1. Introduction

Rethinking the urban spaces focusing on citizens' need, streamlining resources and making more efficient services and utilities play a key role in the achievement of a city' sustainable development. Consistently, the theme of the 'Smart City' is the center of an intense debate. According to the definition of (Batty et al., 2012) "*Cities are becoming smart not only in the way we can automate routine functions serving individual persons, buildings, traffic systems but in ways that enable us to monitor, understand, analyse and plan the city to improve the efficiency, equity and quality of life for its citizens in real time*". Indeed, Smart City development implies continuous innovations not only supplying 'smart objects or smart services' but also ensuring closer involvement of citizens in governance processes and closer monitoring of needs and services (CDP, 2013).

Among the different urban action areas, the waste management systems deserve considerable attention. Undoubtedly, this sector has experienced a steady progress in recent years. It mainly relates technical and organizational innovative solutions from waste collection to waste treatments and valorisation. Indeed, the scientific panorama widely faces waste management issues tailored to technical (Dutta et al., 2007; Massaro et al., 2015), economic (Gnoni et al., 2008) and environmental (Caponio et al., 2015; Gentil et al., 2010) aspects to both support decision making process and to assess systems performance. Greater efforts can be done to involve 'smart actors' who cooperate in decision-making on public or social services. Stakeholders include citizens whose behaviours strongly affect system performance. Consistently, in the frame of the European project "RES NOVAE", the authors developed a web-app named "Smart Waste - Carbon Footprint Calculator (SW-CFC)". SW-CFC is conceived to evaluate and to monitor direct and avoided emissions of municipal solid waste management systems. Giving a clue of other examples allows to gather the core of the topic and to capture the innovative aspects of the proposed solution.

The U.S. Environmental Protection Agency (EPA) developed the Waste Reduction Model (WARM) to assess savings in greenhouse gas (GHG) emission resulting from waste management practices. The tools works on a collection system already defined. To allow the GHGs emissions evaluation, the users enter the amount of waste flows handled for the different treatment options and by means of material-specific emission factors for each management practice, GHGs emissions and energy savings are calculated. Furthermore, in the context of European project "Zero Waste", a carbon footprint tool for municipal solid waste management is developed (Sevignè et al., 2013). The calculator is addressed to solid waste managers, academics and consultants. According to the IPCC guidelines, the calculator allows to inventory and to monitor GHGs emissions starting from the total amount of waste generated, waste composition, waste fraction collected, biogas captured in landfill. In contrast to those examples, the web-app proposed stands as a service planning tool as well as an environmental assessment tool for a pivotal phase, which is that of the municipal waste collection. In Section 2, the main objectives of the developed app are highlights. Materials and methods for the planning and the carbon footprint evaluation are provided in Section 3. The description of the SW-CFC is in Section 4, while conclusions are in Section 5.

2. Objectives

The web-app 'Smart Waste - Carbon Footprint Calculator' represents an innovative smart solution to monitor and to evaluate the carbon footprint resulting from the collection of municipal solid waste. Due to the aim to involve all the different actors and stakeholders, the web-app is designed with two different users' profile: public decision makers and citizens. The public decision-makers can use the app to assess the carbon footprint of the 'status quo' systems and to evaluate the impact of potential changes in different technical and organizational choices for the waste collection in terms on both emissions and level of separated collection achieved. On the other hand, the use of SW-CFC can stimulate citizens' consciousness leading their actions on right collection practice. Indeed, despite a willingness to make personal behavior changes to reduce their climate impact, individual may lack the knowledge to make effective choices (Kim et al., 2009). For this reason, by a short survey section, the app calculates and shows citizen' green attitudes and habits in terms of avoided emissions.

3. Materials and methods of the Carbon Footprint Calculator

The carbon footprint measures the total greenhouse gas emissions caused directly and indirectly by a person, an organization, an event or a product and it is expressed in terms of CO_{2eq}.

Variables object of the service planning by a local decision makers have been identified to evaluate the carbon footprint of the municipal waste collection system. Parameters affected by peculiarities of the application area or of the collection service have to be considered too. It is referred to area' urban fabric constraints or to regulatory and technical constraints.

An overview of the variables identified and relative influences on the carbon footprint are shown in Fig. 1.

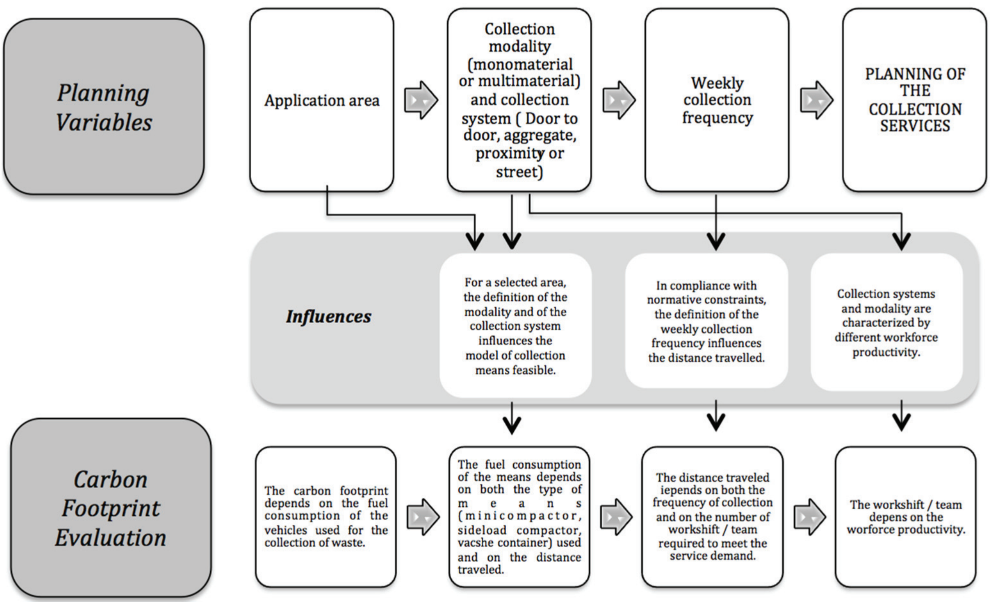

Fig. 1. Decision-making process and influences on the assessment of the Carbon Footprint

For the GHGs emissions assessment, the IPCC guidelines are followed. Basically, emissions depend on the distance travelled to ensure the collection service demand in a defined timeline. Consistently, a '*distance-based approach'* (IPCC, 2006) for estimating CO_{2eq} emissions for each type of vehicle, payload and average speed is used. Going further into details, the total distance travelled to fulfill collection service demand depends on the frequency of collection as well as on the number of work-shifts for each collection route and on the average distance covered in each collection route. The number of work-shifts depends on the productivity of the collection work-team employed that is in turn influenced by the waste fraction collected and by both collection grouping and system adopted. Instead, the average distance travelled depends on the type of mean employed. For each waste fraction, emissions are calculated as in Eq. (1).

$$CF_{collection} = EF \cdot W \cdot \bar{d} \cdot f \quad (1)$$

where:
$CF_{collection}$ = Carbon Footprint for waste collection in a set timeline [t_{CO2eq}/ timeline];
EF = emission factor of the collection mean [t_{CO2eq}/ km];
W = number of work-shift for each collection routes [work-shift/ collection route];
$\bar{d}$ = average distance travelled in a work-shift [km/work-shift];
f = collection frequency [collection route/timeline].

Readers can refer to (D'Alessandro et al., 2012; Caponio et al., 2015) for collection systems and grouping systems features such as collection efficiencies, workforce productivity, and means characteristics (payload, average distance). Emissions factor adopted in the tool for mini-compactor and side/rear load compactor are provided by (Inemar, 2013).

4. Web-app "Smart Waste - Carbon Footprint Calculator"

Hereinafter, a detailed description of the app is provided exploiting actual screens of the tool. The app will be available for free to the users. As aforementioned, the app is build up in the frame of the European project 'RES NOVAE' for Bari Smart City. The tool operates at municipal level with a deeply insight at city's district level. Nevertheless it can be easily scaled up to other city or to regional level. The app' home page is shown in Fig.2. As it can be seen, Section B of Fig. 2 relates the expert user profile while the Section C of Fig.2 relates the citizen user profile. The two user profiles have been developed with different functions and purposes, but with the common goal to monitor the environmental impact and to raise awareness on sustainable development.

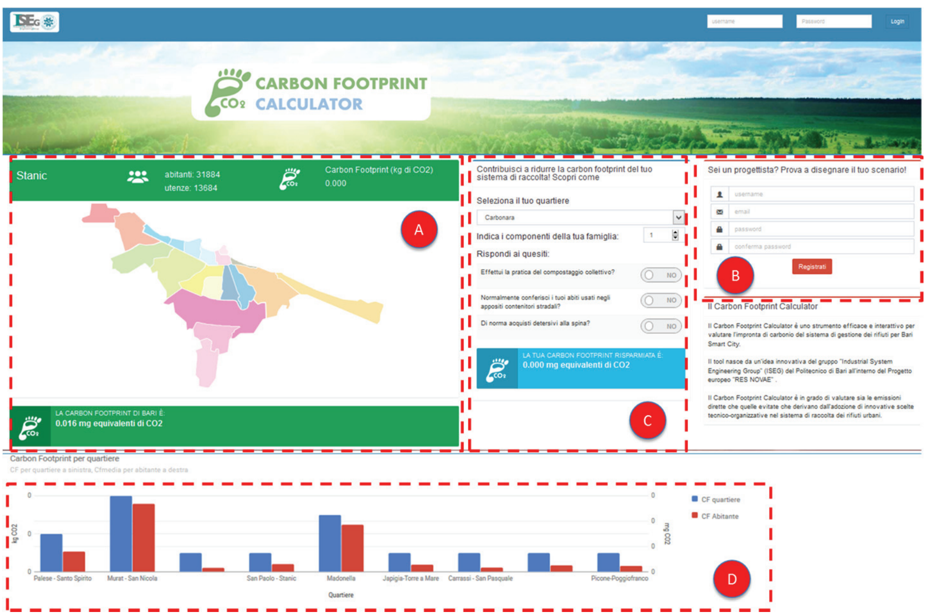

Fig. 2. Home page of 'Smart Waste - Carbon Footprint Calculator'

The Section A Fig. 2 represents the city' map with details of districts and different areas inside the district (characterized by nuances of the same color). A simple scroll on that map allows showing the annual carbon footprint for the different areas due the current collection service in place. For an easier comparison among the different districts, results in terms of (t_{CO2eq}/inhabitants) and (t_{CO2eq}/ area) are also shown in a histogram, as evident in the Section D of Fig. 2.

4.1. App Interface for public decision makers

The web-app will allow the public decision maker to assess the carbon footprint attributable to both the waste collection system already implemented and, through scenario analysis, that caused by innovative technical and organizational solutions for the recyclable and unrecyclable waste flows collection.

The steps followed by the users are shown below. They relate the characteristic elements to identify the interdependent and/or complementary operating modalities that affect the environmental impact of the collection area.

A user registration mechanism is foreseen before proceeding with the assessments (Fig. 2- Section B). The decision-making process starts with the definition of the area. The planning collection service interface is shown in Fig. 3. For each area, in the top left are listed demographic data like the number of inhabitants and the number of families (defined *'users'* from the point of view of the collection) as well as the annual waste production per capita.

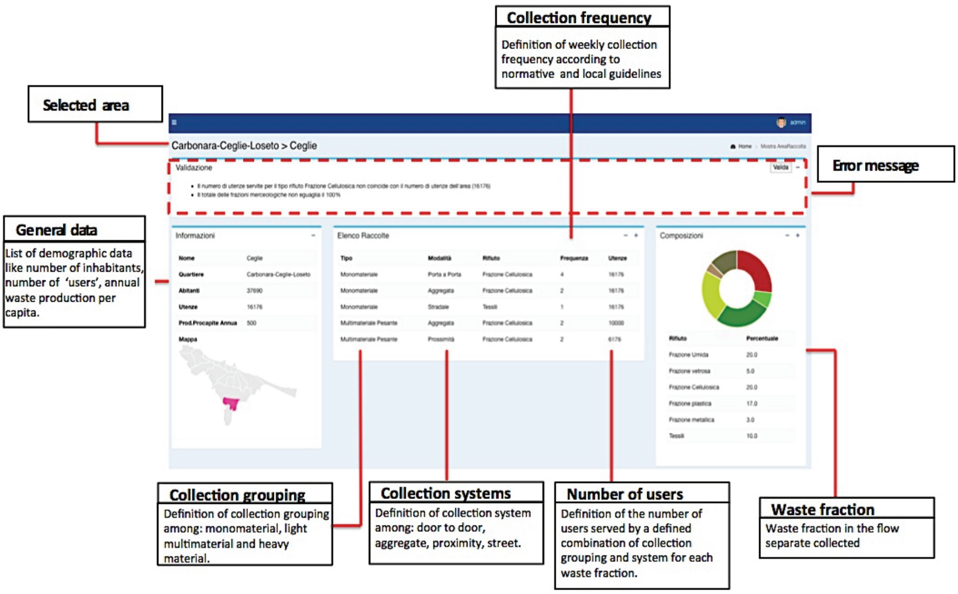

Fig.3. Planning collection service interface

The waste fractions considered in the model are the follow: organic, paper and cardboard, plastics, ferrous and aluminum cans, glass, textile, wood and others. Three types of collection grouping are foreseen in the tool: monomaterial, light multimaterial, heavy multimaterial. The monomaterial grouping system allows each fraction to be collected in a separate flow. Plastics, ferrous and aluminum cans have to be collected together in the light multimaterial. Otherwise, plastics, ferrous and aluminum cans with paper and cardboard have to be collected together in the heavy multimaterial. Four types of collection systems are foreseen in the tool: door to door, aggregate, proximity and street. The definition of the weekly collection frequency occurs in compliance with constraints set by normative regulations and guidelines.

To plan the collection service, the public decision maker is required to enter for each waste fraction the number of users served with a defined grouping system and collection system with a particular weekly collection frequency. In this phase, the planning experience plays a key role. Indeed, city' urban features have a remarkable influence on collection systems. The experience and the awareness of urban fabric restrictions allow for defining a collection service fitting with the characteristics and the needs of the interest area. To help the planning, the maximum number of users employable is added for each collection system. Regard to collection means, the choice of the type of means by the user will be bound to the type of collection system previously adopted. Downstream the definition of the collection service, it is possible to quantify the flows intercepted in the separate collection loop. Indeed it should be pointed out that for every waste fraction, each combination of grouping and collection system is characterized by a specific value of collection efficiency. Therefore, the composition of waste collected is plotted in the pie chart (Fig. 3) and the separate collection index is displayed too, as in Fig. 4.

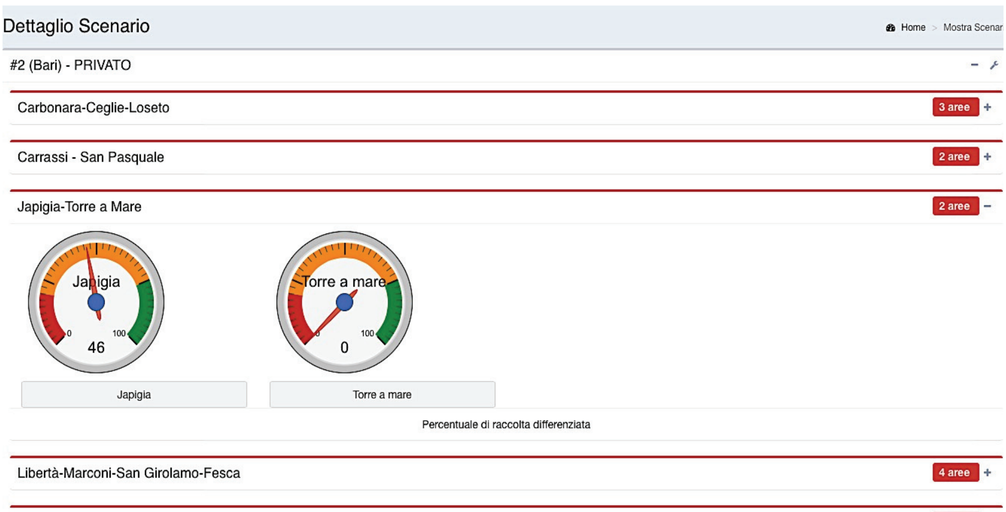

Fig. 4. Planning result: separate collection index

Proper error messages will be displayed to signal failures in fulfillment service demand or failure in the quantification of waste collected. The outcome of the decision-making process will be displayed in terms of annual CO_{2eq} emissions.

4.2. App Interface for citizens

For the citizen profile the assessment procedure is simplified. Coherently, the procedure is consistent with the training, information, and increased social participation purposes. Indeed, no registration is required.

Once the user select the area from the home page (Fig. 2 section A), the app automatically loads the collection system implemented in the district. The results displayed represent the annual GHGs emissions due to the collection in such area. Calculating the avoided individual carbon footprint due to green attitudes and habits represents the interactive section of the 'citizen menu' (Fig. 2-Section C). For the individual carbon footprint evaluation, the user is required to select the home area and to enter the effective number of household member. To increase the awareness of behaviors affecting waste management environmental impact, a short survey is proposed (Fig. 5).

Green attitudes and habits investigated are: home composting for the organic fraction, the use of detergents on tap to reuse the plastic bottle and inserting textiles into appropriate receptacle. Results are shown in terms of individual avoided carbon footprint (t_{CO2eq}/inh year). Increasing citizen participation as well as improving the citizen' awareness of the effects that an individual behavior has on the collective well-being and on the environment, are the main expected benefits.

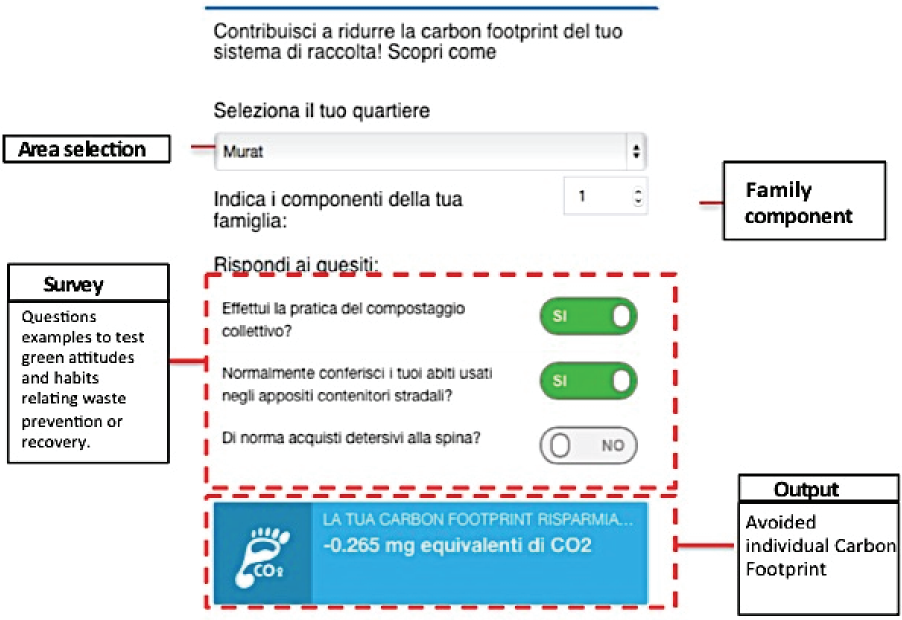

Fig.5. Citizen interface to evaluate avoided carbon footprint

5. Concluding remarks

Starting from KPI of waste production and collection, the 'Smart Waste-Carbon Footprint Calculator' will enable citizens and decision makers to assess the carbon footprint of the integrated system taking into account both the virtuous citizens behaviors and the technical and organizational decisions of policy makers.

Indeed, the public decision maker is able to jointly assess the carbon footprint due to the collection service already implemented and to investigate, through scenario analysis, the effects on the carbon footprint due to innovative technical and organizational collection choices.

On the other hand, the use of SW-CFC can stimulate citizens' consciousness leading their actions on right collection practice. By a short survey section, the app calculates and shows citizen' green attitudes and habits in terms of avoided emissions. The awareness of their impact in terms of emissions will enable individuals to understand the contribution that a virtuous behavior on societal wellbeing.

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