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# Procedia Environmental Science, Engineering and Management

23rd International Trade Fair of Material & Energy Recovery and Sustainable Development, ECOMONDO, 5th-8th November, 2019, Rimini, Italy

Selected papers (1)

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*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.

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# GUEST EDITOR

**Fabio Fava**, born in 1963, is Full Professor of "Industrial & Environmental Biotechnology" at the School of Engineering of University of Bologna since 2005.
F. Fava published about 240 scientific papers, 170 of which on medium/high IF peer-review international journals of industrial and environmental biotechnology. He has 5733 overall citations, a H-index of 46 and an i10 index of 123 (Google Scholar) along with 180 papers quoted by Scopus. He is actively working in the fields of environmental, industrial and marine biotechnology and of the Circular Bioeconomy in the frame of a number of national projects and collaborative projects funded by the European Commission. Among the latter, he coordinated the FP7 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 biodegradation and the tailored depolymerization of wastes from the major oil-deriving plastics, both in terrestrial and marine habitats. He also coordinated the Unit of the University of Bologna who participated in the FP7 collaborative projects ECOBIOCAP and ROUTES (on the production of microbial and biodegradable 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 biorefineries), and ULIXES and KILL SPILL (on the development of strategies for intensifying the *ex situ* and *in situ* bioremediation of marine sediments contaminated by (chlorinated)hydrocarbons and microplastics and the isolation and industrial exploitation of microbes from such contaminated matrices). Dr. Fava served and is serving several national, European and international panels, by covering the following positions:

• Italian Representative in the Horizon2020 Programme Committee of Societal Challenge 2: European Bioeconomy Challenges: Food Security, Sustainable Agriculture and Forestry, Marine, Maritime and inland water research" (European Commission, DG RTD) (2013-);
• Italian Representative in the "States Representatives Group" (SRG) of the Public Private Partnership "Biobased Industry" (PPP BBI JU) (Brussels) (2014-); he is chairing the SRG since October 2018;
• Italian Representative in the BLUEMED WG of the EURO-MED Group of Senior Officials (EU Commission DG RTD and Union for Mediterranean) (2017-);
• Italian Representative in the initiative on sustainable development of the blue economy in the western Mediterranean the "Western Mediterranean Initiative" WEST MED, promoted by the EU Commission (DG MARE) in close cooperation with 10 countries of the area (2016-);
• Member of the "Working Party on Biotechnology, Nanotechnology and Converging Technologies" of the Organization for Economic Co-operation and Development (OECD, Paris) (2008-);
• Chair (2011-2013) and currently Deputy Chair of the "Environmental Biotechnology section" of European Federation of Biotechnology (EFB) (2013- ).

Finally, he is the scientific coordinator of the International Exhibition on Green and Circular economy ECOMONDO held yearly in Rimini (Italy)

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# EVALUATION OF BIOLOGICAL PROCESSES PERFORMANCES USING DIFFERENT STABILITY INDICES*

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## Abstract

The EU's Circular Economy Policy Package aims to minimize waste production in accordance with the Circular Economy concept. In this respect, organic waste valorization through composting and anaerobic digestion process represents a proven solution for converting biomass in bio-based products with high fertilizing and amendment properties. In order to optimize process' performances and reuse the bio-products, biological stability index evaluation of the final products plays a key role. Several respiration tests are currently used for the determination of biological stability and the need to define homogenized regulations both at national and European level, in order to outline harmonized rules for biological stability determination, is becoming increasingly indispensable. Among these, some approaches measure respirometric activity by estimating oxygen uptake rate (SOUR and DRI test) and by recording the maximum temperature achieved by the biomass during the degradation process (Self-Heating test). Others assess the decomposition degree of organic waste by determining the residual biogas potential production (BMP test). This work aims at evaluating biological stability of different organic matrices such as compost, digestate and mixture of them in order to compare different respirometric techniques and define possible correlations between them and their suitability depending on the substrates analyzed. The results show that among the different stability tests analyzed in this work, there is a good linear correlation that allows to affirm a direct proportionality both between DRI and Self-heating test and BMP and SOUR test. The results suggest that all the respirometric methods considered in this study could be used as indicators of the biological stability degree of an organic substrate and are therefore interchangeable with each other, providing the same value of biological

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stability degree. Nevertheless, future studies on stability index determination could be carried out in order to confirm the results obtained from this work.

*Keywords:* BMP, compost, digestate, oxygen uptake rate, self-heating test.

## 1. Introduction

Agriculture is an important sector for Italian economy, hence it is necessary to focus on a more responsible, efficient and sustainable use of natural resources. Fertilizers play a key role in keeping high agricultural production mainly due to the growing need to provide the soil with more nutrients - such as phosphorous (P), nitrogen (N) and potassium (K) – and organic matter. Nevertheless, its responsible use is essential to avoid water pollution problems and also for land and soil safeguard (Wilken et al., 2018).

Based on the EU action plan for Circular Economy (European Commission, 2015), waste production could be reduced by turning them into resources for new purposes (Webster, 2013). In this respect, the valorization of organic waste for bio-based product production such as compost and digestate respectively through composting and anaerobic digestion process, represents an attractive solution for a safer resources' recovery from bio-waste (Tambone et al., 2010). Both compost and digestate are residual organic matrix with high fertilizing and organic amendment properties that can be replace the synthetic fertilizers in agriculture (Tambone et al., 2017; Tambone et al., 2019). Therefore, their use as fertilizer in agricultural system seems to be the best alternative for their recycling and recovery, improving soil structure and leading to a more efficient closure of organic matter and nutrients cycle (Alburquerque et al., 2012; Favoino, 2013). Moreover, the substitution of chemical fertilizers with the organic ones allows to reduce $CO_2$ emissions avoiding the withdrawal of energy related to the extraction and transformation of virgin materials (Centemero, 2017).

However, the fertilizers sector deals with several problems related to the access to the EU internal market due to the different national regulation on fertilizers in force. As regard the Italian legislation on fertilizers, both compost from green and lignocellulosic waste and sorted Organic Fraction of Municipal Solid Waste (OFMSW) are considered as products and can then be marketed, but this is not the case for digestate from anaerobic digestion process. Therefore, the digestate is not marketable unless mixed with other substrates such as those mentioned above. In order that the mixture is recognized as a fertilizer product, it must comply with the limit of 35% w/w of digestates' dry matter presented in the mixture. To overcome this problem, the EU has proposed a Regulation with the aim of harmonizing the rules on the fertilizer market (European Commission, 2016). In order to obtain the CE marking as a fertilizer, products should satisfy defined physical, chemical and structural characteristics and must comply with biological stability threshold values, which can be assessed by means of different harmonized stability criteria.

Biological stability depends on biological activity in an organic matrix and represents the degree of decomposition of the biodegradable matter (Lasaridi and Stentiford, 1996). For this reason, its measurement is linked to the determination of biological respiration activity, which can be assess through respirometric tests (Adani et al., 2003). Amongst the available respiration tests, the most common are based on the measurement of oxygen consumption for the evaluation of biological stability (Scaglia et al., 2000; Adani et al., 2001). The determination of oxygen uptake rate is considered a reliable and simple method for the assessment of the stability index even if it required a rather complex experimental set-up (Scaglia et al., 2007). The rate of oxygen consumption can be measured directly in the process air flow or as dissolved oxygen (DO) in an aqueous solution. In the first case, the Dynamic Respirometric Index (DRI) is determined, the material is passed through by a dry

air flow and oxygen concentration is measured in the exhaust air flow. In the second case, the Specific Oxygen Uptake Rate (SOUR) is detected and the oxygen concentration is estimated in an aqueous solution in which the samples is dissolved. Other methods, such as Self-Heating Test, used biomass' temperature increase during the degradation process to assess biological activity. This method is the most expeditious and suitable for daily operations (Wagland et al., 2009). In addition to these, anaerobic tests, such as Biochemical Methane Potential (BMP) test, also measure the biodegradability of an organic matrix. In this case, biodegradable organic matter is decomposed under anaerobic conditions by methanogenic bacteria and the decomposition degree is assessed by determining the residual biogas potential production (Pecorini et al., 2016).

This work estimates the performance of different composting and anaerobic digestion plants by comparing the stability indices of the final products obtained. This comparison was made in terms of stability index measured by SOUR, DRI, BMP and Self-heating test. This study aims to correlate different respiration methods and evaluate possible relationship between them and their suitability depending on the type of substrates.

The objective of this study is to analyze biological stability of different organic matrices such as compost, digestate and mixture of them in order to compare different respirometric techniques and define possible correlations between them and their suitability depending on the substrates. In this context, four different respirometric methods were proposed for the assessment of the stability index: SOUR test, DRI, Self-heating test and BMP test.

This work is divided in two main parts:

- sample collection and processing: two organic matrices were collected from different plants (composting and anaerobic digestion plants) and mixed together in order to obtain a marketable mixture;
- evaluation of the biological stability index through several respirometric methods, comparison and analysis of the results.

## 2. Materials and methods

### *2.1. Sample collection and processing*

Two different organic matrices from composting and anaerobic digestion full-scale plants located in Tuscany region were used as raw substrates for mixture combinations. Samples with different physical, chemical and structural characteristics were chosen in order to assess biological stability of matrices with variable compositions and origins. Each sample consisted of bio-waste processed materials that include composted green and lignocellulosic waste and digested wastewater sludge (WWS).

Each substrate was collected from each plant, stored and approximately 50 kg of samples were taken for pH, Total Solid (TS) and Total Volatile Solid (TVS) content analysis and for respirometric tests.

Subsequently, the matrices were manually mixed together by means of a blade in order to obtain a mixture of them as a new organic substrate. The mixing procedure was carried out in terms of weight content of each raw material.

The studied samples were as follow:

- GLWc: compost from green and lignocellulosic waste;
- WWSd: digestate from anaerobic digestion of WWS;
- WWSd+GLWc: mixture composed of 50% WWSd and 50% GLWc.

After the processing step, about 50 kg of the mixture was also sampled in order to characterize it as the raw substrates in terms of pH, TS and TVS content and stability.

TS, TVS and pH were determined in according to standard methods (APHA, 2006). In

accordance with TS and TVS measurements, the contents of ashes and moisture were then evaluated. Each analysis and respirometric test were performed in two replicates.

### *2.2. Respirometric tests*

The assessment of respiration activity of an organic matter can be evaluated through several procedures measuring the oxygen uptake, the released heat during the degradation process and the gas production in anaerobic conditions. In this section a detailed description of the procedures and the experimental set-ups used to measure the stability index is presented.

#### *2.2.1. Dynamic Respiration Index (DRI)*

The DRI analysis was carried out using hermetically sealed stainless steel adiabatic reactors with a capacity of 30 liters developed by DIEF – University of Florence according to UNI/TS 11184:2016. The experimental set-up consists of two continuous flow aerobic respirometers in which about 20 kg of sample were placed. Before starting the analysis, the sample has to be adjusted and standardized relating to some process parameters such as humidity, density and pH (Scaglia et al., 2000). The analyzed sample was subjected to optimal insufflation conditions that are ensured by the forced injection of dry air coming from an air compressor that guarantees a constant flow through the system. The air flow is measured by two flowmeters (Aalborg Instruments) placed both at the inlet and the outlet of the system. The incoming air flow is adjusted by the flowmeter during the analysis in order to allow a value of $O_2$ concentration in the exhaust air greater than 14%. At the outlet of the system, special probes are set up to measure the concentration of oxygen (Zirconium oxide sensor, TEC-ZRC, Tecnosens S.p.A.) and $CO_2$ (GasCard NG Gascheck 10%, Edingburgh Sensors) in the exhaust air flow. An external water jacket inside which circulates water from a hot bath heated by a thermostat (FA90, FALC Instruments) is designed in order to maintain the adiabatic conditions of the system. Several thermocouples were installed to provide process air and biomass temperature measurements during the overall test. All the signal coming from the sensors are managed and acquired by a National Instrument acquisition system and processed by a software developed in LabView environment. Figure 1 shows the DRI experimental set-up.

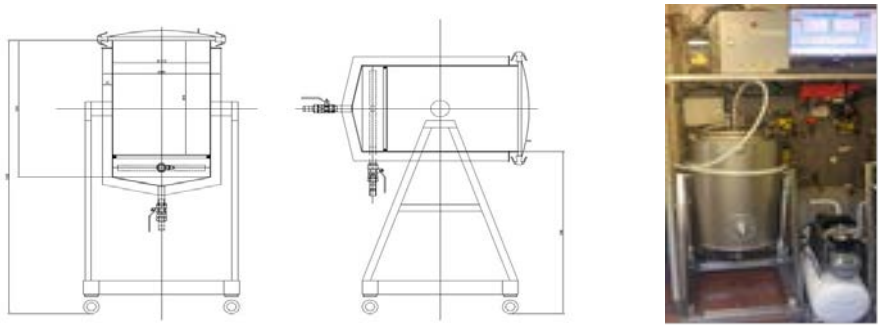


**Fig. 1.** DRI experimental set-up developed by DIEF – University of Florence.

Respiration index was calculate directly by the software in accordance to Adani et al. 2001. It represents the average of the indices measured during the 24 hours in which the biomass' respiration is highest and is measured as $mgO_2/kgTVS*h$.

*2.2.2. Specific Oxygen Uptake Rate (SOUR)*

The assessment of biological stability can be also evaluating in liquid phase. The SOUR test estimates the $O_2$ consumption in an aqueous suspension containing a sample both in solid and liquid form. This measurement allows to obtain two different indices: SOUR and the cumulative oxygen demand in 20 hours ($OD_{20}$). This method was set-up according to the methodology proposed by Lasaridi and Stentiford, 1998, with the modification of Adani et al., 2003 (Albini et al., 2018).

Microbial respiration was evaluated by measuring DO concentration into 1-liter aqueous solution where 2.5 gr (wet weight) of sample were dissolved. The concentration measurement is guaranteed by a DO probe (Mettler Toledo, InPro6000, Optical $O_2$ Sensors). The flask was placed on a magnetic stirrer (Velp Scientifica, AREX Digital PRO), continuously mixed (250 rpm) and heated at 30° C for ensuring the optimal biological conditions. Since the concentration of oxygen in the solution decreases due to the biological process, it is necessary to insufflate air in the suspension in order to increase the content of oxygen available to the process. Therefore, the suspension was periodically aerated by a fish-tank air pump with intermitted aeration cycle. An automatic control system and data acquisition (LabView, National Instruments Corporation, Italy) provided the aeration/reading sequence characterized by 20 min aeration period followed by 15 min of DO measurement and acquired the signal coming from the DO probe during the overall experimental period of 20 hours. For ensuring that nutrients or pH were not limiting, phosphate buffer solution (with a pH equal to 7.2), ATU (allylthiourea) and 5 ml of nutrient solutions ($FeCl_3$, $CaCl_2$ and $MgSO_4$), according to the BOD test standard procedures (APHA, 2006), were added to the aqueous suspension.

The SOUR value was evaluated via DO concentration drops during the reading cycle and was calculated according to Eq. (1) ( Adani et al., 2003; Lasaridi and Stentiford, 1998):

$$SOUR = \frac{|S\max|*V}{m*TS*TVS} \quad (1)$$

where: SOUR is the Specific Oxygen Uptake Rate ($mgO_2*gTVS^{-1}*h^{-1}$); |Smax| is the maximum absolute slope of oxygen consumption ($mgO_2*l^{-1}*h^{-1}$); V indicates the volume of the suspension (l); m represents the mass of the sample (gr, wet weight); TS and TVS are the decimal fraction of dry solids and total volatile solids (dry matter) of the sample.

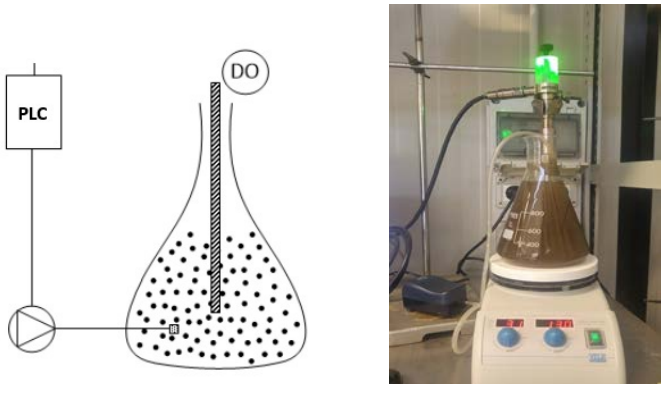



**Fig. 2.** SOUR experimental set-up.

*2.2.3. Self-heating test*

Self-heating test is an indirect measure of the biological activity based on the measurement of the temperature trend of the biomass analyzed over the experimental time. This analysis consists in placing the tested material inside an adiabatic vessel (Dewar vessel), after ensuring the optimal humidity conditions for the degradation process. Inside the sample, a thermocouple is placed to measure the biomass' temperature. There is no forced temperature control, therefore it tends to increase following the typical exothermic trend of the biological activity of degradation of the biodegradable matter. This technique is used to perform respirometric analysis on solid material and the experimental time vary from 5 to 10 days, until the biomass temperature values decreased for at least two days after the maximum temperature value reached. The biological stability is determined by evaluating the maximum temperature difference reached between the biomass and ambient temperature. Base on the difference value obtained, it is possible to define the biological stability degree of the tested substrates.

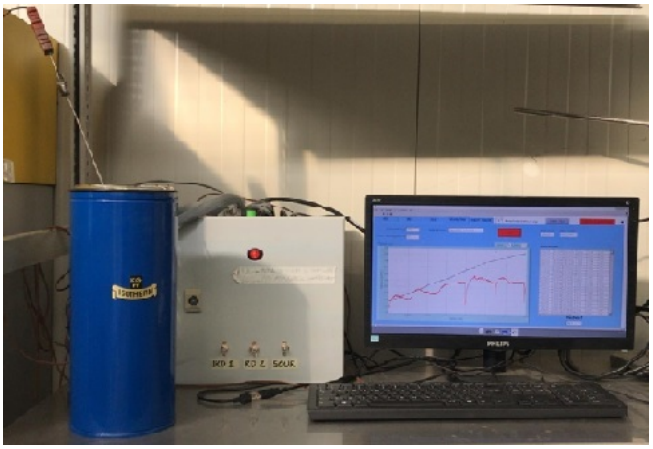


**Fig. 3.** Self-heating experimental set-up.

*2.3. Biochemical Methane Potential (BMP) test*

Anaerobic biodegradability assay was also carried out in order to evaluate biogas and methane potential production of the organic materials. The analysis was carried out for 21 days according to the method proposed by Ponsà et al., 2008. The test was performed using stainless steel batch reactors developed at DIEF – University of Florence (Pecorini et al., 2012). The reactors were maintained constantly at a temperature of 37° C in a water bath heated by a thermostat (FA90, FALC Instruments). Each reactor was filled in with substrate and gas production was daily estimated by measuring the pressure in the head space of the batch reactor. Using the ideal gas law, the pressure measured by a membrane pressure gauge (Model HD2304.0, Delta Ohm S.r.l., Italy) was then converted in biogas volume and Gas Sum (GS21) value measured as Nl biogas/gTVS, was estimated. In order to evaluate the methane content and determinate BMP21 value (Nl $CH_4$/gTVS), an IR gas analyzer (ECOPROBE 5 – RS Dynamics) was used to analyzed biogas' quality.

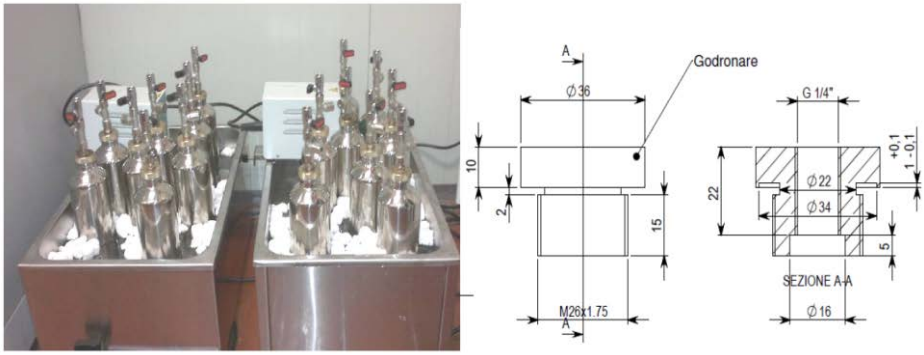



**Fig. 4.** BMP experimental set-up.

## 3. Results and discussion

### *3.1. Samples' characterization*

Concerning TS and TVS contents measured for the analyzed samples and reported in Table 1, different results were obtained, especially for the raw samples. This variability is probably due to the different origins of the raw substrates (green-lignocellulosic waste and WWS) and the biological treatments they have undergone.

**Table 1.** Samples' characterization expressed in terms of average values and standard deviations.

| ***Sample*** | ***Origin*** | ***TS [% w/w]*** | ***TVS/TS [% w/w]*** | ***pH*** |
|---|---|---|---|---|
| GLWc | Green-lignocellulosic waste | 43.48±0.40 | 40.24±1.45 | 7.12±0.30 |
| WWSd | WWS | 23.35±1.37 | 63.33±2.28 | 8.09±0.46 |
| WWSd+GLWc | 50%WWSd-50%GLWc | 35.91±0.29 | 46.97±0.48 | 7.30±0.10 |

The results shown that sample GLWc is drier than sample WWSd, with TS content equal to 43.48±0.40% and 23.35±1.37%.for GLWc and WWSd respectively. On this basis, these two raw samples provided a mixture with different physical and structural characteristics and with a TS content of 35.91±0.29%. This variability in samples characterization allowed to assess the organic matter content, and so biological stability degree, of a wide range of organic matrices.

### *3.2. Biological stability results*

#### *3.2.1. Biological stability results: discussion and comparison*

Table 2 shows biological stability results. It should be noted that DRI is reported both in terms of stability index and maximum biomass' temperature, which was measured during the overall experimental period. Moreover, the results obtained from the SOUR test are presented both as SOUR and OD20 index. Concerning the anaerobic test, either GS21 and BMP21 for biogas and methane residual production respectively are reported for completeness. All the results obtained in this study were compared with the stability threshold values corresponding to each individual method. As regard DRI index, reference is made to the limit value of Italian legislation of 1,000 mgO2/kgTVS*h as this method is not

recognized within the harmonized criteria for biological stability determination in the EU's fertilizers regulation.

**Table 2.** Biological stability data expressed in terms of average values and standard deviations.

| ***Respirometric test*** | ***Raw samples*** | | ***Mixture*** |
|---|---|---|---|
| | GLWc | WWSd | WWSd+GLWc |
| *DRI [mg$O_2$/kgTVS*h]* | 765±181 | 814±206 | 1,090±294 |
| *DRI_Biomass temperature [°C]* | 13 | 21 | 34 |
| *Self-heating test [°C]* | 11±1 | 11±3 | 18±2 |
| *SOUR [mg$O_2$/gTVS*h]* | 3±2 | 18±0 | 11±4 |
| *OD20 [mg$O_2$/gTVS*h]* | 27±3 | 221±0 | 119±34 |
| *GS21 [Nl biogas/gTVS]* | 0.01±0.01 | 0.14±0.00 | 0.04±0.00 |
| *BMP21 [Nl $CH_4$/gTVS]* | 0.00±0.00 | 0.07±0.00 | 0.02±0.00 |

The maximum temperature measured during the experimental test can be considered as an indicator of the biological activity, in fact a high biological activity corresponds to a high process' temperature. Self-heating and residual biogas potential test are considered as stability criteria in the EU proposed regulation, therefore European threshold values are considered as reference. In order to obtain CE marking, a product must comply with the maximum temperature range of 20-30° C for Self-heating test or must meet the maximum residual biogas potential value of 0.45 Nl biogas/gTVS for anaerobic test. Finally, concerning SOUR test, there are no reference for stability determination. Therefore, literature data as considered as references. Scaglia et al., 2007 obtained SOUR values for compost and bio-stabilized products in the range of 2.6-9.0 mg$O_2$/kgTVS*h while Adani, et al. (2003) reported SOUR values for organic matrices between 3.0-19 mg$O_2$/kgTVS*h. Orzi et al., 2010 showed OD20 values between 94.0 and 264.0 mg$O_2$/kgTVS*h for digestate from anaerobic digestion process. It can be stated that the stability data obtained with respirometric tests are consistent with the reference limits.

*3.2.2. Correlation analysis*

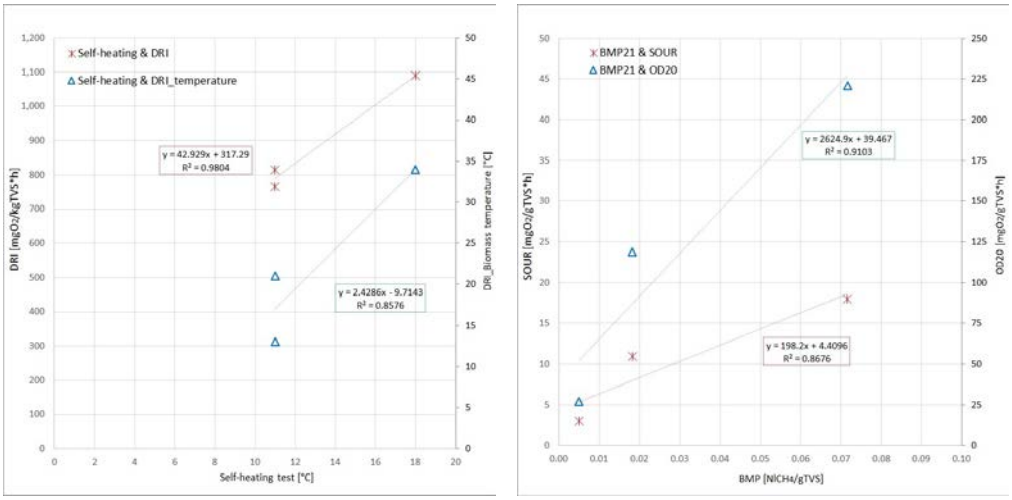
Figure 5 shows the correlation analysis between stability data. In particular, in Figure 5a the correlation between Self-heating test & DRI and Self-heating test & DRI_Biomass temperature is presented. As it can be seen, there is a good correspondence among DRI and Self-heating values with a linear regression characterized by a $R^2$ value equal to 0.98. In addition to this, also the correlation between Self-heating test and the maximum biomass' temperature, reached during the DRI test, shows good results corresponding to a $R^2$ value of 0.87. These results demonstrate that these two tests are interchangeable each other providing the same data in terms of biological stability index.

As regard Fig. 5b, BMP21 & SOUR and BMP21 & OD20 are related. In both cases there is a good correlation between the data determined by the $R^2$ values equal to 0.91 and 0.87 for BMP21 & OD20 and BMP21 & SOUR respectively. These results mean that the amount of fresh organic matter in an organic matrix coincides with a residual biogas production that is directly proportional to the degree of decomposition of the substrate analyzed.

## 4. Concluding remarks

This work demonstrates the need to define homogenized regulations both at national and European level, in order to outline harmonized rules for biological stability determination. The results show that among the different stability tests analyzed in this work,

there is a good linear correlation that allows to affirm a direct proportionality both between DRI and Self-heating test and BMP21 and SOUR test.




a) b)

**Fig. 5.** Correlation analysis: a) Self-heating test & DRI and Self-heating test & DRI_Biomass temperature, b) BMP21 & SOUR and BMP21 & OD20.

In particular, the correlation among Self-heating test and DRI_Biomass temperature demonstrates that these two tests are interchangeable with each other, providing the same stability data referred to the process' temperature. The results suggest that all the respirometric methods considered in this study could be used interchangeably as indicators of the biological stability degree of an organic substrate. Nevertheless, future studies on stability index determination could be carried out in order to confirm the results obtained from this work.

## Acknowledgements

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# HOW TO MINIMIZE INDOOR POLLUTION AND ENERGY COSTS THANKS TO AIR RECIRCULATION NEW TECHNOLOGIES IN THE VIEW OF PASSIVE HOUSES*

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## Abstract

The growing public sector interest in green building makes us wonder about what each of us can do to implement sustainable management of private buildings. Nowadays citizens feel a stronger need to replace conventional heating and cooling techniques with new systems in order to increase energy efficiency, improve air quality and minimize indoor pollution. The Ecohouse company, located in eastern Sicily, has been able to satisfy the most sensitive customers' requirement, providing its buildings with innovative air purification and ventilation systems through heat recovery aspirators, air channeling by fan coil and chiller for radiant floor heating. The company's long-term goal is the construction of houses as close as possible to what the passive house protocol establishes. The air purification systems' functioning is based on a process of air recirculation that implicates a minimum loss of heat (approximately one degree) in order to save energy.

*Keywords:* passive house, energy efficiency, air recirculation, indoor pollution, green building

## 1. Introduction

Primary energy demand in the world has increased drastically in recent decades. Furthermore, the EU Commission has recently stated that one of its highest priority tasks is to address global warning with special focus on reducing greenhouse gases (Rohdin et al., 2013).

"Green" or "sustainable" buildings use key resources like energy, water, materials, and land more efficiently than buildings that are just built to code. With more natural light and better air quality, green buildings typically contribute to improved employee and student health, comfort, and

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productivity (Kats, 2003). Sustainability has become an increasingly important attribute of economic activities describing methods of production, but also qualities of consumption and attributes of capital investment (Eichholtz et al., 2010).

There are many factors that determinate the sustainability of the house: both internal and external characteristics that lead to the concept of "passive house", that are known to outperform conventional buildings in terms of living conditions and energy efficiency due to their heat recovery, good thermal insulation and the overall optimization of the house (Mlakar and Strankar, 2012). The definition of a passive house differs in various countries and depends on the local climatic conditions and building codes. The international definition has been developed by Passive House Institute in Germany.

Among factors that influence the living environment, humidity and temperature are the most important. The ambition to reach high energy performance has led to the development of the passive house standard, where the strategy to reduce the energy demand is followed to such extremes, that a central heating system is not required (Hasselaar, 2008). In energy efficient designs, a three step strategy is followed: reduce the demand for energy, supply energy through sustainable sources and finally apply systems with high energy efficiency. In recent years, indoor air quality in conventional buildings has received substantially more attention than the introduction of passive houses (Jamaludin et al., 2014). Changes in building design devised to improve energy efficiency have meant that modern homes and offices are frequently more airtight than older structures. Furthermore, advances in construction technology have caused a much greater use of synthetic building materials.

Whilst these improvements have led to more comfortable buildings with lower running costs, they also provide indoor environments in which contaminants are readily produced and may build up to much higher concentrations than are found outside. The control of air recirculation contributes to the energy demand for the supply air treatment. This influence is particularly pronounced in transient conditions, which differ during the summer and winter periods. The proposed design solution involving the use of a separate individual recirculation of extract air for warm and cold air installations allows limiting of the energy demand for both warm and cold air temperature settings. This reduction of the energy demand is achieved under transient external air parameters. "Ecohouse Immobiliare" is really interested about these contents and its goal is to became a always more sustainable firm and in particular to represent how to maintain a healthy micro-climate inside its houses by using specific instruments.

## 2. Materials and methods

A plant that often is offered as a consumer of low consumption houses is the "mechanical ventilation controlled to heat recovery". A distinctive complex designation for a simple and effective system to improve the quality of air and the energy efficiency of prefabricated wooden houses. This system provides to the complete replacement of the house air, always guaranteeing fresh and healthy air that can be pre-cooled in the summer and preheated in the winter by means of a high efficiency heat recovery unit (www.caseprefabbricateinlegno.it).

The process of air recirculation prevents the penetration of Radon gas inside the houses, which is released by rocks and can easily accumulate at high concentrations in enclosed places. Radon gas is a radioactive, colorless, odorless, tasteless noble gas, occurring naturally as an indirect decay product of uranium or thorium. Radon is one of the densest substances that remain a gas under normal conditions. Classification systems have been developed where regions are delineated by their potential to cause high concentrations of radon in the houses (Monitoring of indoor radon pollution) (Varley and Flowers, 1998).

Green building and living comfort have become one of the many indispensable elements of daily living. Even in Italy the race towards an increasingly eco-sustainable apartment model has begun and several municipalities are beginning to come to terms with the assessment of environmental impacts over time and space. Choosing to build in green building means integrating

one's own homes into the natural environment, applying a holistic view that would guarantee an admirable work, not only visually, but above all for the common good, for respect environmental and, much more, to cure the psychophysical state and the health of the individual (Jones, 1999).

In a passive house, the ventilation system is an indispensable system for the correct exchange of air in all living areas, but above all to keep the temperature constant throughout the year, so as to optimize energy resources, so that the heating and air conditioning systems are used as little as possible and so that the home is self-sustaining (Langer et al., 2014). The goal of the passive house, as well as that of installing the ventilation system, is to reduce energy consumption as much as possible, which can only be achieved with the natural loss of the least possible amount of energy generated. For this reason, the most appropriate choice in a passive house is the installation of a ventilation system with heat recovery with a high-efficiency motor which, to obtain maximum performance in terms of resistance and efficiency, is recommended with a nominal power of 40-50W. In the type of ventilation system with heat recovery, the hot outgoing air, from the kitchen or bathroom environment, is conveyed to a flow exchanger in which the incoming cold air receives up to 90% of the heat in exit that is completely recovered. In this way, the air is distributed in the environment, in a completely eco-sustainable way, a system that can implement an even more efficient method if it is possible to install a geothermal heat pump, increasing the temperature and heating of the incoming air. However, one should not think that the ventilation system creates a perceptible air flow inside the rooms (Michel et al., 2010). The entire system is perfectly integrated into the building so that the air path and its distribution is not perceived by the occupants: in the summer, in addition, the ventilation system replaces the air conditioning system, significantly contributing to reducing consumption energy, environmental impact and the reduction of heat losses by about 80% (www.prefabbricatisulweb.it). In particular the company “Ecohouse Immobiliare” focuses his attention on these topics and its developing news systems of air recirculation.

## 3. Experimental

Ecohouse real estate, which is located in Adrano (CT), is one of the first builders of certified A++ residences in Sicily. The company has been founded in 2010 by Antonio Donato and his partners, a group of industry professionals with over twenty years of experience who strongly believe in the idea of combining environmental and economic needs. The latest decline in the traditional real estate market and the incentives of the government to replace the traditional construction methods with innovative and environmentally sustainable methods, combined with a great entrepreneurial sense, led Ecohouse real estate to enter in the green building sector. The mission of the company is to promote, through his real estate brand, the sustainable development by building houses that do not pollute and do not produce wastes in the perspective of passive houses.

Ecohouse real estate realizes the so called “Excellent Houses” since these houses are independent in energy terms, thanks to photovoltaic panels, they are provided with rainwater recycling systems, integrated heating systems and they are built according to anti-seismic criteria. The construction of the houses begins with the excavations and the positioning of the lean concrete where foundations, which are made of reinforced concrete too, will be placed. The reverse beam system is used to build foundations and it requires that there are gaps between beams made with igloo so that they are ventilated, and therefore environmentally sustainable. Afterward wooden lamellar pillars are anchored to the foundations by sustainable brackets, then beams and slabs, which are in lamellar wood too, are placed. Once the structure is finished, the process of insulation begins. External wooden walls and partition walls made of plasterboard are established. On the outside the facade will be made of bio stone and natural plasters while on the inside the plants will be painted with water-based paint right after they are laid. Additionally the floor will be laid on the slab and below it there will be the heating system. Eventually the external window fixtures will be

assembled. In the matter of outdoor areas at first the imhoff pits are situated then the process ends up with the installation of external gates and railings. (Pecorino et al., 2018).

## 4. Results and discussion

Ecohouse real estate is a company that constantly tends to improve its buildings' performances, trying to reach ever higher levels of self-sufficiency, sustainability and energy efficiency. Among the various systems designed to achieve this goal, there are highly innovative Mechanical Ventilation systems with heat recovery installed in every Ecohouse branded home. Newly built houses are increasingly sealed and thermally insulated, which means that there is no air recirculation and, therefore, they are more subject to the creation of mold and humidity, harmful elements to human health due to the development of important bacterial colonies that they involve. For the same reason, there is a high concentration of pollutants inside the house, due to the presence of numerous sources of pollution in domestic premises. The Controlled Mechanical Ventilation (CMV) system with heat recovery represents the solution to this kind of problem, as it is a simple technology to apply that helps to create a healthy microclimate throughout the house (www.ilmessaggero.it/ventilazionemeccanicacontrollata).

The CMV is defined as "the process of introducing and / or extracting air and / or towards an environment confined to the purpose of controlling pollutant levels, humidity or temperature" (ASHRAE 62.1- 2020) (www.ashrae.org). This system, in fact, controls the exchange of the air inside the closed spaces in order to have a continuous air circulation without having to open the windows and disperse the heat. The mechanism of this instrument is based on the principle of operation of the double continuous and balanced flow between intake air and extracted air, called the "push-pull" principle. The instrument is equipped with a ceramic accumulator tubular heat exchanger, within which the two air flows pass simultaneously. Through the return grilles, the hot and polluted air comes out of the internal environment and is led to the heat exchanger, and then it exits the building. The ceramic tube (exchanger) stores the heat of the extracted air in the extraction cycle (pull) and then transfers it to the air introduced during the injection cycle (push). In this way, the heat contained in the expelled air is recovered and transferred to the incoming air, which enters the building through ducts and is introduced through the vents. The ducts in which the air entering the building passes are treated with substances capable of sanitizing the air, filtering pollutants, bacteria and pollen. It is essential, in fact, that the pipes in which the incoming and outgoing air pass simultaneously are kept separate to avoid contamination of the filtered and clean air entering with the polluted air coming out. The filters, usually inserted in the heat exchanger, reduce the ingress of external pollutants, smog and dust, and reduce the possibility of mold formation. The filters, as well as the ducts for ventilation and the recuperator, must be maintained constantly, cleaned at least twice a year and replaced in case of wear (https://www.prana24.com).

There are various types of Controlled Mechanical Ventilation with different specific characteristics, but they all are systems that are easy to install in any environment (about 1-2 hours for installation) and have a heat recovery capacity of up to 90%. These devices can also operate at 24h at minimum speed, are easily controllable in the operating speed even by remote control and, thanks to the presence of a humidistat, they can manage their speed by themselves depending on the momentary percentage of humidity in order to always remain within a preset range of humidity (https://www.prana24.com).

Controlled Mechanical Ventilation is a technology that brings many advantages to a structure, as it helps to create living comfort, building protection and energy efficiency. These advantages can be obtained by planting VMC both on existing buildings and new buildings. The spearhead of this technology is certainly the ability to achieve high energy savings. The controlled mechanical ventilation system, in fact, allows an energy saving of over 30% compared to the traditional evacuation system, which is the opening of the windows. Ceramic air exchangers recover heat in winter and cool in summer from inside the environment for over 70-93% (EN13141-7, 2010). These instruments' high yields contribute, therefore, to the containment of expenses to keep

the house warm and reduce the cost in the bill. This high energy saving leads to improve the energy class of these houses, in fact with these ventilation systems a building can be included in a higher energy classification than that with only natural ventilation. Depending on the model installed and, therefore, on its performance, it can also be included in the top of energy efficiency, a level that Ecohouse buildings have already reached (www.expoclima.net).

Among the main advantages of the VMC there is, as already reiterated several times, the creation of a healthy microclimate within domestic premises. Since 1983 the World Health Organization (WHO) has recognized a pathology associated with residential and work environments, the SBS, or Sick Building Syndrome, which corresponds to a combination of disorders related to all aspects of "microclimate" to which people are exposed, which include lighting conditions, but also and above all air humidity, ventilation changes and the possible emission of some harmful substances from the materials used for the construction. Moreover, in Italy almost 25% of the population suffers from allergies and most of these are due to forms of asthma or respiratory allergies to dust mites. One of the most efficient methods to counteract the proliferation of mites is to contain the value of Relative Humidity with controlled ventilation, which reduces the level of humidity, especially in winter, also acting as a dehumidifier. The air is also filtered, limiting the entry of allergens, mites and pollens (www.annuario.isprambiente.it). This type of ventilation helps to eliminate even the pollutants present in the houses and to provide an adequate oxygenation of the living spaces. The main pollutants contained in the air are carbon monoxide, carbon dioxide, tobacco smoke, formaldehyde, asbestos, ozone and nitrogen oxides. These elements are constantly eliminated from furniture, furnishings, stoves, heating appliances or even from the metabolism and physical activity of people. With the VMC, the continuous exchange of the air controls the indoor pollution and allows to reintegrate the oxygen value at optimal levels.

A particularly important element that the VMC is able to eliminate is Radon. Radon is a very common gas that, while in open spaces it disperses rapidly, in closed places it concentrates because it manages to rise from the ground infiltrating the buildings through the foundations, to concentrations more or less high depending on the permeability of the soil. Once infiltrated, this gas transforms giving rise to elements that can induce changes in some cells of our body and generate serious diseases in the lung. Each year, around 3000 deaths are attributed to radon in Italy (Lamonaca et al., 2014). One of the most effective ways to reduce the risks arising from this gas is to provide constant and adequate ventilation. So a healthy indoor climate is maintained through a ventilation that keeps silent and also protects from external noise. The VMC, in fact, provides for a high acoustic insulation, which makes it suitable also for the house's night area, where it can remain active while maintaining an ideal internal acoustic comfort. Finally, the system is convenient, practical and flexible to use thanks to an easily manageable and modulable operation on individual needs. Calculating the cost of a controlled mechanical ventilation system is an operation that considers a series of factors such as the surface of the house, the volume of the rooms, the number of people in the house.

However, although the cost of the system may initially be substantial for a family, it is repaid over time: reduction of heating and cooling costs, protection of the health of individuals, increase in the energy classification of the building and consequent increase in its economic value.

## 5. Concluding remarks

The choices made by Ecohouse real estate in the perspective of sustainable development prove how strong is the need to promote initiatives that face several environmental emergencies throughout Sicily. In particular this case study provides a solution to the issues about energy consumption and presence of pollutants indoor, that compromise both our health and the health of the indoor environments in which we live.

The implementation of a controlled mechanical ventilation in houses, which is a necessary requirement set by German standards and protocols such as Passivhaus and Klimahaus, is an important step towards the process of conversion of traditional houses into passive and low energy houses.

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# MANAGEMENT AND REUSE OF INDUSTRIAL WASTE: INERT ASBESTOS AS A RAW MATERIAL IN THE CONSTRUCTION SECTOR IN A CIRCULAR ECONOMY PERSPECTIVE*

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## Abstract

Waste disposal, over the years, has become increasingly a major problem; in particular with regard to industrial waste, which often require long processes to be eliminated and very often are very difficult to recover. The major problem is represented by the so-called "large-scale waste"; a practical example is given by asbestos, which is harmful. for health. Asbestos is an industrial material that was widely used until the end of the eighties, until several cases related to the dust released by the material, which mainly caused tumors, were detected. The objective of this case study is to find valid alternatives to the reuse of asbestos-derived waste so that it can be made inert to be re-introduced into new production cycles. This is possible thanks to a collaboration with the F.E.R. S.R.L.; in fact the emerging Sicilian company deals with activities aimed at energy saving and energy production from renewable sources and provides the resources needed to develop skills and competences that can be applied by construction companies in future project in a circular economy perspective.

*Keywords:* asbestos, construction, raw material, reuse, circular economy, special waste

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## 1. Introduction

A novel field of research in materials science is the recycling of secondary raw materials for construction and building materials such as concrete (Gualtieri and Boccaletti, 2011; Donaldson and Tran, 2004). Asbestos and asbestos-containing materials have been widely used in many applications, such as insulators, asbestos cement and fireproof construction materials, because of their low thermal conductivity and high mechanical strength. However, asbestos is known to be extremely carcinogenic, especially in causing a severe asbestosis, lung cancer and pleural mesothelioma when the respiratory system is exposed to it (Boccaccini et al., 2007; Fubini and Mollo, 1995; Gulumian, 2005; Iwaszko et al., 2018a).

The hazardous nature of asbestos material lies in the release of respirable asbestos fibers from waste materials into the environment. The inhalation of these carcinogenic substances and their deep penetration into the lungs represents a serious risk of disease. This risk increases with the concentration of fibers in space and time of its impingement on the human body (Gomez et al., 2009; Làzàr et al., 2016). As a result, nowadays, in most countries the mining, refinement and use of asbestos have been banned, apart from some exceptional applications (Arean et al., 2001). Recovering industrial waste heat (IWH) provides an attractive opportunity for a low-emission and low-cost energy source (Mirò et al., 2016, a, b). This heat can be recovered and reused in other processes onsite (to preheat incoming water or combustion air, preheating furnace loads, etc.), or transformed into electricity, cold or other type of heat.

While some of the approaches and models behind the CE discourse have made important contributions to sustainability science in the past, the theoretical connection is not that clear. The research using solid theoretical foundations is rather scanty. In a recently published paper (Korhonen et al., 2018a, b) showed that there are severe limitations and challenges in the practical application of the concept, in the application of material cycles, renewable and cascading type energy flows in production-consumption systems. Asbestos-cement was extensively produced in Italy between 1904 and 1985, with the result that a huge quantity of such materials have been used all over the country and, according to the latest estimates, very large quantities of these are still on site (Bianchi and Bianchi, 2002; Chapman, 2000). Recent Italian directives (and Environment Management Act, 2005; Ministry of Cultural Heritage, 2015) classify all asbestos-containing waste (ACW) as hazardous in line with the European Waste Catalogue code 170605* and requires its treatment prior to disposal in controlled landfills (EU Council Decision, 1994). The Italian Environment Ministry Decree n. 248/2004 lays down guidelines for the treatment, disposal and recycling of ACW and recommends that preference be given to those stabilization and inertization processes that favour recycling in order to reduce ACW-related hazards (Chan et al., 2000; Gualtieri and Tartaglia, 2000; Gualtieri et al., 2008; Leonelli et al., 2006). In particular, high energy milling (HEM) is mentioned as being able to ensure waste amorphisation through the mineralogical and morphological transformation of asbestos phases (Plescia et al., 2003).

The aim of this paper is to develop an economic comparison between technology options. Moreover, an economic analysis taking into account the maximum acceptable investment cost for each technology is estimated and compared with the current investment cost depending on the operating hours of the systems proposed (Brueckner et al., 2015).

## 2. Materials and methods

In our society buildings are omnipresent, but inevitably they entail negative consequences from an environmental point of view. During their lifespan, they consume plenty of resources and energy, occupy land and eventually they are demolished. As the interest in environmental issues is rapidly growing, also within the construction industry, more attention is being paid to sustainable housing technologies and construction methods. This general increasing awareness led to the Kyoto-protocol, an international agreement on reducing the emission of greenhouse gasses and global warming (Buyle et al., 2013; Ewing et al., 2010). Asbestos has a fibrous structure with high mechanical resistance and flexibility, Asbestos-cement industry – generally speaking, in all the products not containing asbestos, contaminated during the asbestos cement production process. Asbestos comes from the Greek ἄrberso (ásbestos), which means ‘‘unquenchable, inextinguishable”. The definition of asbestos, found in the Italian Dictionary of traded goods and commodities (1972), is: ‘‘a mineral that, when adequately prepared, provides fire-resistant and flexible fibers that can be spun and woven and which feature a high dielectric stiffness and chemical resistance” (Nuovo dizionario, 1972). Asbestos has been long marketed and used for its insulating, fire resistance, chemical resistance, soundproofing qualities and tensile strength. Asbestos is classified as a Carcinogen in Category 1A (it may cause cancer). The disposal in a landfill of suitable category, avoiding disposal in structurally unsuitable sites that could lead to undue exposure of workers (prepared for a lower-risk type of waste and not equipped with appropriate PPE) and contamination of the air, water and soil.

The asbestos removal process is a difficult and costly project and can be implemented either by disposal or by depositing in hazardous waste landfills. This second solution is far simpler and cheaper to implement because it only comes down to storage of asbestos-containing materials in special landfills or in inactive mines without interfering with asbestos properties and structure. A solution that is more expensive and more technologically complex, but which makes it possible to completely neutralize asbestos and convert it into a reusable material, is disposal (Iwaszko et al., 2018b).

The construction sector is still the world's largest consumer of raw materials, and accounts for 25e40% of global carbon dioxide emissions (WEF, 2016). ‘Green buildings’ were believed to be a panacea, but it was later found that the sole focus on the operational stage of a building would not suffice to reduce its environmental impact. Whole life approaches were then put forward as the right pathway to sustainability,1 but despite the admirable intention to look at ecological threats and environmental impacts (ISO, 2006), the focus in the day-to-day practice within the construction sector has been rather circumscribed and most often limited to energy consumption and carbon emissions (Pomponi and Moncaster, 2016) without considering the risk of just shifting environmental impacts from one category to another (Pomponi et al., 2016). In spite of these efforts building related $CO_2$ emissions are continuing to rise, with the International Energy Agency (IEA) suggesting that emissions are on track to double by 2050 (IEA, 2014). A new paradigm, circular economy (CE), is now gaining momentum, and it promises to overcome the contradiction between economic and environmental prosperity. There are many different schools of thought on the CE (Blomsma and Brennan, 2017; Ellen MacArthur Foundation, 2016; Winans et al., 2017) however, the shared founding principles lie in the better management of resources. The role of the built environment is therefore crucial, due to its high environmental impacts, which also conversely offer significant opportunities for reductions in energy use, greenhouse gas emissions and waste production.

Compared to other products, buildings are more difficult to evaluate for the following reasons: they are large in scale, complex in materials and function and temporally dynamic due to limited service life of building components and changing user requirements

(Asdrubali et al., 2013). Moreover, their production processes are much less standardized than most manufactured goods because of the unique character of each building. There is limited quantitative information about the environmental impacts of the production and manufacturing of construction materials, or the actual process of construction and demolition, making environmental assessments of the building industry challenging ((Tukker, 2015; Welford, 1998) carried out a survey on acoustical properties of sustainable materials, both natural and recycled. Considered natural materials are hemp, kenaf, coco fiber, sheep wool, wood wool, cork, cellulose, and flax; traditional materials are glass wool, rock wool, and expanded polystyrene. Considered recycled materials are rubber, plastic, textile fibers, and solid wastes (Scheuer et al., 2003).

In the light of the discussed series of challenges and the underlying limitations of a linear economy, i.e. take-make-use dispose, the concept of a circular economy (CE) is considered as a solution for harmonizing ambitions for economic growth and environmental protection. There are various possibilities for defining CE. In line with eco-industrial development CE is understood as “realization of closed loop material flow in the whole economic system”. In association with the so called 3R principles (reduction, reuse and recycling) “the core of CE is the circular (closed) flow of materials and the use of raw materials and energy through multiple phases” (Yuan et al., 2006). Taking into account economic aspects CE can also be defined as “an economy based on a “spiral-loop system” that minimizes matter, energy-flow and environmental deterioration without restricting economic growth or social and technical progress”. For this paper, the relevant CE definition is the one of “an industrial economy that is restorative or regenerative by intention and design” (Ellen MacArthur Foundation, 2016). This definition is more comprehensive as it considers both the environmental and economic advantages simultaneously under the notion of regenerative performance requiring high quality circulation of technical nutrients while ensuring safe entry of bio nutrients in the biological sphere.

## 3. Case study: F.E.R.srl

F.E.R. S.r.l., located in Caltagirone (CT) Sicily, comes from the synergy of managers, engineers and designers and fans of the World of renewable energy, which after years of experience at the best companies involved into activities aimed at energy saving and energy production renewable, and that thanks to their know-how and experience, design, develop and implement photovoltaic and energy saving solutions. F.E.R. consists of a highly qualified and experienced in different situations working in the field of photovoltaics that from 2007 to date have contributed to many photovoltaic and feasibility studies. It is able to offer advice and assistance to the design and construction, centrically the needs of each individual project. One of the purposes of the technical assistance is to provide the resources necessary for the development of new skills and competencies that designers and contractors will apply to future projects. The company is deepening energy issues in relation to their Importance in today's economy. In particular, the company aims to promote alternative energy sources and the diffusion of advanced technologies in the industry, helping to encourage the development sustainable and complete supply chains in the energy sector, encouraging growth technological 3 innovation and competitiveness of Sicilian firms operating in the energy sector (F.E.R. Srl, 2014). In particular, the FER dealt with asbestos with photo-voltaic of our own, with the help of the production of a company, Mirabella Imbaccari, staff with asbestos trainers. Each company was incentivized thanks to 5 cents more for those who used asbestos. The company dealt with 6 asbestos also province of Catania, even from private individuals, the costs for us are more come, asbestos as previously has a strong impacted.

## 4. Results and discussion

In recent years the company has dedicated itself to the replacement of asbestos panels to cover the sheds to replace them with photovoltaic panels; photovoltaic systems whose photovoltaic modules are installed in place of roofs of rural buildings and buildings on which the complete removal of the eternit or asbestos is carried out. The surface of the modules cannot be greater than that of the removed cover; In addition to electricity incentives, photovoltaic systems are entitled to a premium of 12 euros/MWh, which is paid on all the energy produced (Forman et al., 2016). The Gse discloses the documentation to be provided to certify the correct removal and disposal of the eternit and asbestos, in order to access the prize.

The Decree of the Ministry of Health of 06/09/94 defines the techniques that can be used for the carrying out of the clean-up operations; they are reflected in the actions of: - removal-encapsulation - confinement of asbestos-containing material, and finally a certificate is issued by the ASP agency that investigates the correct removal of asbestos.

For the purpose of carrying out the disposal operations, the FER company needs the assistance of specialized and trained personnel in the field of asbestos removal; Costs vary depending on the area that will have to be removed with an average of 10 to 20 euros per square meter. In choosing the technical intervention system, several removal methodologies are possible that take into account multiple assessments on different factors, considering, moreover, that the rules require the removal of the materials must proceed with the subsequent demolition or refurbishment of the structures that contain them.

Inertization treatments differ in seven categories: chemical modification, mechanochemical modification, lithification, vitrification, glassmaking, pyrolytic mytization, clinker production, ceramization, depending on the type of process, which can be of a predominantly mechanical, thermal or chemical nature and the products that can be obtained.

The FER company, to improve the application of the circular economy concept, intends to implement the process through the development of different asbestos recycling techniques; this in order to instead bring asbestos, once confined directly to landfill, to be able to take advantage of a definitive inertization process and then make asbestos a raw material that can be reused in construction or something similar. Among the various inertization treatments, the company aims to carry out the process of thermochemical conversion of asbestos, which involves the combined use of chemical treatments and heat, in order to carry out the re-mineralization of asbestos and other silicate materials. This process allows you to pursue several objectives: to achieve the conversion of asbestos into other mineral forms, without going through fusion; the transformation of the organic components present in the waste to be treated, through the reaction of pyrolysis and/or oxidation; immobilization of metals possibly present in the waste (APAT, 2004). This technology provides for four main systems that provide: 1) power preparation; 2) rotating form conversion; 3) treatment of output gases; 4) Removing the outgoing product. The costs of such thermochemical conversion, excluding the transport costs of the waste, vary within a range of 175 euros to 225 euros per tonne treated, considering a plant that processes 37tonn /per day. The type of plant is very flexible, as it can be built in a place where it is planned to build a permanent plant of felling of the environment but is also offered the alternative of implementing a mobile plant, mounted on trailer, which works in depression, if this choice is more advantageous.

The material obtained through this technology is extremely versatile as it has extensive and varied industrial applications, construction and consumer products. A classification of asbestos-present materials, conducted based on their use, leads to the identification of the following groups: Cement-asbestos, material obtained from Portland cement mixtures, chrystomy asbestos, crocidolite, amphibole asbestos and/or Maoist and

water; Friction materials mainly for the transport sector; Strings and fabrics mostly from thermal and electrical systems, very homogeneous spray materials for composition and chemical and mineralogical characteristics; Vinyl materials such as tiles and vinyl flooring products with asbestos paper gaps; Cards and cartons: materials formed from asbestos and cellulose paste or inert inorganic, used as electric and thermal or acoustic insulators.

## 5. Concluding remarks

The presented approach is a novel estimate for the waste heat potential on a global scale. It reveals the vast amount of waste heat from common sectors of end use energy as well as from electricity generation.

Eternit for example is a composite with a ceramic matrix strengthened with asbestos fibers which found a huge application in the building materials industry. Its application potential resulted from both its very good insulating properties, ease of assembly, but above all from its very competitive price: eternit was thus an economical alternative to other building materials of a similar purpose. It is worth noting that as a result of the thermal decomposition of asbestos, products harmless to humans are created, which can be used, for example, in the building materials industry, or in road construction.

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# INNOVATIVE AND DYNAMIC PRACTICE TO ENCOURAGE THE CIRCULAR ECONOMY IN A SICILIAN BREWERY FIRM*

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## Abstract

The circular economy is an economic system, planned for reuse the products in the next productive cycles. In a new and dynamic world, the smallest enterprises walk to more eco-friendly politics. Between the different practices, is very important the "empty return policy". Thanks to this practice, glass bottles are used by consumers and then, they are picked up and give back to bottles suppliers. So when empty bottles arrive to the factory, they will be sterilized and reused. Sure enough with the empty return policy, the glass waste decreases by 96%. So, our objective is introduce in a small Sicilian enterprise, an eco-friendly policy like the empty return policy. In this way is possible safeguard the environment, and sensitive the citizens. In fact we could invite people to keep their used bottle with themselves, and put it in adapt areas. So for every saved bottle, they could have the right to receive a special coupon. Finally if people collect a lot of coupon, the enterprise will give them a discount.

*Keywords*: empty return policy, eco-friendly practice, environmental sustainability, circular economy, customer awareness

## 1. Introduction

Nowadays, in 2019, our planet is redundant of waste that unfortunately isn't dispose or disposed in a correct way. Like this, the human being applied and engaged for the discovery of alternative methods for reduce both volume and as a consequence, environmental impact. So the circular economy is a subject that take care of recycling and

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the reuse of trash to donate a new life, in recycling case, or to avoid the increase of garbage mass thought the reuse of that certain object, as many times as possible where is needed. About that, "the circular economy, according to Ellen MacArthur Foundation's definition, is a system that defines an economy that regenerates itself. Whit this practice, all economic activities, from extraction to production, are organized showing how waste could still be an economic resource" (Leanza et al., 2018). Circular economy (CE) is currently a popular concept promoted by the EU, by several national governments and by many businesses around the world. However, the scientific and research content of the CE concept is superficial and unorganized. CE seems to be a collection of vague and separate ideas from several fields and semi-scientific concepts (Korhonen et al., 2018).

While the terms Circular Economy and sustainability are increasingly gaining traction with academia, industry, and policymakers, the similarities and differences between both concepts remain ambiguous. The relationship between the concepts is not made explicit in literature, which is blurring their conceptual contours and constrains the efficacy of using the approaches in research and practice (Geissdoerfer et al., 2017). The main aim of the circular economy is considered to be economic prosperity, followed by environmental quality; its impact on social equity and future generations is barely mentioned (Kirchherr et al., 2017)

A very popular practice from a few decades, compatible with the fought of the environmental sustainability is the practice of empty to return. With this practice, we can reuse a glass bottle up to forty times. The only problem is the high costs. "the initial cost of implementing green attributes is expensive, and the cost savings acquired from implementing green attributes are not always sufficient to compensate for the initial green conversion investment" (Jeong et al., 2014).

In the above described context of green product development, a new recycling route has been implemented with the goal of maximizing resources and energy recovery from post-consumer waste glass through integrated waste management and industrial production (Marquis, 2017). Life cycle assessment (LCA) has been used to highlight and quantify the eco-efficiency of such an innovative waste-to-production chain, with the objective of identifying engineering solutions to sustainability during the development of new building products to be used in energy efficient buildings (Blengini et al., 2012).

A typical recycling system of glass bottles called "deposit-and-return" was used quite extensively at the retail level to recover glass bottles for re-filling. However, nowadays the system is considered no longer cost effective to operate and the quantity of glass bottles circulated in a "deposit-and-return" system has dropped to a low level. This situation became even worse after more local beverage manufacturers bottling plants had moved out of cities. This explains why the majority of local beverage manufacturers are opposed to implementing or maintaining the "deposit-and-return" recovery system. The hindering factors for the low recycling rate are that glass has a low commercial value and the immature market for after-use products. Moreover, glass is heavy which increases the transportation and handling costs (Ling et al., 2013). In this project, it's important to propose some alternatives to this aforementioned practice, in the perspective of a constant improvement, a lot more sensible to the theme of sustainability and much more favorable at an economical level for the companies that wants to adopt it.

## 2. Materials and methods

Our target is to find a method much more practical, cheap and eco-friendly as possible. Our company work on the Food and Drink area, especially in beers production. Our target is to reduce costs for glass bottles, though the outsourcing activity and especially going to reduce environmental impact, both at garbage levels and pollution, as the company that produces glass bottles is very far from here, so we would delete, or at least reduce, the

pollution deriving from the production, from the transport and from everything that follows. Our project is to reuse the bottle from the same product, reducing further waste production, thought the method of empty to return, with the particularity to provide incentives to the consumer, such as discounts and coupon to use for the products purchase, obviously in the same company. "Included and are independently and identically distributed random variables. For a given policy, the authors use simulation to estimate the expected cost rate and use the optimization package OptQuest in Arena to obtain the near optimal policy in numerical examples" (Wong et al., 2011). Empty used bottles are similarly reutilized in that they are collected, sorted, and crushed to be used mostly as a raw material for new bottles. However, only negligible proportions of the total used bottles are actually currently being recycled. (Seung et al., 2004). Green marketing incorporates a broad range of activities, including product modification, changes to the production process, packaging changes, as well as modifying advertising. Yet defining green marketing. Is not a simple task. Indeed the terminology used in this area has varied, it includes: Green Marketing, Environmental Marketing and Ecological Marketing (Polonsky, 1994). Another important theoretical insight is provided by transaction cost economics. Rather than assume that CSR is cost-free, transaction cost economics makes explicit what was previously unacknowledged theoretically, namely that stakeholder management, with the ultimate goal of increasing stakeholder satisfaction, often requires substantial resources, including time, as well as financial, and human resources in identifying a relevant stakeholder group, negotiating with representatives of the group, and monitoring their satisfaction. In the long run, CSR can increase trust and possibly reduce transaction costs. However, in the short run, managers must consider transaction costs in all strategic decision making (Orlitzky et al., 2011).

Glass is a great material, because it does not contain any toxic substances and it is resistant to deterioration. But the glass that is thrown away remains in the environment for of time. So glass recycling is a very important practice. It is an ecological process, with which environment is protected. This practice reduces energy consumption, use of raw materials and landfill waste (Moretti, 2019). From our project, came lots of results, we estimate a decrease of glass waste almost of 60% and overall with not so elevated costs, as the innovations to be introduced and the costs to be incurred are the above mentioned coupons, and the introduction of shelving designed to accommodate reused bottles, and this shelving will be located in local spaces, such as, markets, small stores end everywhere the product will be sell.

## 3. Case study: *Birrificio dell'Etna*

The enterprise *Birrificio dell'Etna* was founded in Riposto. The country outreach the coast from the slopes of Mount Etna, the highest mountain in Europe. The firm was born on 2014, thanks to the two entrepreneur Delfio Faraci and Leonardo Biasi. They was inspired by their big passion for the beer, and subsequently they was inspired by their profound creativity and innovation. Speaking of which, is good to remember that the Faraci and Biasi's idea is based on the realization of something unique, but especially tied to Sicilian territory. So the desire to exalt the smell and the taste of their country, bring they to the production of excellent and unique beer. Their product is able to impart to the consumers the same emotions of the people who produce it with very devotion and energy. The bond with the territory is very strong, for this reason the enterprise aspire to take advantage of the raw material of their country, for example the water of Etna, the old Sicilian wheat *Perciasacchi*, the must of Nerello Mascalese and the famous Bronte pistachio. The raw material and the packaging are supplied to third part; after the bottling, with the diligence of their young and dynamic team, the final product is sold to the customers, who are mainly restaurants and wine bars. In addition to the direct sales devote at the public, the enterprise realizes also sales

by means of agent and resale trough supplier. The productive process start with the grinding of malt; this operation is effectuate early in the morning, to prevent the oxidation. After that follow the phase of "crush", this operation is effectuate in about an hour and a half. Later start the filtration, during this phase the trash are washed, in this way is easy to pull out the rest of the sugar. The next phase is the boiling, it will be complete in about one hour, in very high temperature between 98/100°C and the team add also hops and some spices. Moreover begin the phase of *whirpool*, which permit to make clearer the must. After 5 minutes of *whirpool*, the operators insert the yeast necessary for the fermentation. The beer remain inside the fermentation machine for 30 days, before the bottling. The first fermentation last about one week, then follow the cooling down. Then follow the maturation; this phase lasts 15 days. Before the bottling, the operator add little quantity of sugar and yeast. First of all before the bottling, the team labels the bottles and wash them with filter water. Next the bottles are dried and the specialized operator inserts nitrogen to move away the oxygen. Moreover the bottles are filled, closed and boxed. The final product is sold after 15 days, which is after the re-fermentation.

The enterprise *Birrificio dell'Etna* is socially active to defended and respect the environment, for this reason the whole team decided to take advantage of the weather conditions of the famous "land of the sun", that is Sicily, through the installation of photovoltaic systems. In this way the firm can produces clean thermal energy, which is renewable and it is able to reduce electricity consumption. Moreover the enterprise dispose the *trebbie* of the malt, consigned it to a farmer, who will use it as fodder to his livestock. Finally the enterprise to help the environment reuse water to wash the machines. So is evident that the enterprise *Birrifico dell'Etna* operates actively from a better perspective of continuous improvement, green economy and circular economy.

## 4. Results and discussion

Carrying out an investigation it's possible to realize that the environmental protection today is the principal objective of any company. Speaking of which, we as Sicilian students, are looking for a proposal to help the enterprise *Birrificio dell'Etna* to found alternative methods to respect our planet. Our idea is to introduce, in a little Sicilian enterprise, a new common practice very famous in the last period all over the world. This practice involves the use of the glass bottle by the consumers, and then the return to the suppliers. In this way, after the sterilization, the same bottle can be reused for 40 more times. But it isn't an innovation, because in the 80s the consumers used to return the empty bottles; but because of the disregard of the business man this practice disappeared.

Although is important to re-member that some years ago has been approved in Italy a decree in favor of *the empty to return practice*. We are talking about the decree n.142 of 3 July 2017 (Decree 142, 2017). This decree proposes to the beer and water suppliers, the reuse of the empty bottles after their utilization by the consumers. This experiment lasted a year, had as a purpose the sensitization of the population, but it has been no success, in fact this decree today is not an obligation for the producers and consumers. In this regard, we want to suggest to the enterprise the better road. In fact, in spite of the complication, as the high costs for example, the advantages of the empty to return practice are limitless. First of all we can talk about the waste reduction, the energy consumption reduction and the raw material. Next, using this innovative practice is possible reduce the pollution. Moreover on the external level, also the corporate image improves, and not only in Sicily but also in Italy and all over the world. In fact, next to the awareness of the consumers, the enterprise can take advantage of the empty to return practice as a competitive advantage over companies that do not engage in environmental protection. Sensitize a consumer is not easy, for this reason is important to found the better strategy, that can involves and encourages the

population. Speaking of which, our idea is reward the consumer, conferring a coupon for every empty bottle re-turned. The collection of the coupon, give to the consumer the possibility to receive a free beer bottle as a reward. In this way the consumers will increase driven by the desire to receive coupons; and at the same time the enterprise will act consciously, looking for a sustainable economy. So protect the environment it's not impossible, but it's necessary that someone or some-thing supports enterprises.

In this regard a lot of standards and certifications, such as ISO 14001 (ISO 14001, 2015) and EMAS (EMAS 1836, 1993) are useful, because they guide enterprises to a sustainable economy. ISO 14001 is a voluntary and international standard that specifies requirements for an effective environmental management system. Integrating it with other management systems standards, can further assist in accomplishing organizational goals. ISO 14001 defines an environmental management system used to manage environmental aspects, fulfill compliance obligations, and address risks and opportunities. The ISO 14001 standard can be used within a *plan-do-check-act* (PDCA) approach to continuous improvement. Moreover, the EU Eco-Management and Audit Scheme (EMAS 1836, 1993) is a management instrument developed by the European Commission for companies and other organizations to evaluate, report, and improve their environmental performance. EMAS is open to every type of organization. In fact it spans all economic and service sectors and is applicable worldwide. ISO 14001 and EMAS are related. So since the revision of the EMAS Regulation, it is easier for an organization already complying with ISO 14001 to step up to EMAS.

## 5. Conclusion

Protecting the environment it's not difficult: it is very easy when manufacturers, retailers, entrepreneurs and customers commit themselves to respect the environment, because economic activities can harm it. Everyone needs to understand that waste is not a problem, but an economic opportunity. In fact a waste can be at same time, unnecessary to some people and very important to other people. So enterprises, and in this case the Birrificio dell'Etna, must commit themselves actively and proactively to search for eco-friendly activities. In this regard, the empty return policy is a very particular practice.

In fact, it is an effective process to reduce environment pollution. It is an example of circular economy, and it is important because is intended to re-duce waste production and waste of resources. So we are sure that, if small, medium-sized and large enterprises undertake this project, pollution will decrease. But nowadays people use a lot of natural resources and raw material. This is dangerous, because the environment is in trouble. So OCSE has developed the *Policy Guidance on Resource Efficiency*, who supported recycle and reuse. In fact if tread absent caution, resource consumption could double by 2050. In this regard, the glass almost always is recyclable, because it is a *clean* material. But the glass that is thrown away remains in the environment for thousands of years. So recycle will improve environmental condition, and this will be done by energy saving and reducing wasted raw materials. (http://gestione-rifiuti.it/smaltimento-vetro) This will not only be an economic benefit. In fact this will also be an environmental and ecological success.

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# INTRODUCTION OF PHOTOCATALYTIC SURFACES TO MINIMIZE AIR POLLUTION IN IRON AND STEEL SECTORS*

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## Abstract

In recent years, thanks to many initiatives, Europe has witnessed a remarkable reduction of air pollutants in order to reduce the danger for human health, but air pollution still represents a huge issue for the environment.
This paper deals with a firm particularly involved in this pressing theme: Acciaierie di Sicilia S.p.a., operating in the iron and steel sector. It is a company that, due to the processes carried out, must pay specific attention to inevitable environmental impact. To minimize air pollution, a smog eating structure made of photocatalytic cement can be used. In fact, the action of light on a photocatalytic surface improves the oxidation process, decomposing pollutants faster and easier. The main material of this stage is the titanium dioxide. Another material can be the concrete which has the same properties as titanium, in addition to being self-cleaning. The second innovation explained in this paper is the introduction in the company of an eco-index system in order to reduce $CO_2$ emissions and have an economic profit. These innovations entail numerous opportunities not only for the improvement of quality life and for the environment, but also for the production cycle of a company. Minimizing the emissions of the polluting gases translates into achieving significant benefits for the citizens of that specific area and for the entire environment.

*Keywords:* air contamination, photocatalytic surface, titanium dioxide, carbon dioxide, eco-index system

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## 1. Introduction

Air pollution is a mix of particles that can reach harmful concentrations both outside and indoors and its effects can range from higher disease risks to rising temperatures, moreover it is strictly related with climate change and health quality. According to World Health Organization (WHO) air pollution kills an estimated 7 million people worldwide every year and data shows that 9 out of 10 people breathe air containing high levels of pollutants. It must also be said that air contamination costs the world economy $5 trillion per year as a result of productivity losses and degraded quality of life. Those productivity losses are caused by deaths due to disease caused by air pollution and the problem is getting worse.

Even if in Europe emissions of many air pollutants have decreased substantially over the past decades, air pollutant concentrations are still too high and air quality problems persist. Actually, a significant proportion of Europe's population live in areas, especially cities, where excesses of air quality standards occur. In practical terms air pollution releases into the atmosphere various impurities such as sulfur dioxide, carbon dioxide and nitrogen oxide, finely divided solids or finely dispersed liquid aerosols at a rate that exceed the natural capacity of the environment to dissipate and dilute or absorb them. These substances may reach concentrations in the air that cause undesirable health, economic or aesthetic effects. While those effects emerge from long-term exposure, air pollution can also cause short-term problems such as sneezing and coughing, eye irritation, headaches and dizziness. Particulate matter smaller than 10 micrometers (classified as $PM_{10}$ and the even smaller $PM_{2,5}$) pose higher health risks because they can be breathed deeply into the lungs and may cross into the bloodstream.

Though many living things emit carbon dioxide when they breathe, the gas is widely considered to be a pollutant when associated with human activities that involve the burning of fossil fuels. Humans have pumped enough carbon dioxide into the atmosphere over the past 150 years to rise its levels higher than they have been for hundreds of thousand years.

With regard to the iron and steel industry, it can be said that it has significant impact on global environment. Producing steel requires the use of large quantities of energy and minerals, as well as vast mining and waste disposal areas. As a result, steel production generates significant amount of air pollutants, solid by-products and residues, as well as waste-water sludge. The pollution can take many forms and impacts not only on a local area but also it could spread to regional or global scale, including through atmospheric pollution. Air pollution from the steel sector is the result of emissions of particulate matter containing minerals (iron, iron oxide), metals (cadmium, lead, chromium, nickel, sink copper and arsenic) and other pollutants (polycyclic aromatic hydrocarbons, nitrogen oxides and sulfur dioxide). Steel industry is also a source of carbon dioxide ($CO_2$) emissions which is generated during iron and steel making operations. According to the International Iron and Steel Institute (IISI) plants can emit between 1.6 and 2.4 tons of $CO_2$ per ton of steel produced. But the iron and steel industry is without doubt one of the most important foundations of any industrial economy which had to adopt over the last years efficient processes, pollution control systems and practices in order to reduce emissions.

For these reasons the purpose of this paper is to suggest more efficient and cleaner technologies to minimize the environmental footprint and ensure the long-term sustainability of the industry.

## 2. Materials and methods

The problem of air contamination due to the emissions of some types of pollutants, such as sulfure dioxide, carbon oxide, nitrogen oxide and atmospheric particulate, represents a serious and current theme in our country and in Europe.

In recent years, many studies have been carried out on this topic and nowadays the evaluation of the level of air pollutants in places at risk is considered to be a basic step toward prevention. At the 1992 Earth Summit in Rio de Janeiro, over 150 countries signed the United Nations Framework Convention on Climate Change (FCCC) for the purpose of protecting the climate by stabilizing greenhouse gas concentrations at a level that would prevent dangerous interference with the climate system. Successively, in Kyoto in December 1997, governments around the world agreed to take further actions to reduce emissions of six greenhouse gases, the most significant of which was represented by $CO_2$. At the third conference of the parties to the Convention in Kyoto, legally binding emission reduction targets were set for the so-called Annex-I countries (OECD countries and the countries of Eastern Europe and the former Soviet Union). Although the Parties at the Convention were unable to come to an agreement on key elements of the Convention at the last meeting in The Hague (2000), the need to solve the problem still represents a crux topic.

Minimizing the danger of air pollutants is possible through some expedient carried out in the production processes. In particular, through the implementation of a smog eating structure made of photocatalytic cement. The utilization of cement-based building materials allows air pollution mitigation and improves the oxidation process in which the organic substances are reacted with hydrogen peroxide in the presence of inexpensive ferrous sulfate to reduce toxicity and $CO_2$. As a result, pollutants decompose faster and easier. The materials mainly used in this process are the titanium dioxide, which has emerged as an excellent photocatalyst material for environmental purification, and the concrete, which presents a self-cleaning function. Moreover, the problem can be bypassed through the introduction of an eco-index system in order to reduce $CO_2$ emissions.

To reach this goal, we propose a case study of the firm Acciaierie di Sicilia S.p.a., situated in Catania. It is a firm that belongs to an organization which is at the european top in the production of steel for reinforced concrete for construction. The steel companies are becoming increasingly aware about the importance of dedicating attention to sustainability and in order to become a responsible corporate citizen, the industry has begun with the identification of sustainability indicators, developed specifically for steel industry. The steel industry recognizes that it plays a key role in sustainable development because it must raise the living standards of people not damaging the environment. On the other hand, steel making leads to various environment impacts like depletion of non-renewable resources, global warming, depletion of land resources, etc. These issues have led the industry belonging to the steel sector to initiate strategies for responding to the challenges of sustainable development.

## 3. Experimental

Acciaierie di Sicilia S.p.a. starts his busyness in 1950 in Brescia with its primary activity, the steel's production (and lamination). After a few years the industry takes a good position on the market thanks to its social-economic development and receives many investments which led the industry to a consistent growth. In the ’80 Acciaierie introduces two new electric furnace and a new lamination system. In the ’90 Alfa Acciai buys Acciaierie di Sicilia: the effects are an increment of the qualitative standard, production and export. In 2004 the industry takes in consideration the importance of being sustainable and working in an eco-friendly way and starts to receive certifications for quality, environment and security.

Acciaierie di Sicilia S.p.a. has numerous processes which entail the consumption of a huge amount of heat and electricity. It is equipped with an electric-arc furnace and a rolling mill producing billets and reinforcing steel in bars and coils, by smelting ferrous scrap that undergoes preliminary X-ray control using state-of-the-art equipment. But despite the

process carried out, the company stands out for ongoing technological innovation to ensure increasingly high-quality standards while respecting the environment and the workers' health and safety.

Today Acciaierie is situated in Catania, it is certificated (EN ISO 14001, EN ISO 14021, EN ISO 14025, ICMQ ECO, SUSTSTEEL) and is based on the relationship with clients. It produces many types of steel and recently the concrete, but the most important asset is its respect forward workers, environment and security in the system.

The company is also oriented towards the future trying to gradual adopt the best available techniques to be applied in the design, management, maintenance and decommission of industrial processes. The aim is to safeguard the environment in general at the best, and prevent, reduce and minimize pollution as far as possible by intervening at source. This will ensure the careful management of natural resources and drive processes towards increasingly high levels of efficiency.

## 4. Results and discussion

The purpose of this research is to describe some types of innovations in order to minimize air pollutants in the iron and steel sector. The first innovation is linked to scientific studies on photocatalysis started about two and a half decades ago. Titanium dioxide ($TiO_2$), which is one of the most basic materials in our daily life, has emerged as an excellent photocatalyst material for environmental purification.

In this review, current progress in the area of $TiO_2$ photocatalysis, mainly photocatalytic air purification, sterilization and cancer therapy are discussed together with some fundamental aspects. A novel photoinduced super-hydrophilic phenomenon involving $TiO_2$ and its applications are presented. Photocatalyst is the branch of chemistry concerned with the chemical effects of light. Generally, this term is used to describe a chemical reaction caused by absorption of ultraviolet (wavelength from 100 to 400 nm), visible light (400 – 750 nm) or infrared radiation (750 – 2500 nm). A catalyst does not change in itself or being consumed in the overall chemical reaction. This definition includes photosensitization, a process by which a photochemical alteration occurs in one molecular entity as a result of initial absorption of radiation by another molecular called the photosensitized. Photocatalyst accelerates the oxidation process in the atmosphere and decomposes any air borne toxic organic matter. There are various materials that show photocatalytic capability and titanium dioxide ($TiO_2$) is said to be the most effective. When photocatalyst is exposed to light in the presence of water vapor, two highly reactive substances are formed: hydroxyl radicals (OH) and a superoxide anion ($O_{2\text{-}1}$). It allows the oxidation of airborne $VOC_s$ and toxic organic matter into carbon dioxide and water at room temperature with light source. It does not need a special energy and uses only clean energy in ordinary life. Specific titanium has strong photocatalyst reaction, it has strong oxidation and decomposing strength.

A promising approach for remediating volatile organic compounds or $VOC_s$ is to employ photocatalyst that oxidize these compounds. It is a substance that facilitates chemical reactions by photo-irradiation without becoming transformed:

*Toxic $VOC_s$ + light + water + photocatalyst = non-toxic inorganic gas + photocatalyst*

Photocatalyst has the following advantages over any current air/water purification technologies:

1. real destruction of pollutant rather than a simple transfer on a substrate
2. degradation of pollutant at ambient temperature and pressure
3. build with easily available materials and by mean of well-known techniques
4. economical, cheap and low energy consumption
5. adapted for a large range of pollutant (VOC, bacteria, mold…).

The chemical process that transforms those that have always been considered passive inert into active agents against the smog of our cities lies in the oxidative process of photocatalysis for which titanium dioxide ($TiO_2$) is responsible, which, in the presence of light (ultraviolet rays), attracts and retains the molecules of $H_2O$ (moisture) naturally present in the air, capturing the thin dust and with them the nitrogen oxide. An oxidation process that already occurs naturally but that the photocatalysis accelerates, favoring a more rapid decomposition and avoiding the accumulation of harmful substances.

Photocatalysis produces nitrates and nitrites: the whole thing happens therefore at zero cost and in a very similar way to the well-known chlorophyll photosynthesis with the result, perhaps less satisfactory, of producing nitrates and nitrites rather than oxygen. Nitrates and nitrites are salts considered harmless for health because they have always existed in nature. They are responsible for that patina of dirt that covers the surfaces in question and that is however easily eliminated since, being soluble with water, it is carried away with the simple action of the rains. It therefore guarantees a self-cleaning capacity and an antibacterial quality, as well as an anti-pollutant action, since the salts prevent the attack of algae and bacteria and are easily eliminated.

It seems to be a real inexhaustible course: the photocatalyst particles, directly involved in the oxidation process, are not consumed and for this reason the action of titanium dioxide remains unchanged over time.

However, there are hints for some concerns related to the concept of harmlessness of the salts produced. The natural reserves of nitrites and nitrates have recently been radically altered by human action due to the extensive use of fertilizers as well as by their use in food preservation. The consequences of this altered production are the high concentration that accumulates in the groundwater and in soils with not a few negative effects on human health. Nitrites and nitrates are responsible for decreasing the oxygen transport capacity of the blood, reduced thyroid function and vitamin A scarcity, not to mention the indirect implications in the most common causes of cancer.

The second innovation of this paper is strictly linked to the adoption of pillars of sustainability and in particular of sustainability indicators. For this reason an eco-index system, specifically developed for iron and steel sectors, is presented. Integration of key sustainability indicators is quite essential for decision-making, performance evaluation, economical, environmental and social growth, in fact this goal can be achieved with the introduction of AHP (Analytical Hierarchy Process) wich is used to evaluate the impact of an organization's sustainability performance.

The advantage of data envelopment is that no functional form is imposed to the data as the benchmark is not based on the theoretical bounds but it is linear combination of best performances. The value of the composite indicator depends on the benchmark performance and the best performer will not see their progress reflected in the value of the composite if there are not enough data. With highly correlated indicators, there could be identification problems: it depends on the chosen sample of respondents and how questions are framed. The estimation process is quite complex and it requires a large sample of respondents and each respondent is required to express a large number of preferences. Weighting according to missing data method improves the reliability of a composite indicator by giving more weight to the components with higher quality and availability. However, eventual skewness of the results of composite rankings towards simpler, more readily available or identifiable factors. AHP is a widely accepted technique which enables consistency check of the comparison-matrix through the calculation of eigen values. Both quantitative and qualitative measures can be included in the evaluation scheme. Subjectivity in setting priorities for evaluation criteria and assessing divisional performance is reduced. Because of the vast diversity of the conditions in sustainability issues, a 'universal' methodology is not realistic; rather, existing methodologies are sometimes adopted in part or modified to suit the problem at hand but the

AHP is adopted, as it offers a logical and representative way of structuring the decision problem and deriving priorities. AHP explicitly ranks tangible and intangible factors against each other for the purpose of resolving conflict or setting priorities, moreover it compares decision factors by pairs and assigns weights to reflect their relative importance.

AHP can help to improve the decision-making process, furthermore, it can be easily understood and applied by operating managers and can enable all members of the evaluation team to visualize the problem systematically in terms of criteria and sub-criteria.

## 5. Conclusions

The photocatalytic technology involves the pollutants carried out and it requires a certain light intensity. For this reason, thanks to the optimal geographical position of Acciaierie di Sicilia, this innovation is particularly suitable for such an industry.

The eco-index system represents a huge advantage for the monitoring of processes, data and the pollutants carried out and is a source of economic, environmental and social growth. Acciaierie di Sicilia S.p.a. is future-oriented, tries to improve quality standards every day and it works in a sustainable way in order to protect our territory and the environment. It is an example to be followed for the other companies in Sicily and all over Europe.

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# NEW CIRCULAR ECONOMY VIEWS IN THE SICILIAN IRON METALLURGICAL SECTOR: RECOVERY AND SURPLUS VALUE OF PRECIOUS MATERIALS FROM THE METAL MELTING PROCESS*

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## Abstract

New solutions in the field of waste treatment technologies allow the separation of valuable materials, that come out during the production process, and their recovery. The steel sector is particularly involved in the application of these innovations; it's able to take full advantage of these new technologies and serves as perfect base for a "circular economy" production process. The objective of this paper is to show how this technology allows the special metals, once considered waste, to have a new circle of life by removing dump materials and obtaining added value. "Acciaierie di Sicilia S.p.a. is a leader in steel production in Italy and it is the main focus of this study. This company already embraces an eco-sustainable production process using junked cars and other metals that were sent to landfills as raw material. The purpose of this study is to evaluate an investment which could introduce a recovery system of dross, produced from the melting process of metal, in the company.

*Keywords:* circular economy, special waste, steel, material recovery surplus

## 1. Introduction

In recent years, special attention has been paid to environmental issues that is affecting humanity. In their book "Green to Gold," Esty and Winston (2006) offer a list of the top 10 environmental issues affecting humanity: climate change, energy, water, biodiversity

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and land use, chemicals, toxins and heavy metals, air pollution, waste management, ozone layer depletion, oceans and deforestation.

To avoid and/or limit the environmental impact, we are talking about sustainable development, that is “development which guarantees the needs of current generations without compromising the possibility that future generations will be able to satisfy their” (WCED, 1987), and it combines environmental, economic and social issues. This type of approach is also known as "triple bottom line" or "balance rule of 3 E" (equity, economy, ecology). To ensure sustainable development, a circular economy is used to reduce resource consumption and minimize waste. The circular economy is a shift from linear business models, in which products are manufactured from raw materials and then discarded at the end of their useful life, to circular business models that lead to repair, the re-use and recycling of products. A study of seven European nations found that a shift to a circular economy would reduce each nation’s greenhouse-gas emissions by up to 70%. The hierarchy of principles on waste at European level (Directive 2008/98/EC) makes it necessary to optimize the exploitation of resources (both raw materials and waste) and to minimize the dispersion into the environment of pollutants resulting from human activities. Many companies implement waste management programs that consist in taking back and treating products used in an environmentally friendly way (product recovery).

The steel industry is an integral part of the global circular economy, and steel has fundamental advantages as a material for achieving the following objectives: promotion of waste, reduction of the amount of resources and energy used, manufacture of products easier to reuse or regenerate. This makes steel an essential material for the future. In order to improve the company’s interaction with the environment, both in terms of resource exploitation and in relation to the production of waste and pollutant emissions, an assessment of the environmental performance shall be followed. To do this we use quantities that describe the interaction of the enterprise with the environment, called environmental indicators, which are compared with reference values that take into account legislation, the latest environmental performance assessment and data for the same type of companies. The assessment of environmental performance allows the company to obtain a number of advantages: cost reduction, compliance with legislation, anticipation of future legislation, reduction of environmental risks, customer needs adequacy, better relations with supervisory authorities, better corporate image, increased business opportunities, employee satisfaction. The objective of this document is to obtain added value from the waste materials of the production process of the steel industry, in particular from lead and zinc deriving from the dust suppression system.

## 2. Material and methods

The approach that we will use in this project aims to optimize the advantages obtainable from the materials collected after the abatement of the dust coming from the towers of the chimneys. In fact, the aim will be to obtain added value from these residues, using them after their recovery. So there will be two basic steps to take: The recovery of the materials to which we are interested, and subsequently identify a useful input for the business in question. As will be shown in the section dealing with the detailed analysis of the results of the survey carried out, the main materials recoverable from the dusts produced during the steel production cycle are zinc and lead. These two materials are extremely used and usable for many purposes.

ZINC: Zinc and its oxide is used as a white pigment in colors and water-based paints, and as an activator in the rubber industry, it is used in alloys for the production of goldsmiths and silverware, it is used in alloys such as brass, nickel, metal for typewriters, various welding alloys, German silver etc.

LEAD: It is used to form glass bars for stained glass windows or other illuminated multi-window; lead sulphate and lead chrome are used as colouring elements in paint and ceramic enamels, especially in red and yellow colors.

To achieve these goals we will use the "Waeltz Process" which allows to recover, by chemical processes-lead and zinc and subsequently identify a market that may be interested in purchasing these materials from a circular economy process. It is interesting to assess the extent of the surplus that this new activity could generate, not only monetary but also ecological that in its entity is defined as "an estimate of the level of sustainability of a community's lifestyle compared to the resources of the area taken as a spatial reference" (S. Franco, E. Blasi, 2012). Such environmental benefits are also useful to achieve the goal of becoming a "Green company", in which "environmental accounting is also fairly developed showing the highest average value ever" and "respond to the environmental agenda in a very vigorous way by implementing a number of different practices" (Cinquini, et al., 2016). In this way we will be "able to satisfy the economic and social needs of all the parties involved, with totally acceptable burdens on the socio-economic system and with great benefits for the development of the system itself" (Thione, 2004).

The application of this method is proposed and therefore the achievement of the sprayed objectives mentioned in the "Acciaierie di Sicilia S.P.A.". This company, which produces sustainable steel B450S, is the only one in southern Italy to use as raw material metal from carcasses of cars and other waste metal. This feature allows it to be unique in its kind and gives it a competitive advantage towards all customers who pay attention to the topic of sustainability. Moreover, its many voluntary certifications made it even more valuable from this point of view.

## 3. Experimental

Acciaierie di Sicilia S.p.A is purchased by Alfa Acciai in the 1990s, the only steelworks on the island about steel industry. It focuses on quality standards, on production levels and consequently on exports, also supported by the strategic position in the center of the Mediterranean, specifically in the industrial area of Catania. The production process of Acciaierie di Sicilia S.p.A is characterized by an electric arc furnace and a rolling train and produces billets and rebar in bars and rolls, through the smelting of ferrous scrap previously verified by a radiometric control system. The continuous casting, which produces billets of square section of 130 mm on the side and 6 or 12 m of length and intended for internal rolling and selling, is supplied by the EAF (electric arc furnace).

Lamination takes place constantly through the continuous casting and through roughing cages, intermediate and paver and the process ends with a Tempcore treatment of thermal type reaching mechanical characteristics in compliance with national and foreign regulations. There is also a complex system of cutting, packaging and binding of the bars in bundles for lengths from 6 to 15 m for diameters from 8 to 32 mm, which guarantees high quality standards and a plant for hot winding (spooler or coiling machine) for diameters from 8 to 16 mm. Acciaierie di Sicilia S.p.A has several fundamental certifications in the field of sustainability. First of all, the EN ISO 14001 for: the protection of the soil, the subsoil and the waters; reduce energy consumption; limiting noise pollution; manage waste. EN ISO 14021 focused on recycled material that covers 97% of the company. EN ISO 14025 guarantees transparency on emission and impact levels and on the energy efficiency of processes. Environmental performance is measured thanks to ICMQ ECO, a certification that emphasizes compliance with the principles of environmental sustainability which requires as a prerequisite the certifications of management systems for quality, the environment and safety (EN ISO 9001- EN ISO 14001 and OHSAS 18001). Moreover, Acciaierie di Sicilia S.p.A was among the first companies to obtain SUSTEEL Sustainable Steel Certification. To

approach the Green Economy, the company has not only obtained environmental certifications but has also adopted several maneuvers. In fact, plants are used to reduce the environmental impact thanks to the upper hand of new advanced technologies and continuous monitoring of the environment takes place thanks to environmental policies.

## 4. Results and discussion

This business uses materials deriving from the local demolition, which would normally be considered as refuses. Thanks to the used technology, the company's product is EcoSustainable Steel B450S, produced as bobbins, rolls and billets, which during the years obtained the highest as eco-sustainable product. To confirm it, Acciaierie di Sicilia starting from 2001 attains all of the most important Italian environmental certification:

- UNI EN ISO 9001:2015, from 2001 it keeps on being renewed
- UNI EN ISO 14001:2015, also this from 2004 keeps on being renewed

The company is subjected to continuous checks, both actively conducted and, most of all, conducted by external agencies, such as ARPA Sicilia and ANPA, both on raw – second material coming in to the industry, studied by a radiometric control system, but most of all continuous monitoring of the production waste. These can be dived in:

- demolition materials
- scrap ferrouses
- flakes for rolling
- wastes from electric arc furnace
- dust suppression from industrial chimney (cer 100207)
- absorbent materials and filtering materials
- white slags form furnace

The main study conducted regards the level the type of materials/waste coming form the Dust Suppression (CER 100207): this study showed the presence of different materials and their trend, among which the most important are Lead and Zinc (Fig. 1).

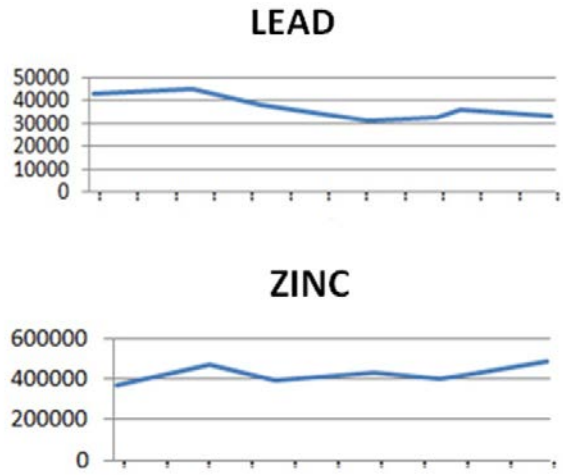


**Fig. 1.** Levels of Lead and Zinc in the industrial filter

Fig. 1 shows the trends and, first, how the company stays in the limits imposed by the law, but most of all underlines the success of the investment in the Industrials Chimney. Thanks to this implant, there's the opportunity to regain some materials filtered by the filter

in the chimney. Adopting this new technology could achieve all the results set, thus being able to use what was previously a waste of production as a resource. Object of the study is to adopt a technology that can close the cycle of two different production cycles, the lead's one and the paint's one. In order to obtain this type of results, as it emerges from the completed study, it could be adopted the "Waelz Process": it consists in a series of chemical and physical proceedings (drying, reduction, vaporization, oxidation etc.) conducted in a tubular oven, whose dimension vary with the requested potentiality, and using carbon as fossil fuel.

As Fig. 2 shows, the fumes produced by the Electric Arc Furnace are introduced in to the Waelz filtering system, mixed with coke and lime or sand. Once in the system, vapors of Zinc and Lead are introduced in to the process, and brought to ever higher temperatures (600°C – 1100°C – 1300°C). The chemical process is completed with the input of oxygen and the use of a burner, in the 4$^{th}$ phase, from which are then produced the Waelz Slags. According to the prospect of using the "Waelz Process", the company has already equipped a coal dust filtration system, which could be used to feed the chemical and physical process (Fig. 3).

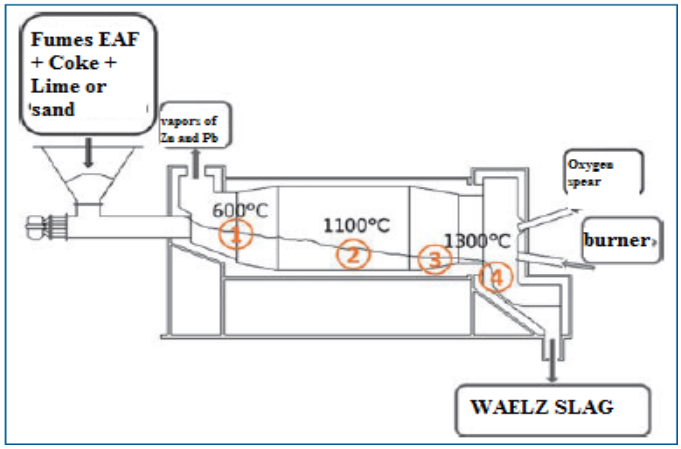


**Fig. 2.** Operating Scheme of the Waelz Process

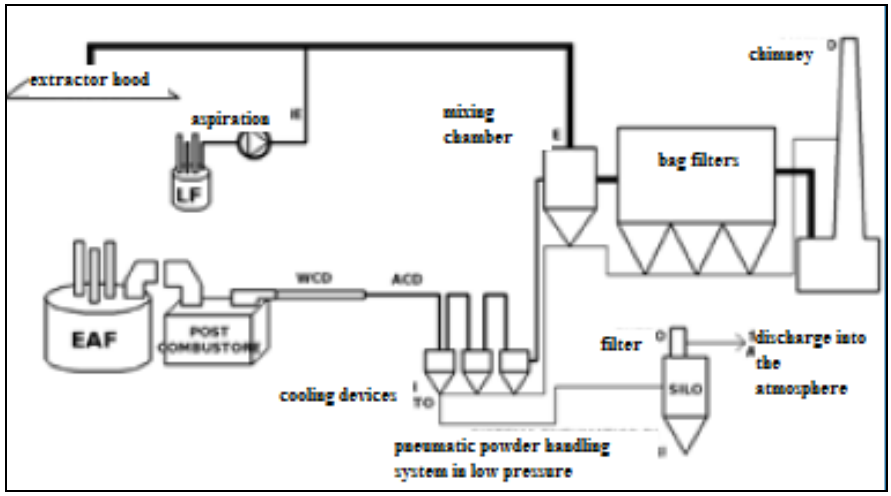


**Fig. 3**. Scheme of the Waelz Implant

The raw material mostly used are the steelworks powders, and normally disposed of in landfilss, produced by the processes in the EAF, aspirated by one the bores and suppressed and stored in special filtering installations. The production capacity of today's plant is about 60.000 t/a of Waelz oxide, compared to a supply of fumes of about 180.000 t/a, with a zinc extraction yield of about 90%. Today the steel industry in the European Community produces more than 1.000.000 t/a of steelworks dust than if it is recycle at Waelz, lead to the production of about 250.000 t/a of metallic Zinc with a total slag share sent to the landfill of about 600.000 – 800.000 t/a. The Waelz process is ranked among the BAT (Best Available Technologies) and remains by far the most used technology for the recovery of steel fumes in the world, despite several new processes tested for this purpose in recent decades, but which for various reasons have not succeeded in. The Waelz process permits the recycling of the steelworks powders, reducing so the environmental impact, allowing the production of a secondary raw material, that being mostly destined to the zinc production, would be a perfect improver between the final sector of the Eco-sustainable Steel production, and reducing the environmental impact (Fig. 4).

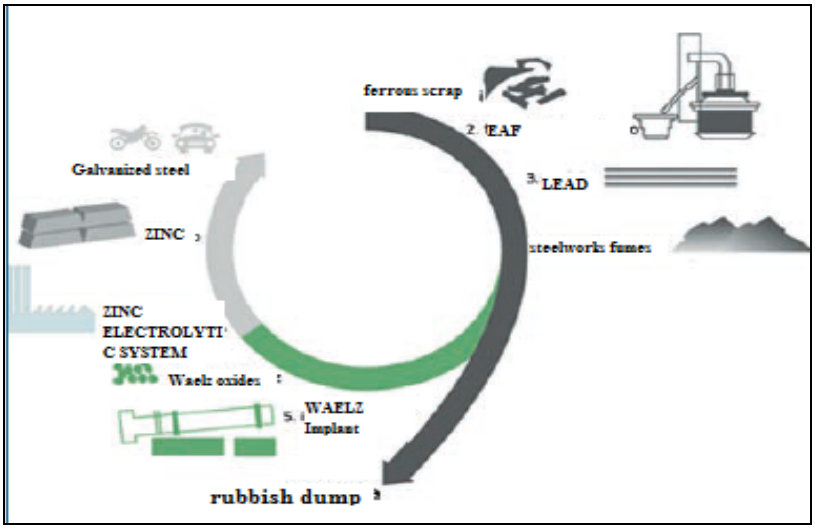


**Fig. 3.** Closing of the production Cycle of Zinc

Indeed, one of the main problems of steel production technology has long been considered with hard technology, with a high environmental impact, and over time there have been numerous cases of steel producers, whose environmental impact has been found to be among the highest in the world, and which have therefore been forced to close (for example, Acciaierie di Terni). Normally, most of the companies in this sector use raw material taken directly from natural resources for the production of steel. Sicily's steelworks, on the other hand, thanks to its current production plant, already manages to create a system of circular economy, using the carcasses of disused cars. Thanks to this solution, their environmental impact is very low, eliminating thousands of tons of materials that otherwise should be disposed of differently, surely creating environmental damage; instead, matter is given a second life, being still reusable. With the adoption of a process such as this proposed, the main aspect on which one could focus would be the creation of a further cycle of circular economy For the first time using the Waelz process, in addiction to increasing the quality of the final production slag, there would be several advantages:

- economic, because it would permit to put down the slag's disposal costs, making the installation more efficient, and eventually reuse slags by entering them in the new productive cycle; the company could also sell the new material to all of those companies interested in the use of the "new" Zinc and Lead, so they could also cover the costs of the new installation.
- productive (and so also economic of course) because it could let the company have more continuity in the production flow, lowering creation of fouling in the furnace, so making the cycle more efficient.

Using a very elaborate installation, which could let the raw material be divided depending on the composition and the density of the materials, there would be an even more controlled reaction that would bring several economic and productive advantages, and mostly there would be a so low slags content that the company could avoid further treatments, and enter them quickly the paint production cycle. Despite the enormous advantages that this technology could bring, there are some fundamental aspects to consider in order to consider the investment: The cost of the system is not irrelevant, a high amount of slag is needed for the process to work as efficiently as possible, the economic benefits are more important if finishing the material if subsequent processes is avoided, only increasing the yield of the machinery would result in a greater economic advantage.

## 5. Conclusion

Investments in production facilities according to the Waelz process would allow to increase the production capacity of the company and of the whole sector, in addition, the environmental impacts of the production cycle of both steel and the extraction of new raw materials in the paint industry would be reduced, in the light of the Green Economy, but above all, it would be possible to obtain strong economic increases for the companies themselves, thanks to the possible resale of this "new" raw material produced, and closing a previously linear production cycle, in full consistency with the optics of circular Economy today pursued and adopted by the company.

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# POLICIES FOR THE DISPOSAL OF AGRI-FOOD WASTE IN THE GREEN ECONOMY SPHERE: SUSTAINABLE MANAGEMENT OF FOOD WASTE IN LARGE-SCALE ORGANIZED DISTRIBUTION*

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## Abstract

In the world one third of the produced for human consumption becomes waste: there are several losses along the food chain and this bad habit brought to useless waste of natural resources, energy, and labour, with prohibitive economic costs and worrying environmental impacts. In European countries bad habits and marketing policies of large retail chains contribute most to food waste. In response to this "new" alarming social issue, in recent years many Italian companies have improved new strategies to face the problem in a sustainable way. Sicily is working on policies to manage food waste from the perspective of environmental sustainability, in an attempt to define guidelines for the prevention and management of food surplus, according to an approach that involves various levels of the food chain up to the distribution, with the aim to improve efficiency and effectiveness throughout the different phases of the process. The Deco supermarket chain, of F.lli Arena S.r.l. actively engages in innovation and coordination projects and policies to better manage food waste, with agreements and donations to local non-profit associations, such as Caritas that redistribute products with TMC (minimum allowed term) expired but with a far final deadline. Each donation requires a deep audit process, an accurate delivery note (transport document) containing a self-declaration for a complete health and hygiene check.

*Key words:* food waste, human consumption, non-profit organizations, social benefits, sustainability

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

Circular economy is a continuous positive development cycle that preserves and enhances natural capital, optimizes resource yields, and minimizes system risks by managing finite stocks and renewable flows. It works effectively at every scale. (https://www.ellenmacarthurfoundation.org). Although there is no commonly accepted definition of CE so far, the core of CE is the circular (closed) flow of materials and the use of raw materials and energy through multiple phases. The "3R" principles - reduction, reuse, and recycling of materials and energy - are often cited to describe the three possible approaches in practice (Yuan et al., 2006). With the development of CE, it was increasingly recognized that this approach would be a more efficient solution for the improvement of resource productivity if it shifted its focus from recycling waste to adjusting.

Sustainability has become a mantra for the 21st century. It embodies the promise of societal evolution towards a more equitable and wealthy world in which the natural environment and our cultural achievements are preserved for generations to come. The importance given to food waste is linked to the increasing global awareness of environmental impact of large scale distribution wastes. Although waste is formally defined in different legal jurisdictions, definitions relate to particular points of arising and are often framed in relation to specific environmental controls. Food waste occurs at different points in the FSC, although it is most readily defined at the retail and consumer stages, where outputs of the agricultural system are self-evidently 'food' for human consumption problem with much scope for improvement (Parfitt et al., 2009).

Swedish Institute for Food and Biotechnology (SIK) in 2011 on behalf of FAO (Gustavsson et al., 2011) studied global wastes and losses among the production chain that have been estimated to be 1.3 mld tons per year, that is 1/3 of the whole human food consumption (Azzurro and Giordano, 2014). An amount of 5.6 million tons of food surplus, meant to be generated, transformed, distributed or prepared to be sold is not consumed. The management process quality of food surpluses depends on many choices made analyzing four different key variables: surplus regulation methods, process formalization level, coordination between the functions and the logic of setting up the booking process.

The process is well structured if waste measurement is methodical, activities and decisions are formalized and if there are explicit mechanisms of coordination between the various functions involved in the process and clear mechanisms of relationship with Non-Profit organizations (https://www.bancoalimentare.it). The primary source of surplus food is shown to result from products reaching the internal sell-by date, i.e. the date by which manufacturers and warehouses must supply perishable products. Donation to food banks is found to be a relevant management practice in the ambient and chilled manufacturing segments and at retail distribution centers, while frozen food companies and retail stores are found to rely nearly exclusively on waste disposal (Garrone et al., 2014). There are many serious negative consequences of household food waste. Firstly, it has a social impact as it contributes towards increases in global food prices, making food less accessible for the poorest as well as increasing the number of malnourished people both in developed and developing countries (Stuart, 2009).

Food loss and waste have many negative economic and environmental impacts. Economically, they represent a wasted investment that can reduce farmers' incomes and increase consumers' expenses. Environmentally, food loss and waste inflict a host of impacts, including unnecessary greenhouse gas emissions and inefficiently used water and land, which in turn can lead to diminished natural ecosystems and the services they provide (Lipinski et al., 2013).

The complexity of the food waste issue also links it to the three parts of sustainable development: economics, social issues and environmental impact. This does not mean that reduced food waste automatically results in sustainable development but reducing unnecessary food waste has the potential to make an important contribution and also has a high symbolic value (Eriksson, 2015).

## 2. Material and methods

Starting from the issue of the undesirable food surplus, the priority is to prevent overproduction and oversupply of food beyond human nutritional needs at all the stages of the FSC. In retail and the consumption stages, such as the food service sector and households, food surplus prevention includes the supply of only what is required, correct portion sizing and addressing unsustainable consumption patterns. For the surplus food that has not been consumed, the option of redistributing it to groups

affected by food poverty is proposed; assuming food safety can be ensured (Papargyropoulou et al., 2014).

There are many management tools that a company can use to analyze and control "food wastes" in the large scale distribution such as:

- LCA methodology is the internationally standardized method that is considered one of the most effective management tools for identifying and assessing the environmental impacts related with waste management options. In particular, the broad perspective of LCA makes possible to take into account the significant environmental benefits that can be obtained through different waste management processes (Cherubini et al., 2009). In contrast to other materials, such as waste paper or metal, the open loop recycling in the food waste management chain makes the discussion related to characteristics related to losses in the recycling process as well as effects on the demand for goods and services in the background system due to the recovery in the foreground system less relevant. LCA of food waste management is still a complex field as it includes both technical and biological processes. A characteristic of food waste, different to many other waste fractions, is that food waste will be subject to biological processes during the waste management chain (Bernstad and la Cour Jansen, 2012) since it is "best before", which allow us to consume the product in a longer term than the one wrote on the back.

- Life Cycle Impact Assessment (LCIA) aims to understand and evaluate environmental impacts based on the inventory analysis, within the framework of the goal and scope of the study. In this phase, the inventory results are assigned to different impact categories, based on the expected types of impacts on the environment (Roy et al., 2012).

The company analyzed in this paper adopted the ISO 22000, which is a global standard developed to harmonize, on a global level, the requirements for food safety management, for businesses in food businesses (BS EN ISO 22000, 2005), apart from food manufacturers.). The standard combines interactive communication, system requirements, prerequisite programmes, and HACCP principles to assure food safety (Mensah and Julien, 2011).

The systemic approach adopted by the ISO 22000 standard is based on the application of process management principles. In this context, the management system of an organization can be viewed as a single large process, based on the Deming cycle (Plan-Do-Check-Act), which may be broken down to several sub-processes (Bhuiyan and Alam, 2005). Effective management of food safety oriented processes ensures effective management of the whole organization (Armistead, 1999) The development of ISO 22000 was based on the assumption that the most effective food safety systems are designed, operated and continually improved within the framework of a structured management system, and incorporated into the overall management activities of the organization.

If waste minimization in all aspects of the food and drink industry is to be achievable, supermarkets of the future must actively pursue and disseminate purchasing policies based on better supply chain optimization according to environmental criteria and objectives.

One of the problems closely associated with food waste is food security and the moral implications of throwing away food while people in parts of the word are starving (Stuart, 2009), recent studies of food waste in supermarkets mostly focus on describing the quantity of waste, problems causing it and how it could be given to charity in order to avoid waste (Ericksson, 2015; Gustavsson and Stage, 2011). There is therefore a need to take this problem one step further and investigate waste prevention and waste valorization measures, and the potential to reduce the environmental, social and economic impacts related to food waste (Eriksson, 2014).

## 3. Experimental

In the mid-seventies, the Arena brothers founded the Società F.lli Arena s.r.l. in Valguarnera Caropepe, in province of Enna. In 2006 the Deco project was born, with daily work Decò has become a reality of widespread distribution, which makes of reliability and closeness the values of excellence to be offered every day. They suddenly had success that was the result of their knowledge of the territory and the needs of consumers. High quality is no longer a slogan but the essence of the Mediterranean tradition, to offer a safe and delicious taste experience. In 2007 Decò started growing. Due to the enthusiasm of the staff and the trust of its customers, it expanded its commercial network, opening the first Maxistore Decò, which together with the supermarkets expanded the offer of quality and convenience, adding many new features.

Large outdoor parking spaces and large spaces to market over 6,000 products: an offer that was renewed several times a day that was completed with a vast and high quality assortment of Decò brand. Subsequently in 2008 Decò launched a new formula: the first Superfreddo opened, specializing in the sale of frozen and deep-frozen products divided between branded and Decò branded products. Their economic advantage was the rich assortment of bulk products, to allow a "tailor-made" cost, convenient and with no wastes, with the guarantee of Decò on the maximum conditions of hygiene and traceability of the supply chain. In 2010 Decò decidedly reached an important milestone: the 200th store.

With the pressing crisis Decò shows itself close to its customers, launching promotions and special offers regularly and frequently. A couple of years later “market” Deco were born, they are "neighborhood sales points" due to their size they can be more present in the inhabited centers. In 2014, thanks to its organization, a quite perfect logistics and distribution network and a high reputation of the Decò brand, it also reached Rome, opening its first stores in the capital. It was an important moment of growth, a goal achieved with pride and passion for everything that is genuinely Italian. With less effort and work, in less than ten years, the three 300$^{th}$ point of sale is opened. Decò's success starts from people who choose it every day to do the shopping, having the customer at the center of their marketing plan, making them feel good and receive a “familiar” welcome and a first-rate service, together with a rich and quality choice. Decò celebrates its 10th birthday in 2016: today there are more than 500 sales points spread throughout central and southern Italy. Today Decò employs more than 6,000 families. Decò wants to be more and more the daily choice and to achieve that goal it has expanded the number of formats of its stores. The SuperStores are added to the Supermarkets, Maxistore, Market and Super-cold: even more extensive sales areas with more than 15,000 references between packaged products and fresh products to compose its assortment. Decò meets the needs of a large target group of customers, like many large-scale retailers. The suppliers of Decò products are selected companies with a traceable and transparent supply chain, which always maintain the standard of "high quality with anaffordable price". The Decò brand products include experience, knowledge of the territory and attention to consumers, respecting the culinary traditions of the Mediterranean culture.

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The company makes quality one of its key factor, which is why it operates in accordance with ISO 22000, the fundamental standard for safety management systems in the agri-food sector, thus communicating to all stakeholders and demonstrating the company's commitment to the issues corporate security, in compliance with the requirements of Corporate Governance, Corporate Responsibility and Sustainability Report. Decò cares about the earth, it actively engages in the respect of environment, creating a cycle of recycling aiming to recover 100% of the plastic from packaging and installing solar panels to produce energy and be able to target a zero impact goal. This is why an environmentally aware brand like Decò, since 2012, has decided to increase the use of photovoltaic panels to meet their energy needs. A commitment that produces 5.5 KWH of electricity, clean and sustainable, from photovoltaics, equal to the average electricity consumption of 687 Italian families in 3 years. Decò knows that sustainability of today's structures means the best for everyone's future.

## 5. Results and discussion

In order to reach its sustainable objectives the F.lli Arena company has favorably adhered to the Law No. 166/2016, concerning provisions on the donation and distribution of food and pharmaceutical to limit food waste. This Act pursues the purpose to reduce waste for every stage of processing, production, administration and distribution of food, pharmaceuticals and other products through the

implementation of some expedients. In particular it encourages companies to donate food rather than to destroy it by simplifying the administrative procedures to be given to public authorities; it establishes a hierarchy for the use of products prioritizing the recovery for human consumption; it simplifies the donation of agricultural and farming surplus that fit for human and animal consumption and it enables municipalities to reduce waste taxes for companies donating surplus food. In 2017 the company stipulated several agreements among the various Sicilian voluntary associations. The F.lli Arena donates food surpluses to non-profit organizations (such as Caritas) that deal with distributing them to the needy. In 2018, considering only 34 PDVs, the F.lli Arena has calculated a sale of 99.97% pieces of which 0.13% sold to the charities with which it has stipulated the conventions. Among the various food categories sold in 2018, the category of fresh products (dairy products, cheese, cured meats etc.) is the one that is donated the most.

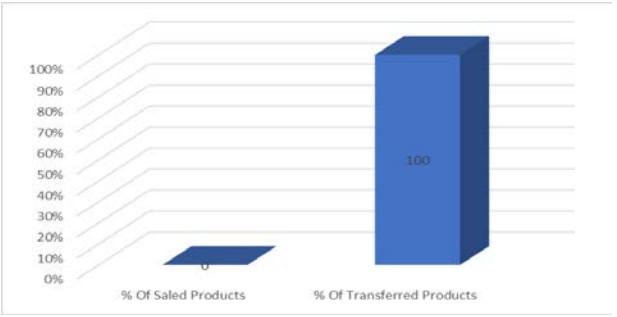


**Fig. 1.** Wasted and sold products

The transferor company, for each individual transaction, must prepare a transportation document (DDT), progressively numbered, or an equivalent document, containing the indication of the date, of the identifying details of the transferor, of the transferee and of the person in charge of the transport , as well as the quality, quantity or weight of the goods donated. In order to obtain the taxation exclusion, the beneficiary (Caritas) must make a specific declaration of use of the transferred goods, to be kept in the records of the transferring company, indicating the details of the transport document, and in which he attests « its commitment to directly use the goods received in accordance with the institutional purposes, and that, under penalty of forfeiture of the tax benefits provided by this decree, it realizes the actual direct use for non-profit social solidarity purposes ". From the objective point of view, the total deductibility (the sum that is subtracted from the income on which the taxes are calculated) from the transferring subjects' business income, concerns the production or purchasing costs of donated food products whose production or trade is part of the business of the company.

Relating to the financial advantages for local taxes, municipalities can apply a coefficient of reduction of the waste tax (TARI) to non-domestic users related to commercial activities that produce or distribute food wastes, and that, transfer such foodstuffs to the needy or for animal feed. Preventing food from being wasted has benefits in boosting the availability of food locally and resilience, reducing costs and land used to dispose of food waste, and avoiding greenhouse gas emissions, particularly methane. The awareness that food products have a life, a purpose and an end, and the knowledge that their value is not only found in their price but it includes the work and the dignity of the man who produced them, and the use of natural resources, will lead us to waste less food.

## 6. Concluding remarks

In the large scale distribution we have lot of food surplus and wastes, this is due to close deadlines of products. This surpluses could be faced in many ways, the company we analyzed got a proactive view. The main use of this food is bound to onlus association, such as local caritas that receive the 100% of potential wastes. Most of the wastes are linked to bad habits of families that consume food in a "wrong way". An alternative way of reducing wastes could be an awareness policy of local families, with a sensibilization about the respect of the environment and all the catastrophic consequences that could be linked to it.

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# BIOACCUMULATION OF CHLORINATED ORGANIC COMPOUNDS IN MUSSELS: SPACE-TIME VARIABILITY AND IMPLICATIONS FOR HUMAN HEALTH*

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## Abstract

In this work, data related to the levels of polychlorinated biphenyls (PCBs) and polychlorinated dioxins and furans (PCDDs/Fs) in mussels bred in the marine coastal area of Taranto town are shown and discussed. The analysis of the data, acquired in five years of monitoring, in relation to the "Monitoring Plan" started by the "Local Health Authorities", has allowed to identify the farming areas with the greatest contamination. A seasonal variation in the concentrations of the organic contaminants was highlighted, related to the physiological state of the bivalves, with an increase in the summer months. The evaluation of the distribution of the various congeners (Fingerprint) was useful to identify the contamination sources. The obtained results show that the areas of the first Inlet of the Mar Piccolo basin are those in which the pollutants concentrations in mussels are often higher than the limits set by the legislation. As regards the risk for human health, associated with the consumption of mussels in the examined areas, it generally depends not only on the level of contamination but also on the dietary intake. The results indicate, however, that for the populations residing in contaminated coastal areas, the consumption of a greater quantity of seafood could be a risk factor for the bioaccumulation of non biodegradable toxic compounds.

*Keywords:* bioaccumulation, chlorinated organic pollutants, mussels, human health

## 1. Introduction

The study of contamination in highly industrialized coastal areas represents a central element for the assessment of risks to human health. The Taranto area (Southern Italy) has

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been declared an area of high environmental risk due to its high industrial concentration (presence of a large iron and steel industry and an oil refinery) and the extensive phenomena of environmental contamination (Fig. 1). In this area, polychlorinated dioxins and furans (PCDDs/Fs) and polychlorinated biphenyls (PCBs) are the main compounds that have attracted attention in recent years due to their high toxicity and persistence (Esposito et al., 2011, 2012). PCDDs/Fs and PCBs represent three of the twelve classes of Persistent Organic Pollutants (POPs) regulated by the Stockholm Convention of May 2001 (Stockholm Convention, 2001).

Due to the poor degradability and lack of metabolic detoxification processes, these pollutants accumulate in organisms with even serious toxicological effects. In the marine coastal area of Taranto, site of important mussel farming activities, the sediments represent a phase of accumulation and, at the same time, a secondary source of contamination. Diffusion phenomena along the water column determine the dispersion and possibility of bioaccumulation of toxic substances especially in filtering organisms, such as mussels. This phenomenon influence the transfer of pollutants to humans through the mechanisms of the food chain.

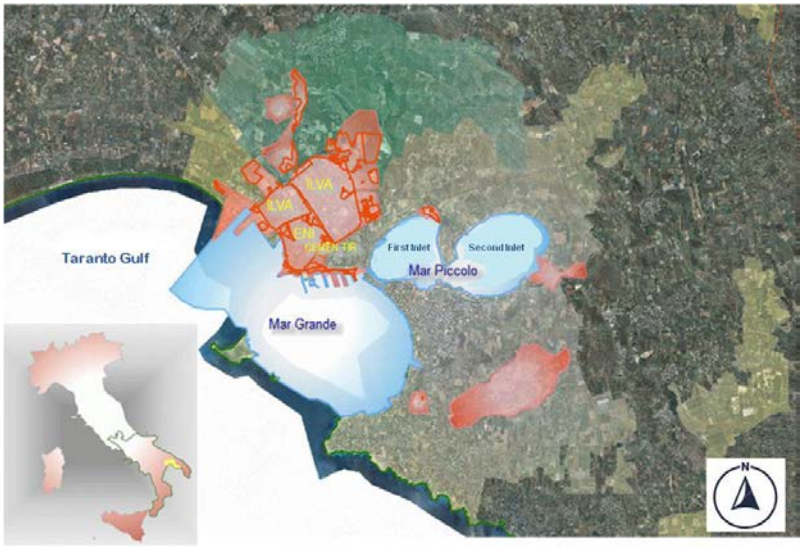


**Fig. 1.** Mar Piccolo and Mar Grande basins of Taranto and location of the industrial area

Monitoring the levels of contamination in bivalve mollusks reared in this area therefore represents an important factor both for assessing the health of the sea and for defining the risk to human health deriving from seafood consumption. The most important characteristic of mussels, species chosen as bioindicators, is the lack of biochemical or physiological mechanisms able to regulate the concentrations of contaminants in tissues. In this way the organism concentrates toxic compounds in proportion to the environmental concentration. The main advantages offered by a monitoring program conducted through the use of mussels (Mussel Watch) are both the possibility of assessing the degree of contamination of the marine area with an "integrated in time" measure, and the estimate of the "bioavailability" of the toxic pollutants present in the marine environment (Azizi et al., 2018; Okay et al., 2009).

Because of the high environmental contamination in the coastal marine area of Taranto, since 2011 the Prevention Department of the Local Health Agency (ASL) has started an "Extraordinary Monitoring Plan" for the assessment of the risk associated with the consumption of shellfish (ASL, 2018). The project has involved the determination of priority pollutants such as PCDDs/Fs and PCBs in mussels (*Mytilus galloprovincialis*) bred in the Mar Piccolo (First and Second Inlet) and Mar Grande basins, intensively exploited for mussel farming activities. In the present work, the elaborated results related to five years of monitoring (from 2011 to 2015) are discussed; the areas of greatest contamination and the main congeners of examined pollutants were highlighted. The analysis of the distribution of congeners (Fingerprint) has represent a key element to identify the sources of contamination. Finally, the risk to human health deriving from the consumption of shellfish raised in the coastal area is also discussed.

## 3. Materials and methods

### *3.1. Study areas*

According to the monitoring plan started from 2011 by the Prevention Department of the ASL of Taranto, monthly samplings of mussels raised in the Taranto Seas (Mar Piccolo and Mar Grande basins) were carried out. In particular, the Mar Piccolo is an inner, semi-enclosed basin located on the North side of Taranto town showing lagoon features. The basin is divided in two smaller inlets, called the First and the Second Inlet, which have a maximum depth of 12 and 8 m respectively. For the samplings, five areas have been identified named Area A and Area C for the First Inlet of the Mar Piccolo basin, Area B and Area D for Second Inlet of the Mar Piccolo and Area E for the Mar Grande basin (Fig. 2). Each area was divided into square sampling grids where mussels were randomly sampled. In total, from 2011 to 2015, 539 samples of mussels were taken at depths ranging from 0 to 4 m. The sampling was performed according to a standardized protocol (ICRAM-ANPA, 2001). After collection, the organisms, of uniform size, were stored at 4 °C in a humid environment and sent to the Experimental Zooprophylactic Institute of Abruzzo and Molise for analysis.

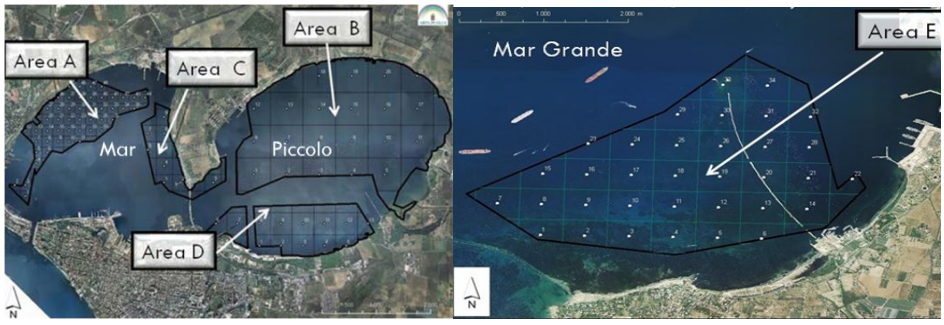


**Fig. 2.** Sampling areas in the Mar Piccolo and Mar Grande basins

### *3.2. Chlorinated pollutants analysis*

The analyzes were performed by gas chromatography / high resolution mass spectrometry (GC/HRMS) according to the EPA method 1613 B (US-EPA, 1994) for the analysis of PCDDs/Fs and the EPA method 1668 (US-EPA, 2008) for the PCBs

determination. In particular, the focus was on the analysis of 29 toxic congeners (twelve dioxin-like PCBs, ten PCDFs, seven PCDDs and six non-dioxin-like PCB, called markers. Before the analysis, the mussels samples were homogenized, lyophilized and extracted with solvent. The extracts, subjected to purification and separation of the various classes of compounds, were then analyzed by GC/HRMS using a Thermo Fisher MAT 95XP spectrometer. Although the six PCBs markers do not have toxicity similar to dioxins, with Regulation (EU) No.1259 (2011) of 2 December 2011 their analytical determination was approved as they constitute 50% of the total non-dioxin-like PCBs present in the food (EFSA, 2012). Therefore, these PCBs are an important marker for assessing human exposure to environmental contamination.

## 4. Results and discussion

The processing of the results showed high levels of contamination especially for mussels raised in the First Inlet of the Mar Piccolo. Table 1 shows the average annual concentrations of dioxins, furans and PCBs: as can be seen, PCBs are the highest concentration contaminants, with the highest levels found in year 2013. For the First Inlet of the Mar Piccolo, the average values are refer to the mussels sampled in the areas A and C, while for the second Inlet to the mussels sampled in the areas D and B. In the year 2011 the six PCBs markers were not analyzed since the regulation of these congeners took place only with the enactment of Regulation (EU) No. 1259 (2011), entered into force from 1 January 2012 (EFSA, 2012).

**Table 1**. Average of annual concentrations and standard deviations of PCDDs/Fs, PCBs-dl and PCBs markers

| Years | **Mar Piccolo,** First Inlet | | | **Mar Piccolo,** Second Inlet | | | **Mar Grande** | | |
|---|---|---|---|---|---|---|---|---|---|
| | PCDDs/Fs (pg/g w.w.) | PCBs-dl (pg/g w.w.) | PCBs m*arkers* (ng/g w.w.) | PCDDs/Fs (pg/g w.w.) | PCBs-dl (pg/g w.w.) | PCBs m*arkers* (ng/g w.w.) | PCDDs/Fs (pg/g w.w.) | PCBs-dl (pg/g w.w.) | PCBs m*arkers* (ng/g w.w.) |
| **2011** | 11.8±3.8 | $1.0\cdot10^4\pm3.3\cdot10^3$ | n.a.* | 4.1±1.1 | $2.6\cdot10^3\pm8.1\cdot10^2$ | n.a.* | 3.2±0.6 | $2.9\cdot10^4\pm7.7\cdot10^2$ | n.a.* |
| **2012** | 9.6±1.6 | $1.1\cdot10^4\pm1.9\cdot10^3$ | 57.0±8.2 | 5.5±2.0 | $4.3\cdot10^3\pm1.8\cdot10^3$ | 21.5±10.2 | 4.3±0.9 | $3.3\cdot10^3\pm7.8\cdot10^2$ | 17.7±4.0 |
| **2013** | 14.8±4.8 | $1.3\cdot10^4\pm4.5\cdot10^3$ | 60.8±16.7 | 6.4±2.3 | $5.4\cdot10^3\pm2.4\cdot10^3$ | 23.5±8.7 | 4.6±1.0 | $3.4\cdot10^3\pm9.1\cdot10^2$ | 17.8±3.9 |
| **2014** | 13.1±3.6 | $1.2\cdot10^4\pm2.6\cdot10^3$ | 56.9±15.1 | 7.1±0.1 | $4.2\cdot103\pm1.2\cdot10^3$ | 21.7±5.4 | 5.9±2.1 | $3.0\cdot10^3\pm1.3\cdot10^3$ | 16.8±7.0 |
| **2015** | 11.8±2.2 | $1.0\cdot10^4\pm2.0\cdot10^3$ | 46.2±12.8 | 5.5±0.9 | $4.0\cdot10^3\pm9.7\cdot10^3$ | 22.5±6.7 | 4.8±1.1 | $2.8\cdot10^3\pm1.8\cdot10^3$ | 15.5±9.3 |

n.a.*= not analyzed

Applying to the data the Student's t-test for paired data, the concentrations of the various contaminants in the Mar Grande and in the Second Inlet of the Mar Piccolo were significantly different from those found in the First Inlet of the Mar Piccolo (p value $\leq$ 0.001); in this area the results show an increase in concentrations especially in the summer months. This seasonal variation, correlated to the physiological state of the mollusc, is evident from the analysis of residues referred to the year 2014 (Fig. 3).

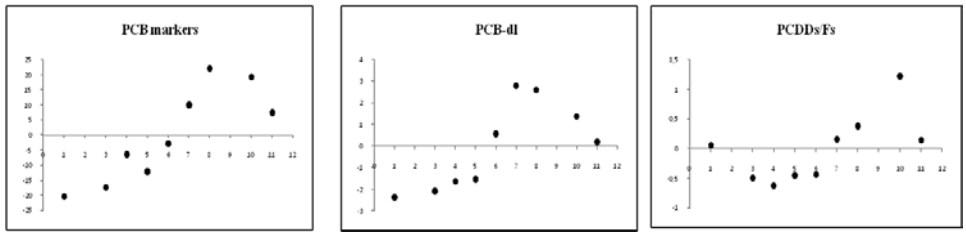


**Fig. 3.** Residual values, compared to annual averages, of monthly concentrations of PCBs and PCDDs/Fs in mussels of the First Inlet of the Mar Piccolo. The x-axis refers to months

As for the distribution of the congeners of the six PCB markers, this is shown in Fig. 4. The distribution is dominated by the PCB 153 congener, followed by the PCB 138 and PCB 101. This profile is characteristic for mussels, in agreement with other Authors (Okai et al., 2009). As can be seen, the PCB 180 congener has lower relative concentrations.

The organic contaminants concentrations in aquatic organisms depend, in fact, from the absorption capacity and on the excretion rate: important factors are the solubility in water and the octanol-water partition coefficient (Kow) of the various pollutants. In particular, correlations between the bioaccumulation factor (BAF) and the Kow have been determined (Jarrat et al., 2001).

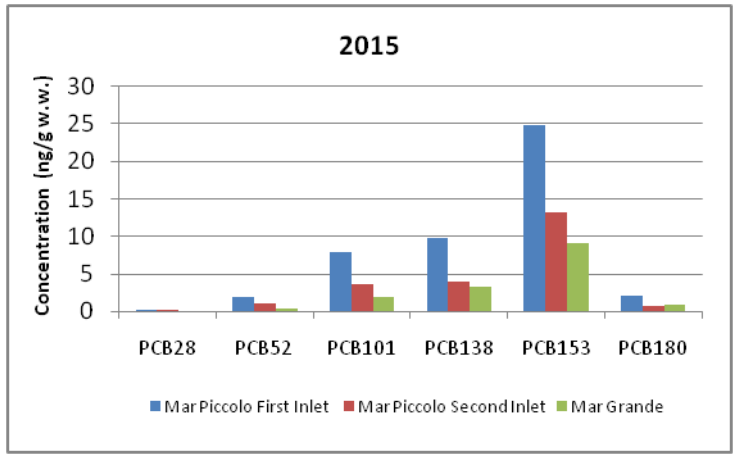


**Fig. 4.** Profile of PCBs markers in the mussels (year 2015)

Bioaccumulation is favored for pollutants that have a Log Kow value ranged from 5 and 7. This could explain the high concentration of PCB 153 (Log Kow = 6.92). For the PCB 180 instead, even if the log Kow is high (7.36) the bioaccumulation could be disadvantaged by the high molecular weight and by the high degree of chlorination which reduce its absorption. In fact, the steric hindrance does not favor transport across the cell membrane. The profile of PCBs dioxin like (Fig. 5 A) shows that the most abundant congeners are, respectively, the mono-ortho PCBs 118 and 105. The percentage distribution of the congeners was not significantly different between the various sampling areas. This could indicate that the sources of contamination are the same in all the areas investigated.

As regards the percentage distributions of dioxins and furans (Fig. 5 B), in all the study areas, a clear predominance of tetra-chlorinated furan (TCDF) has been seen, whose percentage with respect to the total varies from 50 to 76%. Minor concentrations were found

for the OCDD congeners, 1,2,3,4,6,7,8-HpCDD, 2,3,4,7,8-PeCDF and 1,2,3,7,8-PeCDF. The most toxic congener 2,3,7,8-TCDD was detected in concentrations lower than 0.2% compared to the total.

In mussels the concentrations of OCDD are significantly lower than those of 2,3,7,8-TCDF, contrary to what is often found in sediments, where the OCDD is the predominant congener. This inversion of the abundances in the two matrices, also found by other Authors (Metcalfe and Metcalfe, 1997) is probably due to the lower water solubility of the OCDD compared to TCDF and therefore to the lower possibility of bioaccumulation by filtering organisms.

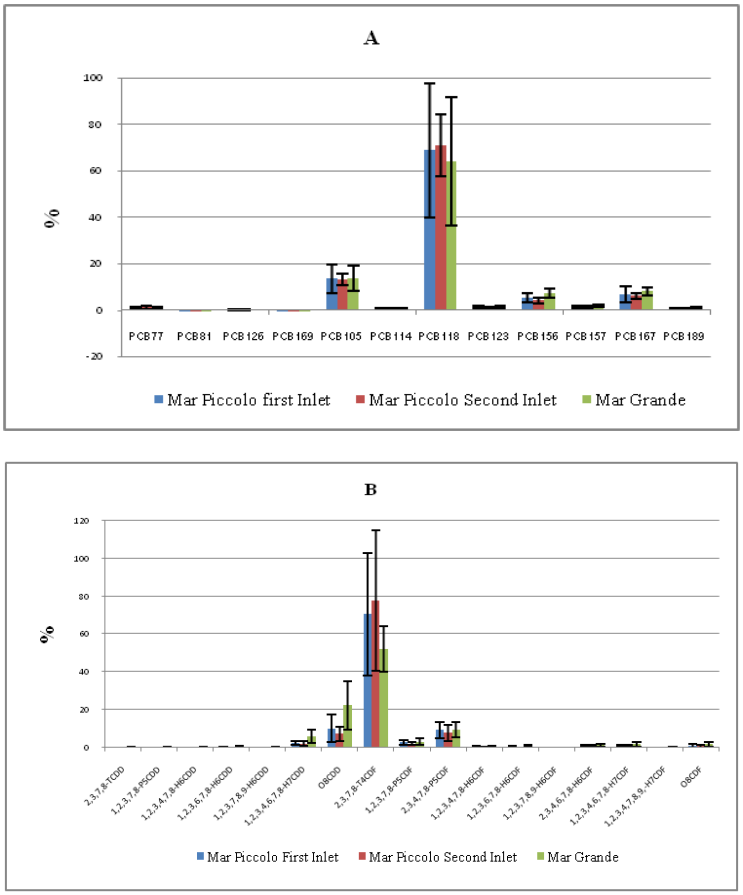


**Fig 5. (A-B)** Percentage distribution of annual averages of PCB-dl (A) and PCDDs/Fs (B) in the mussels sampled in the investigated areas (year 2015)

The Equivalent Toxicity was evaluated considering the average annual concentrations of PCBs-dl and PCDDs/Fs related to each marine area examined. The Equivalent Toxicity Factors (TEFs) used have been those defined by WHO 2005 for both PCBs-dl and PCDDs/Fs (Van dei Berg et al., 2006). The calculated Equivalent Toxicity showed values ranging from 0.3 ± 0.1 pg TEQ/g w.w. to 1.4 ± 0.3 pg TEQ/g w.w. for PCBs-dl and from 1.1 ± 0.5 pg TEQ/g w.w. to 4.7 ± 1.6 pg TEQ/g w.w. for dioxins and furans. Total Equivalent Toxicity factors (TEQ PCBs + TEQ PCDDs/Fs), reported in Table 2, varied in a range between 1.5 and 5.8 pg TEQ/g w.w.

**Table 2.** Total Equivalent Toxicity (TEQ PCBs + TEQ PCDDs/Fs) (pg TEQ/g w.w.) calculated from the annual averages of the individual congeners for the three monitored basins

| Years | Mar Piccolo First Inlet | Mar Piccolo Second Inlet | Mar Grande |
|---|---|---|---|
| **2011** | 4.9±1.8 | 1.5±0.5 | 5.7±1.6 |
| **2012** | 5.7±1.6 | 2.4±1.3 | 2.6±1.2 |
| **2013** | 5.1±1.1 | 2.5±0.8 | 2.6±1.2 |
| **2014** | 5.8±1.8 | 2.1±0.5 | 2.1±0.8 |
| **2015** | 4.5±1.3 | 1.7±0.4 | 1.5±0.5 |

As expected, the highest equivalent toxicity values were found in the Fist Inlet of the Mar Piccolo. The greatest contribution to the equivalent toxicity for PCB-dl is given by the congener PCB 126 (84-92%), which is normally present in the mussels in rather low concentrations. As regards, instead, the equivalent toxicity for dioxins and furans, this is almost entirely due to the congeners 2,3,7,8-TCDF and 2,3,4,7,8-PCDF, which contribute to the total TEQ with percentages variable from 90 to 97%. The values of the TEQ for PCBs-dl and PCDDs/Fs and the levels (expressed in ng/g w.w) of PCBs markers were then compared with the limits imposed by Regulation (EU) No. 1259/2011 (EFSA, 2012). These limits are 3.5 pg TEQ/g w.w. for PCDDs/Fs, 6.5 pg TEQ/g w.w for the sum of PCB-dl and PCDDs/Fs and 75 ng/g w.w for PCBs markers.

As can be seen from Table 2, the average annual values of the total equivalent toxicity are lower than the legal limits even if, starting from 2011 especially in the summer months, some exceeding of the limits have been recorded. The observed seasonal variability has been related to the physiological state of the organisms: sexual maturity, reproductive cycle, lipid content. An indicator of the physiological status of bivalves is the Condition Index (CI), calculated from the ratio between the weight of the soft tissue and the length of the shell (Mubiana et al., 2006). From the variation of the Condition Index it is possible to identify the reproductive period of the mussels, which in the Taranto basins occurs mainly in the winter months. At the end of each reproductive cycle both the Condition Index and the lipid content of mussels reach their minimum value to then increase in the following months.

With the Regulation 1881 (2006) the European Commission has established that the tolerable weekly Intake (TWI) for dioxins and dioxin-like PCBs is 14 pg TEQ/kg of body weight (Regulation E.C., 2006). For the 6 PCBs markers, although the tolerable doses have not been fully defined, there is a "guide value" of 70 ng/kg per body weight per week adopted from several years internationally (RIVM, 2001). The average national daily consumption of fresh and / or frozen mollusk is approximately estimated at 3.6 g / person (Arnich et al., 2009; ISS, 2004), although this value is however underestimated for populations living in coastal areas.

However, considering the values of Total Equivalent Toxicity (Table 2) for the various years monitored and an average body weight of 70 kg for adults, it was possible to evaluate the Dietary Intake (DI) for the considered years, as reported in Fig 6. This Figure shows that the weekly intake of chlorinated compounds from mussels of all three basins in the Taranto Gulf is lower than the limits established by the Regulation E.C. (2006). As regards instead PCBs markers, the values of the Dietary Intake for the various years are shown in Fig. 7. As can be seen, the Figure shows that with regards to PCBs markers, weekly intake is higher than the tolerable dose only for mussels raised in the First Inlet of Mar Piccolo for all the years examined.

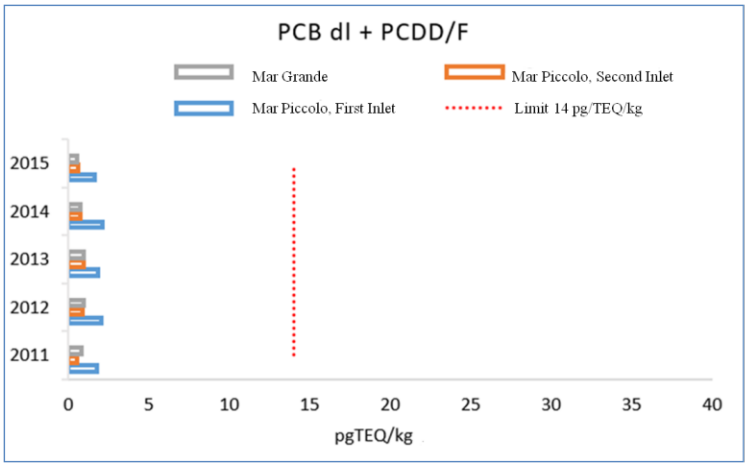


**Fig. 6**. Weekly dietary intake for PCBs-dl and PCDDs/Fs related to a consumption of seafood of 3.6 g/day

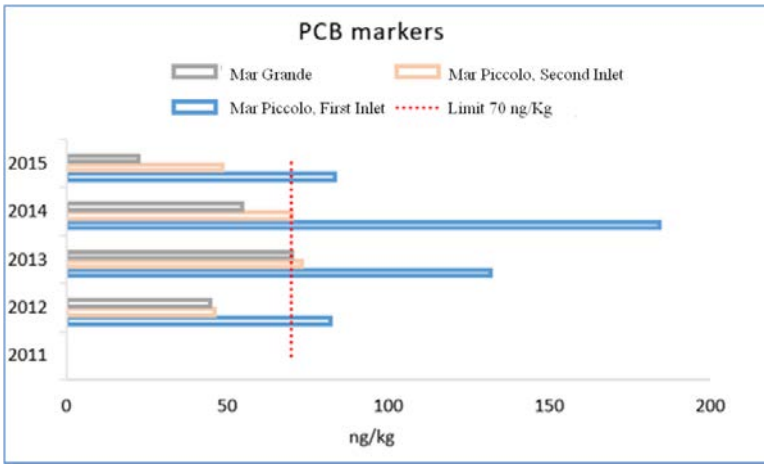


**Fig. 7**. Dietary weekly intake evaluated for PCBs markers related to a consumption of seafood of 3.6 g/day

## 5. Conclusions

The elaboration of the data acquired in five years of monitoring related to the concentrations of chlorinated pollutants in the mussels raised in the Taranto area has shown that the limits established by the legislation have been exceeded only for the mollusks of the First Inlet of the Mar Piccolo.

From the assessment of the toxicological risk for humans deriving from the consumption of mussels, it can be deduced that, although the contamination in the basins is not such as to induce the authorities to stop production and sales, coastal populations are exposed to a risk deriving mainly from the intake of contaminants such as PCBs, whose levels, especially in the First Inlet of the Mar Piccolo, require particular attention.

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# WSX - EUROPEAN WASTE SERVICES EXCHANGE, INSTRUMENT TO START THE TRANSITION TOWARDS CIRCULAR ECONOMY*

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## Abstract

The WSX BM project, developed under the Climate-KIC's Pathfinder Programme, aims to test and validate the basic assumption of the WSX project, namely the existence of a "market gap" of international scope to which to respond, in order to stimulate the circular economy, with the construction of an innovative platform that facilitates the meeting between supply and demand for services dedicated to waste recovery.
The integration of the stock exchange platform with the most advanced information technologies (rule engine, machine learning, blockchain etc.), will lead to the creation of an innovative expert system that facilitates the meeting between the demand and the complex and articulated world of supply and availability of services necessary for proper waste management. The system, designed to automatically create multi-service offer prices for each request, even by different operators for a single transaction and thus give rise to a complete multi-service response to market demands, will also allow the preparation of the documentation required by EU legislation, to trace the various stages of implementation for transparency and to communicate the mandatory data to the bodies responsible for control.
WSX BM Pathfinder project aims to test and validate the existence of the market gap identified by the WSX.

*Keywords:* block chain, circular economy, machine learning, raw material, rule engine, waste recovery, waste recycling, waste services regulated market

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## 1. Introduction

The WSX Project is an attempt to apply an idea born from over thirty years of knowledge about the market for industrial waste recovery/disposal. This peculiar and indispensable activity of the productive world, specifically industrial, arose in the second half of the twentieth century, but assumed a strategic importance at a time when international organizations dealing with the territory protection have perceived and scientifically proven that human action impact induces significant changes in the natural evolution of our planet, especially with regard to the climate.

This trend has generated the current theories/practices of the so-called Circular Economy, which constitute a first attempt to limit the damage caused by human action in the ecosystem that hosts us (Andretta et al., 2018; Oyelola et al., 2017). WSX in-tends to propose a reasoned regulation and compliance with the existing regulations of the services market that has been established in the last 50 years to address the problem of the correct start to industrial waste recovery/disposal. The WSX purpose is to encourage the Circular Economy activities and practices by expanding competition in the free market and producing savings in the implementation of its processes.

## 2. Objectives of the projects

**WSX** Project **main specific objective** is to develop a new and innovative technology, tested and validated, necessary to launch a new Business to Business (**B2B)** instrument aiming at **regulating the EU waste-management service market**, to be owned in part by a New Company named "WSX" and in part by strategic investors active in waste-industry, financial department and industrial sector.

**The final general and long-term objective is to run a pan-European Waste Services Exchange, or so-called WSX, managed through the WSX on line EU Platform, this latest to be developed during the first years of the WSX project running**. This will facilitate trade in waste, increase the transparency and liquidity of EU waste markets, reduce the cost of compliance with EU and member states regulations, improve the profitability of waste producers, optimise the use of EU waste treatment plants, improve waste-management practices in an ethical way aiming at illegal activities removal. Moreover, this initiative shall boost the recycling of raw materials coming also from the desirable new "end of life" processes of the artefacts. **The WSX implementation will accelerate a smoother transition to a circular economy in Europe**.

The *immediate objective* of the project is, therefore, to develop this new and innovative **EU Waste Service Exchange on-line interactive platform** (**WSX**) for the business and the services that, in the long-run, WSX will provide. Such a system can provide useful services to support the transboundary shipment of hazardous waste, as well as the local shipment of non-hazardous waste. *Our immediate goal*, however, is *to shorten the route-to-revenue for a new "WSX company"* and *optimise its chance of success* by focusing first *on the market for services supporting the transboundary shipment of hazardous waste in Europe performing business towards a circular European economy*.

**The real innovation foreseen by WSX is not only the expansion of a platform dealing with EU waste management but also the development of a new business model, and related services, that will allow transparent waste trading through an innovative on-line EU interactive platform**, which has previously been overlooked in some ways but only achievable with logical models such as the ones proposed by WSX.

WSX is innovative in the sense that no other existing system either in Europe or elsewhere is capable of handling such complex multi-party transactions. The WSX Project will employ an innovative WSX Engine, based on rule engine, machine learning and blockchain technology, to help users navigate the complexity of regulatory and compliance

**requirements as well as the constraints this place on waste disposal options. The matching of WSX Engine technology with the consolidated one of the stock exchange platform will enable services exchanges as well as of shares and commodities**, this is by far the main WSX project added value.

Fig. 1 best presents what WSX platform will try to achieve and what are the technological and business innovations foreseen on the EU waste market.

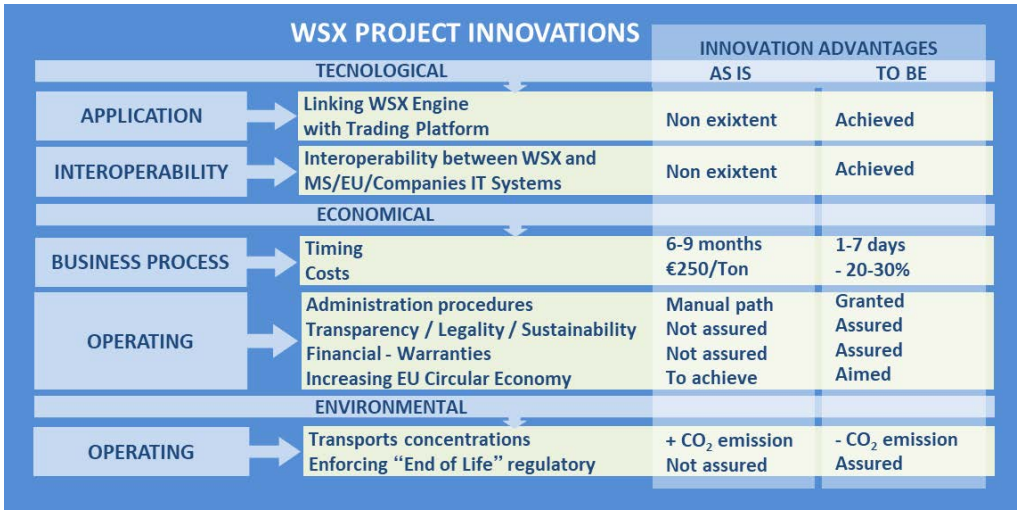


**Fig. 1**. WSX Project innovations

**A future new "WSX Company"** in the long-run, will propose through the advanced WSX telematics platform, a services market for the proper disposal/recycling. The new business model will chair a market regulated by an open, transparent and international stock exchange system who will be enabling to:

- **Open access to the business model especially to SMEs, either directly or through brokers,**
- **Develop specializations recovery plants increasing turnover and promoting internationalization,**
- **Concentrate shipments favouring rail rather than by truck, obtaining a significant reduction of GHG,**
- **Regulate prices decreasing significantly the weight,**
- **Fostering a "circular economy" of raw materials recovered at end of life of the artefacts that contain.**

### 3. Relation to the market

WSX is fully in line with the spirit and the overall policy strategy set out by the EU Roadmap for a Resource Efficient Europe (http://ec.europa.eu/environment/resource_efficiency/, as it can make a significant contribution to the development of what is referred as a "*circular economy*". According to the Roadmap, the EU vision for a sustainable economy is based in part on heading 3.2 "Turning waste into a resource" that refers to milestone "By 2020 waste is managed as a resource". To carry out the vision of an increasing recycling market, the European Commission refers to future measures so as to stimulate the secondary materials market and

the demand for recycled materials through economic incentives and the development of end-of-waste criteria and artefacts end of life future regulatory.

WSX intends to facilitate administrative procedures involved in the waste shipment for treatment, making it easier, less costly and less time-consuming to comply with waste related regulations. It promotes a vision of the EU as a "circular economy". This vision is defined particularly in the **European Resource Efficiency Platform's (EREP)**. Furthermore, at the international level, the **Ellen MacArthur Foundation** has defined the principles of circular economy (http://ec.europa.eu/environment/resource_efficiency/re_platform/index_en.htm; http://www.ellenmacarthurfoundation.org/circular-economy). It should be noted that most of the partners and members of the Ellen MacArthur Foundation could be the ideal users of WSX platform. If you were considering the entire existing artefacts as an immense mine of raw materials, as indeed it is, in order to reuse at the "End of Life" (EOL) moment of artefacts containing them, the issue would shift in the identification of the most economic, but also cleanest, methods for re-extracting these raw materials for later reuse.

In our opinion the "industrial symbiosis" and "closed loop processes" concepts will create increasing demand for services to support trade in waste. However, this market is not efficient, not transparent and it presents many opportunities for entrepreneurial development (Albino and Fraccascia, 2015; Fraccascia and Yazan, 2018). We believe that it is important to establish, develop and systematically evolve modern on-line trading systems that will make trade in waste easier, expanding the markets for existing large and small actors, lowering the barriers to entry for new actors, improving the margins for buyers and sellers, while reducing the cost of transactions through open market platform. Obviously, one should consider and evaluate primarily the convenience of these innovative industrial processes with full respect of human health and the environment integrity (Bridgewater et al., 2015). From this point of view, WSX intends to operate.

The project could be of direct relevance for the **European IMPEL Network** for the Implementation and Enforcement of Environmental Law (http://impel.eu/). Set up in 1992, it now has 47 members from 33 countries, including all EU Member States, Croatia, FYROM, Turkey, Iceland, Switzerland and Norway. It plays an important role in the implementation of the European Environmental Action Plan (EAP). Its activities are grouped under project clusters, one of which focuses on the **Trans Frontier Shipment of waste (TFS**) (http://impel.eu/cluster-2/). In August 2014, with a view to reinforcing its contribution to the implementation of the 7$^{th}$ EAP, IMPEL published a "new strategic program" for the period from 2016 based on 5 themes, one of which is "Waste and TFS" (Trans-Frontier Shipment) (http://impel.eu/wp-content/uploads/2014/08/New-Strategic-Direction-for-IMPEL.pdf). Last but not least, Interim report on the **IMPEL TFS Multi Annual Work Programme for 2011-2015** that reveals the **projects related to the enforcement of the Waste Shipment Regulation 1013/2006, found that there are still high levels of non-compliance with EU legislation and illegal waste shipment** (http://impel.eu/wp-content/uploads/2013/07/IMPEL-TFS-MAP-2011-2015.pdf). The **findings of the TFS IMPEL program underline the potential for innovations such as WSX, to catalyse the implementation of environmental legislation and accelerate the adoption of compliant behaviours.**

The "Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal" regulates the trans-frontier shipment of hazardous waste. This is only one of several international conventions governing the hazardous waste shipment. Other relevant conventions include the Stockholm Convention on Persistent Organic Pollutants (2004) and the Rotterdam Convention on Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade (1998) (http://chm.pops.int/; Further regulations specific to the EU law are based on:

- The Directive on Packaging and Packaging waste (EU, 1994)
- The Landfill Directive (1999/31/EC)
- The Waste Incineration Directive (2000/76/EC)
- The Directive on End–of-Life Vehicles (EU, 2000)
- The E-PRTR Regulation of the European Parliament and of the Council the establishment of a European Pollutant Release and Transfer Register (EC No. 166/2006 dated 18 January 2006)
- The Waste Shipment Regulation (EU, 2006)
- The Waste Framework Directive (EU, 2008)
- Industrial Emissions Directive (EU, 2010)
- The Directive on Waste from Electrical and Electronic Equipment (EU, 2002 and 2012)

Depending on how the waste is shipped, the handling of waste may also be subject to:

- The ADR regulation for transport of dangerous goods by road
- The IMDG code for maritime transport of dangerous goods,
- The RID regulation on carriage of dangerous goods by rail, and
- The IATA regulation on transport of dangerous goods by air.

In this context, the EC DG Environment is pushing coordination among member states to advance towards a European system for the electronic data interchange, within the legislative framework of regulation 1013/2006. At present, a working table is in place between the Member States for the data exchange protocol definition.

## 4. Concept and approach

The trading of "*waste services*" is **a complex multiparty transaction** that **starts with the identification of the complete range of services required to execute the physical transfer of waste from one location to another**. This represents a step-up in complexity compared to modern commodity exchanges. Systems have been developed to support such complex transactions**.** That is why WSX requires a mechanism to manage the presented transactions complexity. WSX proposes an approach based on the use of **WSX Engine**.

WSX Engine is a system capable of proposing matching between supply and demand using the **"Collective Intelligence"** created on the basis of the data entered by users of an on line market platform constituted by WSX platform and by previous data on transactions carried out and functional for the learning phase used by the Machine Learning algorithm at the base of the predictive process. WSX Engine is an innovative tool applied to the growth of the Circular Economy and destined to identify the supply chains of materials making available to large players, but also to SMEs, waste treatment plants destined for recovery in the entire European market.

The ability of WSX Engine to **automatically recognize certain affinities and peculiarities of waste**, combining them with those of plants capable of processing them, for the purpose of recovering secondary raw materials, will be the first step in the correct functioning of the telematic platform for exchange between supply and demand.

In this ability lies the technological innovation of the project and will be based on the construction and use of four elements in progress: (i) **a data dictionary** that will define **the words that can be used by users** to fill in questions and offers in order to make it easier and feasible the **matching**, (ii) **a database** that will be used by the automatic generation system of matching between supply and demand to produce its own results, which will be **based on previous results and on a reliability rating**, (iii) **big data type accesses** made on the **waste movements** carried out in the past by the same users as by other similar ones, (iv) **a data base of the waste data sheets** that specify the peculiarities for the purpose of their acceptability by the plants .

All these components are dynamic and will be built over time, gradually increasing the capabilities and reliability of the system thanks to the Machine Learning self-learning. The automatic matching between supply and demand will be generated by algorithms that are inspired by the theories of "Collective Intelligence" aimed at overcoming the limits of the individual and providing solutions based on the experience of multiple similar cases occurred and recorded in the past. WSX Engine will constitute an innovative process of digitalization of waste recovery marketing, especially aimed at **recovering second raw material in full compliance with the dictates of the Circular Economy**. The project will constitute a new business model for value-added services applied to the recovery of waste that, properly inserted in a telematic trading platform, will make the market more transparent, accessible to all and regulated by controlled transactions in full compliance with the regulations national and international regulations in force.

Moreover, the WSX engine component "knows" the complexity of the administrative and compliance procedures involved in the transactions needed to complete a transboundary shipment of hazardous and non-hazardous waste. It is able to cope with the fact that the user may not formulate a request correctly or that there may be ambiguity in the applicable legislation.

**Given the presence of existing systems described above, the WSX philosophy is to adopt an open architecture approach that will enable existing systems to integrate with the WSX platform so that their previous efforts and investment is not wasted, while creating integration pathways for fuller adoption of WSX over time**.

During the WSX Project development **it will be required an integral part, that is qualifying and essential to achieve conclusive test procedures for testing and validating the WSX Product/Platform, called as the "Trading Platform Exchange Regulation".** The WSX Project, through the study of the regulation and the development of integration components and interfaces (API-UI), will result in the creation of a working platform directly available by the Market.

A typical **use case** could be as follows:

- The waste producer and the brokers access the WSX platform and make a request for help finding a treatment plant with available capacity for a certain quantity of waste of a certain kind. The WSX engine identifies available plants and possible routes, the regulatory constraints that apply, the services needed to ensure compliance, as well as the authorities that need to be contacted to provide approvals. It generates this knowledge from its continuously updated database of actors, regulations, administrative procedures and workflows.
- The platform then generates a range of options available to the waste producer, allowing the producer to decide which ones are best either in terms of time, price or availability of capacity. The WSX will help to do it almost in real time.
- Finally, the WSX platform supports the waste producer in making contact with the various authorities and service providers, contracting with them, completing the paper work and organising the overall trade.
- The WSX platform keeps a record of the transaction, and progress in its completion, to support traceability requirements or for use in the event of an independent audit by relevant authorities,
- The WSX platform also keeps up to date and presents a listing of materials and services.

## 5. Target

Today the paperwork for waste management procedures is done manually in 80% of cases. Anywhere from 3 to 9 months is required to complete pre-shipment procedures for trans-boundary shipments and several weeks if national (http://ec.europa.eu/environment/waste/shipments/studies.htm). WSX Project ambition is to

reduce the time required for processing by a factor of 10 compared with current performance. The aim is to develop a platform that will be transparent, secure, low-cost, dynamic and capable of supporting complex, near real-time, multiparty transactions. Our ambition is to see 55% to 60% of shipments treated electronically within 3 years of the formal launch of a functioning WSX exchange.

The aggregate cost of processing transboundary hazardous waste in Europe is about €1.5B for the processing of 6 Million Tonnes at an average cost of €250 per tonne. Of this 75% to 80% corresponds to real or justifiable costs incurred for services related to processing requests, securing bank clearance, organizing and executing shipment, and processing in appropriate plants. **We estimate that the WSX system can generate savings of the order of 25% to 30% on current expenditure levels. In the case of transboundary hazardous waste shipment this corresponds to potential savings of up to €240M per year**.

The entire market for good starting or recovering hazardous waste in Europe is 75 million tons per year, which can reasonably be expected to have an average cost of € 150 per tonne. In domestic markets the savings introduced by the business model proposed by WSX will be lower but not lower than 10% - 15%. Fig. 2 shows the enormous differences between the actual and the new business model procedures.

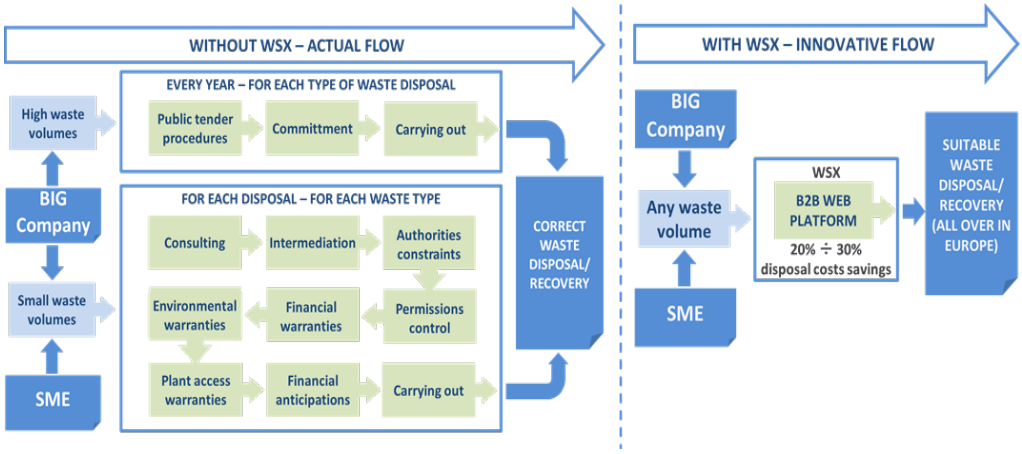


**Fig. 2.** Comparison between without and with WSX innovative flow

## 6. Market impact

According to the World Bank, waste generation rates are rising fast, on pace to exceed 11 million tons per day by 2100. The amount of garbage humans throw away is growing rapidly and won't peak this century without transformational changes in how we use and reuse materials (http://www.worldbank.org/en/news/feature/2013/10/30/global-waste-on-pace-to-triple). In Europe, we currently use 16 tons of material per person per year, of which 6 tons become waste. Although the management of that waste continues to improve in the EU, the European economy currently still loses a significant amount of potential 'secondary raw materials' such as metals, wood, glass, paper, and plastics present waste streams. In 2010, total waste production in the EU amounted to 2.5 billion tons. From this total only a limited (albeit increasing) share (36%) was recycled, the rest was landfilled or burned, of which some 600 million tons could be recycled or reused (http://ec.europa.eu/environment/waste/index.htm). This behaviour of Europe, the levels of

recovery and reuse of waste, offer large areas of possible progress: **WSX provide a new business model capable of catalysing the circular economy's recovery**.

WSX will make the market for waste more *transparent*, and *compliance less costly and less time-consuming*, contributing, moreover, to *increase the rate of recovery, both as the processing of waste into energy, both in the production of raw materials from the reuse.*

The main impact of WSX can be summarized in the word "*competitiveness*". In this way WSX aims at achieving a "*systemic innovation*" in waste management in Europe, which **goes well beyond the adoption of single solutions of technologies**, to actually **bring about a substantial change in the "framework", and current EU fragmentation, in which waste services are implemented.** Given the current situation, a "WSX Company" expects, with the creation of the new business model, to be developed during the running of the project, to create **new behaviour standards** more virtuous than the current situation; more profitable and more responsive to environmental regulations.

## 7. Market opportunity

The expected **overall impact on users and EU markets** is shown in Fig. 3. EUROSTAT publishes the annual figures of hazardous waste generation for the year 2012 in Europe amounts over 101 million *Metric Tonnes* (**tons**). The average cost of treatment comes to €250 per metric Ton any services included, it totals more than €25B per year. We must stress that, despite a number of national, EU and international efforts to address the problem, Europe remains a patchwork of fragmented partial-solutions, and paperwork is done by hand for 80% of all shipments (http://ec.europa.eu/environment/waste/shipments/studies.htm). Processing paperwork in these cases can take anywhere from 3 to 9 months and accounts for 20% to 30% of the total cost of waste disposal. **This suggests that the WSX could create savings for the waste sector from € 500M up to € 700M per year, if all actors were to employ its services for the final destination of hazardous waste alone**.

| WSX POTENTIAL MARKET | TONS | €/Ton | VALUE € | WSX SAVINGS TREND (20-30%) |
|---|---|---|---|---|
| European annual hazardous waste production | 101.000.000 | 250 | 25.250.000.000 | 6.312.500.000 |
| European annual hazardous waste cross border transportation (TFS) 6% of production | 6.060.000 | 250 | 2.525.000.000 | 631.250.000 |
| WSX annual TFS market (10% captured of total TFS) | 606.000 | 250 | 151.500.000 | 37.875.000 |

**Fig. 3.** WSX potential market

European treatment plants suffer from an estimated 18% under-utilisation. For some plants this can be as high as 30% and seriously undermine the viability of their business. **We expect that with WSX, an open exchange will make the market more transparent, more circular, more liquid and more competitive, waste treatment plants will on average reduce their rates of under-utilisation by 50%, bringing un-used capacity to less than 9%. Consequently, systemic and cost-effective solutions will benefit from innovative ICT solutions for waste traceability, waste material flow management, and the estimation of the availability, composition and quality of waste.**

Producers and managing Companies of large amounts of waste or requiring services above a certain threshold value are required to advertise on the basis of public tenders. This

is independent of the nature of the waste, the nature of the service and whether it is shipped to final destination at regional, national, EU or international level (Hall and Nguyen, 2012). In other cases, in a system where no publicity is given to demand, practice and pre-existing relations mostly determine response, which of course hinders market openness and competitiveness. This has resulted in globally higher prices than processing shipments should cost, if **managed without an open, transparent and multiparty system**. **WSX alone can reduce the cost of disposal by between 20% and sometimes 30% due to competition.**

The Article 3 of the EU Directive 2008/98/EC, shows these definitions:

*5.'waste producer' means anyone whose activities produce waste…;*

*6.'waste holder' means the waste producer or the natural or legal person who is in possession of the waste;*

*7.'dealer' means any undertaking which acts in the role of principal to purchase and subsequently sell waste…;*

*8.'broker' means any undertaking arranging the recovery or disposal of waste on behalf of others…;*

*9.'waste management' means the collection, transport, recovery and disposal of waste…;*

The Article 6 of the EU Regulation (EC) 1013/2006, shows these requirements for the shipment of waste:

*Financial guarantee - 1. All shipments of waste for which notification is required shall be subject to the requirement of a financial guarantee or equivalent insurance covering…*

Therefore, the main **waste market actors** are:

- **Waste producers & holders:** The savings which can be achieved, will lead the Companies producers of waste, in a short time, to become users of the WSX platform services.
- **Waste dealers & brokers:** The advanced trading capabilities available in the WSX platform will enable these operators to spend less time on customers and service suppliers research activities, and to focus its activities on high value-added services (expertize, notification, shipment arranging, regulations and environmental compliance, etc.)
- **Waste management companies:** The major waste companies in Europe are shown in table 2.1, in order of size of revenues from waste management in Europe. They will be the **main users of the WSX platform** where, through the Multi Service Proposal Generator, they will offer their waste services (collection, transport, treatment, disposal and recovery, etc.).
- **Power companies** & **raw materials recovering companies** (glass, wood, plastics, metals, paper, cloth, etc.), which often use large amounts of waste for their plants.
- **Insurance companies:** The Multi Service Proposal Generator, available in the WSX platform, will enable this companies to offer their guarantee services.
- **MS Countries Authorities:** in the WSX platform they can find all the functionality to easily provide the notification procedure documents.

About the waste management companies, the **FEAD**, **European Federation of Waste Management and Environmental Services**, in its Position Paper on a new Commission proposal on Circular Economy (March 2015), shows **«***To achieve a circular economy, free and fair competition is needed throughout the value chain to stimulate customised services and solutions, and possibilities for innovation and investment* (http://www.fead.be/en/position-papers/). ***Market-based solutions are a key driver for investment and innovation»***, and subsequently, in the introduction of its Position Paper Ensure open markets and fair competition to reach a circular economy (April 2015), shows: *«A circular economy and a more resource efficient society require major changes in the use of resources and new EU policy measures. To reach a circular economy, **market- based***

***conditions must be introduced in the whole value chain to incentivise all actors to take their responsibilities. Open markets and fair competition stimulate customised services and solutions, and possibilities for innovation and investment. They also help small companies to enter the market».***

**WSX provides the open and transparent market-based solutions to determine the conditions that the market itself demands.**

Fig. 4 summarizes the differences and the benefits of WSX Platform with respect to waste market operators, which initially could be its possible competitors, even though in the market there aren't similar systems.

| | Dealer | Broker | Waste Management Company | Big Waste Producer Company | Waste Authority | Custom Authority | WSX |
|---|---|---|---|---|---|---|---|
| **Waste purchasing** | ✔ | ✘ | ✔ | ✘ | ✘ | ✘ | ✔ |
| **Waste selling** | ✔ | ✘ | ✘ | ✔ | ✘ | ✘ | ✔ |
| **Waste arranging** | ✘ | ✔ | ✔ | ✘ | ✘ | ✘ | ✔ |
| **Waste digital dossier** | ✘ | ✘ | ✘ | some ✔ | some ✔ | some ✔ | ✔ |
| **Market price setting** | ✘ | ✘ | ✘ | ✘ | ✘ | ✘ | ✔ |
| **Demand and offer matching** | ✘ | ✘ | ✘ | ✘ | ✘ | ✘ | ✔ |

**Fig. 4.** Comparison between principal operators activities and WSX Platform

## 8. WSX BM

Computer Solutions S.p.A. will lead the Pathfinder project WSX BM in the Climate-KIC's Pathfinder Programme in order to verify the feasibility of the idea of building a new WSX platform that facilitates the meeting between supply and demand of national and international services dedicated to waste recovery. The main idea at the basis of the innovative platform WSX is to stimulate the circular economy by identifying and promoting international chains of recovery initially intended for the main players in the market but later also for SMEs.

WSX BM aims to test and validate the existence of the market gap identified by the WSX through the preparation and dissemination of a questionnaire, built by experts in the field in order to collect relevant data for our survey, among the most representative interlocutors of this market on an international scale: large producers and large waste treatment plants, first interested in the benefits of using a platform that facilitates the meeting between supply and demand of services on waste. Companies and organisations representing the 5 most industrialised countries in Europe will be interviewed; the interviews will be conducted personally by our experts, who will then be able to answer any questions on the operation of the WSX. Consolidated our Business Idea, demonstrating the enormous advantages of a platform that multiplies the possibilities to meet the demand and supply of special waste, meets the needs of large waste producers or large plants, we will be ready to develop and implement the WSX. The innovative WSX Business Model envisages a new positive approach to the issue of waste management, both industrial and urban.

Starting from the latest guidelines of Ellen MacArthur Foundation, through WSX, it will be possible to predict which types and quantities of waste will be generated or collected at a time and separate them and accumulate them locally in large homogeneous lots of waste.

Through the WSX model it will be possible to carry out transactions that involve large quantities of waste, share transactions with all the actors in the supply chain, prepare railway trains (with less $CO_2$ emissions than occasional small road trains!), sending large

quantities of low cost and low environmental impact material impact even over long distances, reaching the large European treatment centers, normally more controlled, more efficient and more sustainable.

## 9. Concluding remarks

The team that is preparing the WSX project intends to explore the international market in advance through the WSX BM Project budget before making the substantial investments required to implement the WSX Project.

The survey results will be published on the website www.wsxbm.com so that anyone who has participated in the survey but has only accessed this publication can have an understanding of the impact that this initiative has encountered in the European manufacturing world through the answers that a significant sample has kindly provided.

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# DEVELOPMENT OF MONITORING AND CONTROL SYSTEM TO IMPROVE THE MANAGEMENT OF LANDFILL GAS*

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## Abstract

It is estimated that only 50% of the biogas produced by landfills is recovered, while the remaining part is dispersed in the atmosphere filtering through the covering. The ability to capture gas from landfills is limited by the extension of the area, the type of coverage, and the management of the collection system. Therefore, the best way for improvement in quantity and quality relies in the optimization of the operating system. This study is focused on a monitoring and control method to improve the efficiency of the biogas collection system. Thanks to the representation of the conditions of the wells through the visualization of 3D models and color indicators, it is possible to quickly identify the problems relating to the individual wells and also to the collection lines, thus making it possible to understand how to regulate the opening of the well valves for correct aspiration and schedule maintenance and repair operations. The entire work was conducted in an Icelandic landfill in 2017 and it has been possible thanks to the collaboration of landfill operator SORPA bs. At the end of the four-month project, the results showed the possibility to increase landfill gas collection of about 60% for an additional 2.000.000 $Nm^3$ biogas collected and so rescued from the atmosphere.

*Keywords:* biogas recovery, emission, landfill, monitoring

## 1. Introduction

Biogas is produced in absence of oxygen from waste disposed in landfills. It is composed of about 60% methane, 40% of carbon dioxide and in less quantity from other

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polluting gases. Methane is a highly energetic gas, but it is also a greenhouse gas highly impacting (about 21 times more than $CO_2$). Currently it is estimated that, of all the biogas produced by a landfill, only 50% is captured, while the remaining 50%, migrates through the cover and is dispersed in the atmosphere, generating economic and environmental damage.

## 2. State of the art

Until now, monitoring is performed manually by an operator who records, on papers or file sheets, gas pressure and composition values at the head of each extraction well. After recording the various parameters, the operator makes an adjustment on the opening of the interception valve, trying to adjust the applied suction. Although this work is done by an expert operator, regulation is conducted by logics related to experience and considering only some gas parameters (almost always only pressure and composition); therefore he fails to perform a careful and precise analysis due to considering only some of the useful parameters and considering the behavior of the single well, not in relation to neighboring ones. As a result, the adjustment results in a lower efficiency of the plant, with a lower biogas capture and a greater leakage from the cover.

The goal of this work is to create a 3D model of the landfill with the representation of all the measurements. It offers the opportunity to have a quick and clear view of the behavior of each well, to understand which wells need adjustment and which maintenance.
This work has been divided into three parts:

- Measurement campaign for data collection: measurements of gas pressure, flow, and composition, leachate level and temperature;
- Graphical representation of data: visualization of the working condition of each well and the relative criticalities;
- Analysis of results: Mapping and discussion of the possible solutions related to the wells affected by problems;

## 3. Site description

The project was carried out in the Icelandic landfill of Álfsnes, located in Reykjavík area, in the south-eastern part of Iceland (Aubert, 2007). The landfill (Fig. 1) has a surface of 40 ha and its cover is characterized by a layer of peat soil with a thickness by about 1.0-1.5 m, placed on the surface above the waste layer that have a thickness of 15 m. The bottom is composed by bedrock with low permeability, a small layer of clay (about 30-50 cm and a permeability of 8-10 m/s), a layer of geotextile, a drainage layer for the collection of percolated above (Meyles, 2003, 2006; Wu et al., 2012).

The gas collection system is composed of 190 extraction wells connected by six main lines which then converge into a single gatherer before reaching the blower. The 190 extraction wells consist of pipes of HDPE DN 110 mm, about 15 m long with a series of small holes starting from a depth of 3.5 m, to allow the biogas to be sucked up. The empty space of the hole between the pipe and the garbage is filled with draining material to allow the passage of biogas, while in the upper part of each well this space is filled with a layer of bentonite to prevent external air can penetrate inside of the landfill, reducing the quality of the gas and by inhibiting the anaerobic process (Zeng et al., 2017).

## 4. Material and methods

Measurements, made for obtaining the parameters, are carried out through various tools, among which the most important is a biogas analyzer device, designed specifically for anaerobic digestion. This kind of device works by means of a sensor inside a probe that is

placed in contact with the gas flow, measuring pressure (mbar) and gas quality that is the composition in percentage of volume in terms of: methane (%vol), carbon dioxide (%vol), oxygen (%vol), hydrogen sulphide (ppm) and other gases called "Balance" (%vol), which are all gases, mainly nitrogen, necessary to arrive at 100% of the composition. Another important parameter to measure is the pressure, which is recorded as an absolute value because it is a depression since the plant works in aspiration. With the probe used for measuring gas pressure and quality is not possible measuring the flow directly, so this was indirectly estimated by gas pressure and temperature.

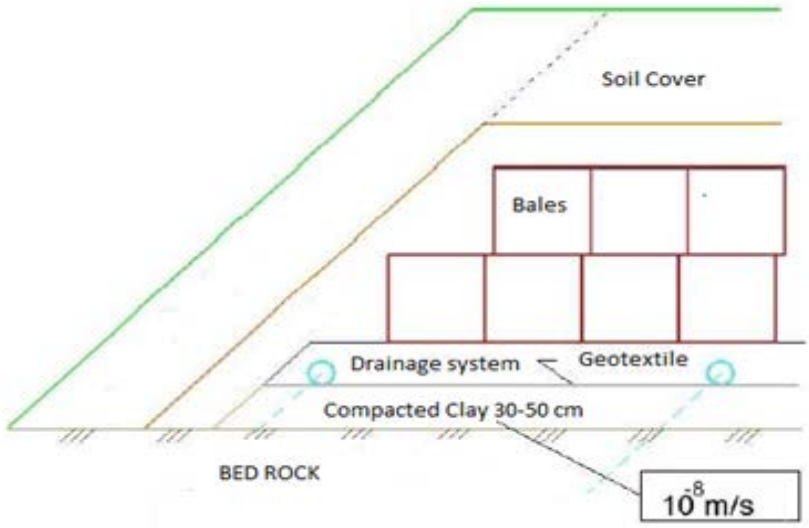


**Fig. 1.** Schematization of the landfill with the main layers

Other important field measurements have been conducted with a graduated probe that has a thermometer in the tip. With this device has been estimated the leachate level and its temperature in all 190 boreholes; Instead, with a camera composed of an extendable cable has been measured the perforations depth in order to understand where the biogas catching starts.

## 5. Results and discussion

This study shows an example of applying this method using a 3D model as a visualization tool, in order to understand in which case, the wells are critical, requiring maintenance. Pressure measurements carried out manually on each well of the landfill allow estimating the outgoing flow and the composition of the gas in terms of methane, carbon dioxide and other minor constituents (Table 1). It is possible to make two measurements immediately upstream and downstream of the valve: upstream it is possible to measure the pressure close to the well ($P_1$) and downstream the pressure in the connecting pipe ($P_2$). The outgoing flow was calculated indirectly with the measurements of the pressures $P_1$ and $P_2$, their difference $\Delta p$, and gas temperature and density.

Nevertheless, a tabular reading of the characteristics of the wells is slow and not always effective to be able to identify critical situations, which is why, a three-dimensional representation that makes them immediately readable is better. All the data collected are then placed on Tables on which 3D models of representation and calculation are then built.

**Table 1**. Gas composition in volume of some boreholes
(in bold the values to pay attention)

| *Line* | *Well* | *$CH_4$ (%)* | *$CO_2$ (%)* | *$O_2$ (%)* | *Balance (%)* | *Flow [$Nm^3/h$]* |
|---|---|---|---|---|---|---|
| 1 | 4205 | 60.4 | 37.1 | 0.5 | 2.0 | 2.7 |
| 1 | 4210 | 50.7 | 44.9 | 0.7 | 3.7 | 3.4 |
| 1 | 4215 | 59.5 | 38.3 | 0.4 | 1.8 | 11.2 |
| 1 | 4405 | 62.1 | 37.9 | 0.0 | 0.0 | 0.6 |
| 1 | 4410 | 45.0 | 41.1 | 2.7 | 11.2 | 1.6 |
| 1 | 4415 | 61.9 | 38.1 | 0.0 | 0.0 | 3.4 |
| 1 | 5105 | 10.9 | 10.5 | 14.1 | **64.5** | 0.8 |
| 1 | 5110 | 35.3 | 33.1 | 6.2 | **25.4** | 1.5 |
| 1 | 5115 | 6.3 | 4.5 | 16.9 | **72.3** | 0.3 |
| 1 | 5120 | 58.2 | 39.0 | 0.5 | 2.3 | 3.3 |

*5.1. Gas quality and flow*

In Table 1 there are some cases of wells with a high percentage of Balance, particularly critical and representative of all those gases that can not be recorded by the device, completing the missing percentage to reach 100%. The predominant compound of the Balance is the nitrogen contained in outside air, which manages to penetrate inside the landfill. On the other hand, the air also contains oxygen, and its presence inhibits the action of anaerobic bacteria, limiting the production of methane. Consequently, higher is Balance, value, lower is the volumetric percentage of methane present, and therefore the quality of the biogas is worse. Therefore, a well that captures a good flow, but with low quality, will negatively affect the entire production.

In order to have a quick and clear representation of the current conditions of the wells, it was decided to represent, in the 3D model, the flow and composition values of the outgoing gas, obtained from the measurement campaign conducted in situ, which thus allow to identify the wells in which any maintenance operations were necessary (Fig. 2). Wells have been represented as spheres, where the diameter represents the outflow from the well, (the radius of the sphere is equal to the square root of the output flow), while through the properties of the layer, spheres were categorized with a different coloration based on the quality of the gas. The chromatic division, chosen according to the percentage of Balance present, is divided into nine classes ranging from green (with a percentage of 0% Balance) to red (with a percentage > 25%).

The red spheres of Fig. 2 are the most dangerous, while the larger and green spheres are those that make the most contribution to total production. Thanks to this representation and interpretation, it is possible to intervene directly on the individual wells, increasing the quality of the entire plant and reducing the various risks. For example, in the case of a red sphere (high percentage of Balance, and therefore also of oxygen), the operator can intervene by closing the well promptly and sealing the cover; or in the case of large and yellow spheres (well that captures a large flow but rich in balance and therefore poor in methane), the operator can intervene by adjusting the opening of the valve so as to reduce the applied depression, and therefore the entrance of air in landfill, with a consequent decrease in flow but increase in quality.

*5.2. Blockage and emission problems*

Through this kind of rapresentation is possible to observ further problems related to the landfill wells; They can be divided in two main categories:

1. Wells with no enough suction to guarantee a good biogas collection (yellow spheres)
2. Wells with blocking and obstruction issues (red spheres)

In the first case the small suction leads to possible emissions into the atmosphere; the second case instead is certainly caused by a too high level of the leachate. In both cases, we are faced with a criticality that does not allow the proper functioning of the biogas extraction system (Meyvantsdóttir, 2014).

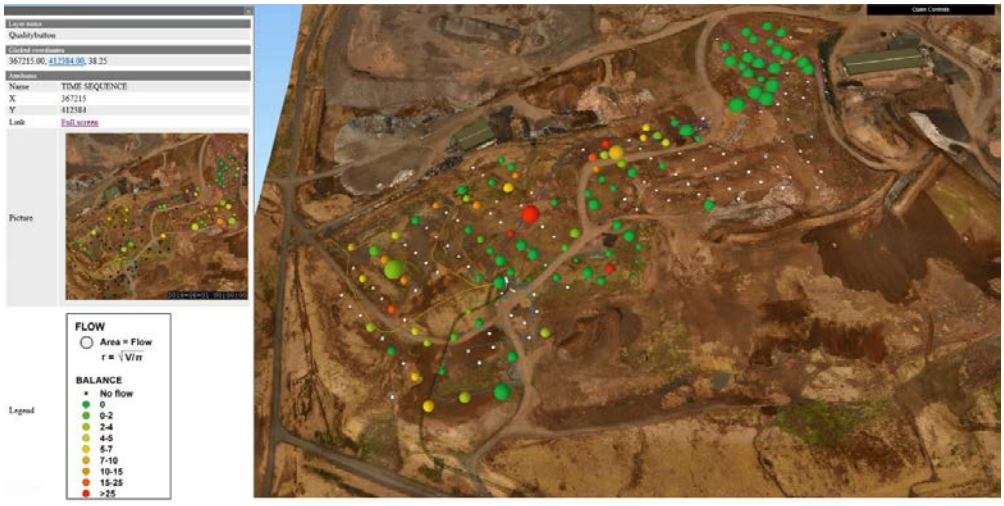


**Fig. 2.** 3D visualization of the gas quality

Among the cases of clogging are those where the pressure inside the well is similar to that inside the pipe even if the opening of the valve is very small (less than 1); in fact, with this type of valve throttling, the two pressures should present different values. When the two pressures are so close, the percolation level has probably exceeded that of the perforations, preventing the capture. Table 2 shows the case in which the inlet and outlet pressure, respectively $P_1$ (upstream of the valve) and $P_2$ (downstream of the valve), have almost the same pressure value, due to the high level of the leachate that, blocking the perforations, does not allow adequate collection.

**Table 2.** Inlet and the outlet pressure present very similar value, due to possible borehole blockage (in bold the values to pay attention)

| ***Well*** | ***Line*** | ***Atm. pressure (mbar)*** | ***rel $P_1$ (mbar)*** | ***rel $P_2$ (mbar)*** |
|---|---|---|---|---|
| 1 | 5115 | 993.0 | -43.7 | -44.8 |
| 1 | 5215 | 993.0 | -4.9 | -44.8 |
| 1 | 5310 | 993.0 | -44.8 | -44.9 |
| 1 | 4405 | 993.0 | -44.0 | -44.8 |
| 1 | 4415 | 993.0 | -44.0 | -44.9 |

Problems of this type are clear only through a three-dimensional model, as in the image above, as they would escape a 2D representation or a table data reading. From Fig. 4 it is immediately understood which well is affected by this criticality. The yellow spheres instead include cases in which the internal pressure can be positive ($P_1$, the pressure measured upstream the valve is greater than zero) or cases in which the biogas production is high, generating a large flow rate, but the suction applied is too small to guarantee its collection. A high accumulation of gas produced inside the waste mass can generate a

positive pressure, and when this is greater than the atmospheric pressure, the gas of landfill can migrate into the atmosphere (Yechiel and Shevah, 2016).

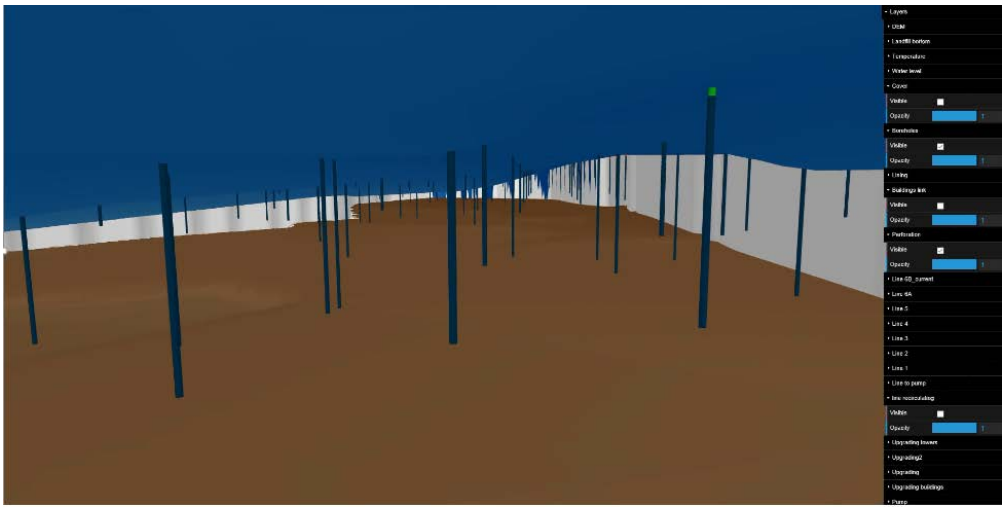

**Fig. 3.** 3D visualization leachate level inside the landfill


**Fig. 4.** 3D visualization of emissions and blockage issues. Red spheres correspond to blocked wells, while yellow spheres correspond to wells with excessive overpressure inside

Methane, in fact, has a specific weight lower than that of air, thus tending to migrate upwards and presenting a greater concentration near the cover. Furthermore, the presence of methane in the air in concentrations between 5% and 15% can lead to the risk of explosive phenomena. Therefore, more attention should be paid in case of possible migration and consequent mixing with the air, with the possible risk of explosiveness. (Sirini et al., 2009). Pressure measurements have reported cases with high pressure in some landfill wells, presented in Table 3. It can be seen where the pressure generated in the well ($P_1$) is higher than the external atmospheric pressure, avoiding a complete capture of the biogas that tends

to migrate outwards. For this reason, 3D visualization is useful in order to identify where to intervene, to improve both economic and environmental aspects (Saltiola, 2014).

**Table 3.** Positive pressure in some boreholes of the youngest line of the landfill

| *Well* | *Line* | *Atm. pressure (mbar)* | *rel $P_1$ (mbar)* | *rel $P_2$ (mbar)* | *abs $P_2$ (mbar)* | *abs $P_1$ (mbar)* |
|---|---|---|---|---|---|---|
| 12365 | 6B | 1006.0 | +1.3 | +1.3 | 1007.3 | 1007.3 |
| 12465 | 6B | 1007.0 | +2.0 | -0.7 | 1006.3 | 1009.0 |
| 12565 | 6B | 1007.0 | +1.8 | -1.2 | 1005.8 | 1008.8 |

## 6. Conclusions

In order to use the biogas produced by the landfill as fuel for vehicles, it is necessary to maintain a good quality, which is a methane percentage of the order of 95%. The best way to achieve this is to ensure an adequate monitoring plan on the wells of the main parameters. Pressure study allows monitoring of parameters such as gas composition, flow and relative pressure between the boreholes and the collection lines in order to understand how many boreholes do not work properly (Proietti and McQuilkin, 2017). To get a clear representation of the data about the current state of the landfill, three-dimensional models are one of the most effective and immediate tools. In this way, it is therefore easier to identify boreholes that need maintenance. Maintenance interventions provide valve adjustment operations or interventions on the cover to avoid splits that would allow air to enter the mass.

Key indicators for maintenance are the gas quality and the suction pressure, if the first is not good the borehole will probably be closed. Instead, when the pressure inside the mass is positive, it is necessary to provide greater aspiration, to reduce the risk of methane emissions.

Thanks to this innovative method, the operator can have a general view of the entire landfill, immediately identifying visually the wells to be rewarded, such as those to be repaired and which ones to repair. Furthermore, having an image of the entire landfill, it is possible to have an overall view of several wells and eventually understand if there are problems affecting an entire line. it is thus possible to increase the absorption of landfill biogas, using it for energy purposes and drastically reducing its emissions into the atmosphere.

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# FROM FLOW TO STOCK. NEW CIRCULAR BUSINESS MODELS FOR INTEGRATED SYSTEMS: A CASE STUDY ON REUSABLE PLASTIC CUPS*

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## Abstract

In recent years, the Circular Economy paradigm has gained its momentum among researchers, practitioners and policy-makers. The Circular Economy is underpinned by the transition towards renewable energy sources and circular business models following three simple principles: design out of waste and pollution, keep products and materials in use and regenerate natural systems. Such a framework needs new business applications to face the challenge on materials' transition (i.e. from single use to reuse). In this paper, an innovative business model for an urban integrated system is described - aiming at transforming material flows into material stocks. The model allows private companies (food and drink providers) to reduce the usage of single-use products and the amount of exploited raw materials. A pilot project, focused on the reduction of single-use plastic cups, is discussed; the business model is based on a service company which introduced a Deposit-Return System (DRS) for reusable plastic cups within the urban area of the City of Turin. The integrated system aims at reducing the splitting of the material, i.e. the plastic cups, flow by aggregating them into a new material stock. Results from one survey, related to the consumers' behaviour, from a BM Canvas and from the Material Money Flow are presented, highlighting pros and cons.

*Keywords:* circular economy, reuse, material flow analysis, single-use plastic, business model

*Selection and peer-review under responsibility of the ECOMONDO

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## 1. Introduction

The ubiquity of plastic in our everyday life and in any industrial process and commercial product is unequivocal. Plastic is a very versatile material which has contributed, and is contributing, to many product innovations. Indeed, plastic production is constantly growing since the '60s and it reached a global production of 335 Mt in 2016 (Plastics Europe, 2017). However, inefficient and flawed plastic waste management ends in impactful consequence on environment. Plastic leakages, i.e. plastics dispersed into the environment, sooner or later, end up into the oceans. Currently, 150 Mt of plastic is the amount estimated to lie in the oceans (World Economic Forum, 2016) and, every year, more than 8 Mt may arrive to the seas. Littering and plastic leakages into oceans are becoming a global emergency due to the slow degradation and to the so-called microplastics (Li et al, 2016) which enter into the food chain of fishes (do Sul et al., 2014), birds (Tanaka et al., 2013) and humans (Li et al., 2016; Wright et al., 2017), causing premature animals deads. Generally, plastics are fossil-fuel based and energy recovery is a common practice due to the high energy bonded into the chemical structure. Unfortunately, incineration, or landfilling, plastic waste generates a large amount of greenhouse gas (GHG) emissions and, moreover, plastic materials exit from a circular supply chain and cannot be recycled again as a secondary raw materials.

Despite the huge effort of practitioners and academic researchers in investigating innovative solutions to increase plastic recycling efficiency, as well as the commitment of policy-makers to adopt new policies and strategies (European Commission, 2015a; European Parliament, 2019), the Recycling Rate (RR) in European Union (EU) is still far to be considered satisfactory with an average percentage lower than the 50% in EU28 (Plastics Europe, 2017) and a target for Packaging Recycling Rate of 75% by 2030 (European Commission, 2019a). It is clear that the over-production, and the over-consumption, of plastic products cannot be solved simply by improving the Recycling Rate. Indeed, the single-use plastics constitute the largest part of plastic production, and in 2016 plastic packaging reached nearly the 40% of the global production (Plastics Europe, 2017). New and innovative Business Models (BMs) have to be introduced in order to face the plastic emergency and to reduce environmental impacts by adopting Circular BM improving the reuse and the reduction of single-use plastic usage.

## 2. Circular Economy: the future-proof economic paradigm

In order to facilitate an effective circular economy understanding, the current industrial-economic system can be questioned first. The current economic paradigm is designed along what can be defined a linear sequence of "take-make-use-dispose" (Moreno et al., 2016), based on the exploitation of natural resources (exhaustible) and on the dispose of products at the end of life. This model has guaranteed well-being and prosperity until now but has, at the same time, generated relevant impacts both from an environmental and a social point of view. First, climate change is a matter of fact: the raise of global temperatures will have noteworthy impacts on human activities and on natural ecosystems generating economic damages, desertification and agricultural productivity decrease, as well as threat to food security and human health (Commoner, 1971; IPCC, 2018, 2019; Lafakis et al., 2019). Moreover, in the current (linear) economic model, the exploitation of natural resources to drive economic activities leads to more than 11bn tons of waste annually worldwide and over 50% of Green House Gas emissions are related to virgin materials management activities - extraction, manufacturing, transportation and disposal (OECD, 2018). On average, Europeans are consuming materials and resources at twice the speed the Planet can

regenerate them (European Environmental Bureau, 2017); as a consequence, resources are becoming more expensive, due to their scarcity, and raw materials extraction is constantly becoming less sustainable (European Commission, 2017; FAO, 2011).

In this context, businesses (-as-usual) across the world are dealing with several risks, such as raw materials price volatility, scarcity of resources and new consumer behaviours. On the contrary, a different economic paradigm, such as the Circular Economy, can mitigate such risks and create economic opportunities (KPMG, 2018). A shift in values and purposes is required for the sustainable transition (Bocken and Short, 2016; Bocken et al., 2018; Ehrenfeld and Hoffman, 2013). To avoid the negative externalities of the linear system, we cannot just "do less bad", a re-design on how materials and products are produced is necessary in order to decouple the amount of needed natural resources and the negative impacts from the economic development (European Commission, 2018a).

The "Circular Economy" can be the paradigm to tackle environmental issues while boosting competitiveness of companies (European Commission, 2018b); basically, it decouples economic growth from consumption of finite natural resources, by redefining the approach to value creation and natural capital regeneration. As stated by the Ellen MacArthur Foundation (EMF), the circular economy is a new economic paradigm based on three effective principles: i) design out waste and pollution, ii) keep products and materials in use and iii) regenerate natural systems. The new paradigm refers to an industrial framework that is restorative by intention, distinguished into a biological and technical cycles (Ellen MacArthur Foundation, 2013; European Commission, 2019b). For businesses, there are multiple way to implement circular economy principles, depending on the side chosen (biological versus technical) and the inner / outer cycle in which the company's business model operates. As shown in the butterfly diagram of the EMF, the main scope is to minimise or, even better, eliminate waste in order to make useless waste-to-energy solutions (e.g. incinerators) and landfills, because every single products is designed to be reused, repaired, remanufactured or recycled. The idea of a circular economy is not new. It directly derives from the industrial ecology (Bocken et al., 2016; Jackson, 2009), P). In the 1990s, Robert Ayres introduced the idea of industrial metabolisms defining it as an "*integrated collection of physical processes that convert raw materials and energy, plus labour, into finished products and wastes*" (Ayres, 1994). More recently, McDonough and Braungart (2002) highlighted the necessity to close material loops, divided into "technical" and "biological" type, in a "cradle-to-cradle" economy, rather than cradle-to-grave economy. Moreover, Stahel (2010) discussed the fundamental difference between recycling and reuse, highlighting the importance of the latter one for a circular approach. Especially in the Food system, including packaging industry, the Circular Economy represents a huge opportunity to reconnect business purposes with social values, leveraging on cities as a catalyst for change. The way we currently produce food, and manage the resulting waste, generates significant negative economic, health, and environmental impacts. If nothing changes, by 2050, the food system will have used two thirds of the remaining global carbon budget to keep the world under 1.5°C increase (Ellen MacArthur Foundation, 2019a).

The aim of this paper is to represents an example of a circular Business Model at local level, based on a reuse & redistribute model for cups and drinks in local bars, cafes, exhibitions and events, leveraging on a Product Service System (PSS). In the circular economy framework, Product Service System is a sustainable BM (Tukker, 2015) in which enterprises sell services instead of products and they directly own the products; thus, companies are responsible for the end-of-life of the products (Brezet, 2001; Charter and Tischner, 2001; Manzini and Vezzoli, 2002; Mont, 2004; Tukker and Tischner, 2006a, b). Such business model can improve user experience, optimise logistics and, consequently, lower production and maintenance costs, as well as help businesses to enhance customers brand loyalty and fit products to personal needs (Ellen MacArthur Foundation, 2019b).

The rest of the paper is structured as follows. In Section 2, an overview on European Union normative framework relative on generic packaging, with a focus on Deposit-Return System (DRS). Afterwards, in Section 3, a new Business Model for an integrated DRS for reusable cups is introduced and Results based on a case study are discussed in terms of BM Canvas and Money Material Flow (MMF). Furthermore, results of a survey on consumers relative to single-use versus reusable plastic cups is discussed. Finally, in Section 4, brief concluding remarks with tips, suggestions and barriers relative to the plastic packaging ecosystem are underlined.

## 3. Background

### *3.1. Shortly about legislation*

Currently, many Governments (and various relevant Government agencies) are increasingly dealing with the problem of the high use of single-use plastic. For instance, Canada (Walker et al., 2018) and United States (Wagner, 2017) have promoted initiatives aimed at reducing and gradually eliminating single-use plastics. The connection between the use of plastic (especially the disposable one) and the dispersion of waste in the marine environment has been widely demonstrated; research studies highlighted as, only in the coastal countries, from 4.8 to 12.7 million metric tons of plastic waste end their life into the oceans. These numbers are destined to increase progressively by 2025 (Jambeck et al., 2015).

The legislation approved by the European Parliament on 5th June of 2019 (European Parliament, 2019) moves exactly in the same direction, i.e. towards the reduction of single-use plastic components. The European Union had already dealt with these topics with the "European strategy for plastic in the circular economy" declaring that "*a solution must be found for the growing production of plastic waste and for the dispersion of plastic waste in the environment in which we live, particularly in the marine environment*". The European Union, in order to stem this problem, proposes circular approaches to the use of plastics that give more space to reusable and more sustainable products than those used so far, so as to minimize the amount of plastic waste. For instance, recently, certain products - e.g. plastic straws, single-use plastic cutlery, plastic plates, plastic balloon sticks, cotton bud sticks made of plastic, Oxo-degradable plastics and food containers and expanded polystyrene cups - will no longer been placed on market (European Parliament, 2019). When it will not be possible to stop the use (and the production) of plastic objects, the legislation requires that these be gradually reduced in their use, as well as increasing the proportions of recycled and differentiated plastic waste. Each Member State is free to implement the aforementioned regulations in the most congenial manner, providing that the restrictions are "*proportionate and non-discriminatory*".

In Italy, the EU legislation has not yet been implemented. Every single region is taking steps to issue and implement legislation on its own behalf. The reference law of the Italian legislation does not aim directly at plastic waste deriving from single-use material but tends to eliminate waste at sea at the end of its life cycle, leaving fishermen "free" to collect the plastic they find in their nets, without having to throw them back into the water (Italian Government, 2019).

### *3.2. Deposit system background*

In this subsection a brief review on common Deposit-Return Systems for beverage containers is discussed. Currently, worldwide, dozens of countries adopted a DRS with national laws in order to increase the recycling rate of the particular fraction of plastic waste related to the single-use packaging of the food and drink industry (CM Consulting, 2016).

Figure 1 shows a generic DRS for single-use containers. The supply chain starts from the Producers/Importers (1) who sell the filled beverage containers (e.g. water bottle, plastic bottle for soft drinks, beer cans, …) to the Retailers who pay the price of the drinks plus a little amount of money for the deposit. Afterwards, Consumers buy beverages, paying the deposit to the Retailers (2) and consume the drinks (3). Thanks to the DRS, consequently, Consumers are allowed to bring back the empty containers directly to the Retailers, or to ad-hoc redemption centers or depots, in order to receive back the deposit (4). At this point, the Retailers, who are aggregating packaging in their private spaces, can give back the gathered empty containers to the Recyclers, receiving back the deposit. In addition, the Retailers may provide data information on the recycling rate, the typology of containers and so on (5). In some cases, as in Iceland, the collection of the empty bottles takes place in some dedicated, automated or manual, return facilities. Finally, the Recyclers process the beverage containers such that to obtain secondary raw materials which can be sold again to the Producers/Importers (6). Generally, in centralized system, Producers/Importers, in addition to the deposit, have to pay an administrative fee to the Recyclers or to the private/public organization which manage the waste supply chain. Indeed, in many countries the Recyclers represent both the private actors who proper recycle the materials and a public central organization, a national consortium for instance, who manages the entire deposit system.

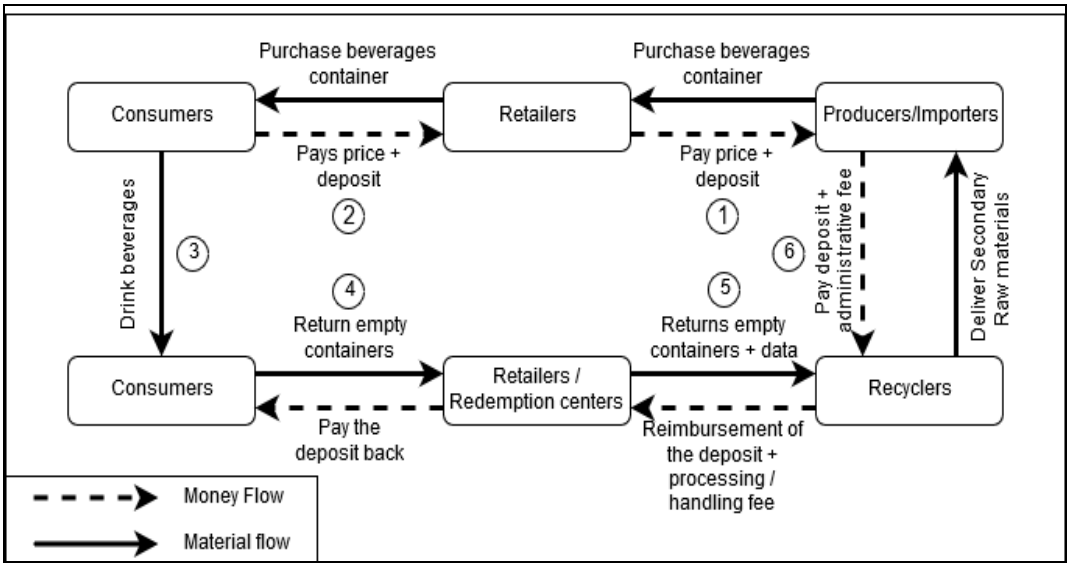


**Fig. 1.** Simplified supply chain of a Deposit System for single-use beverage containers (adapted from CM Consulting , 2016)

The central organization, usually, is responsible for the Clearing System, i.e. it is the entity responsible for the DRS in order to close the money flow. Examples of centralized national system in Europe are the cases of Croatia (Environmental Protection and Efficiency Fund), Denmark (Dansk Retursystem A/S), Estonia (Eesti Pandipakend OÜ) and Finland (Suomen Palautuspakkaus Oy - PALPA). In some cases, the central actor belongs to a few different entities such as the danish Dansk Retursystem A/S, which is a shared property of five organizations - the Dansk Retursystem Holding A/S (85.62%), the Dansk Harboes Bryggeri A/S (14.27%), the Dansk Harboes Bryggeri A/S (14.27%) and the Mineralvandsfabrikken Frem A/S (0.01%) - or, as in the finnish case, PALPA belongs to seven partners - KESKO, Alko, Puotiin, Hartwall, Sinebrychoff, Tuko Logistics, Inex Partners - where each company is specialized in a sector as drink and beverage, alcohol retail

or logistics. In a few cases, there are many organizations (Rhenus Logistics, Interseroh, …) in a decentralized system, as in Germany, where the Deutsche Pfandsystem GmbH, the system administrator, is owned by the Hauptverband des Deutschen Einzelhandels (HDE) and the Bundesvereinigung der Deutschen Ernahrungindustrie (BVE), a German Retail Association and a German Food Association.

In this framework, the flow is linear up to the Recyclers and there are no financial aid, neither incentive to reduce or reuse products. Indeed, it is straightforward that the material loop is closed only between the Recyclers and the Producers when, effectively, the recovered waste are recycled. As shown in Fig. 2, the recycling sequence consists of, at least, four steps (Graedel, 2011): 1) the *Collection*, acted by the citizens and the municipalities/local multi-utility companies, 2) the *Separation* and 3) the *Sorting*, generally acted by a private-public company, and, finally, 4) the *Processing*, i.e. the effective waste recycling. The whole sequence can be improved only by increasing the efficiency of each step individually; the final efficiency can be computed as a conditional percentage of the four stages. For instance, as exhibited in Fig. 2, the final percentage of recycled material (25%) derives from the 50% of the Collection, the 70% of the Separation, the 80% of the Sorting and the 90% of the Processing processes. The last two steps, Sorting and Processing, completely depends on technology and they can be improved by technological innovation. The second step, Separation, can be improved by technological innovation as well as on the quality of the collected materials, while the first stage, the Collection, primarily depends on the awareness of the citizens and on proper local and national policies, which stimulate the separate collection, such as door-to-door collection (Teerioja et al., 2012), penalties/taxes/incentives (Miranda et al., 1994) or intrinsic reasons for citizens (Aprile and Fiorillo, 2019).

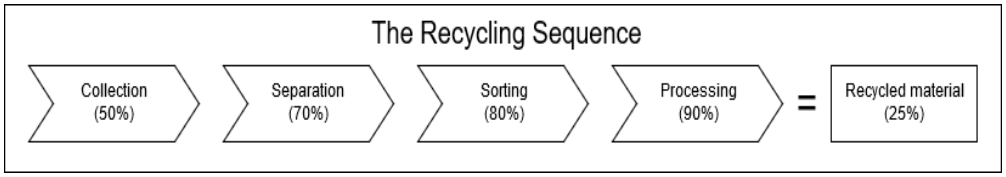


**Fig. 2.** Representation of recycling rate for a generic material reverse supply chain (adapted from Graedel, 2011)

Although the right policies and incentives may improve the efficiency of the Collection process, its efficiency cannot achieve the 100% due to many reasons such as psychological, administrative or logistics barriers; thus, the entire Recycling Sequence will always be affected by an "original sin". For these reasons, DRSs have been introduced worldwide in the past decades achieving very satisfactory results in terms of recycled materials even if the physical limit of the 100% of recycled material is still very far. For instance, Croatia achieved a total return rate for single-use containers (Plastic, metal, glass) in 2015 up to 90% with a target of 95%, Denmark of 89% in 2014 with a target of 95%, Estonia reached 82.3% in 2015 and Germany 97% in 2014 (CM Consulting, 2016). On the contrary, the European Union Target, according to the Packaging Waste Directive, was 22.5% while the total European Union recycling rate for plastic packaging waste was 40.8% in 2016 (Plastics Europe, 2017). 27.1 Mt of generic plastics was collected over a total production in European Union countries (EU28+NO/CH) of more than 60 Mt of plastics (Plastics Europe, 2017). 8.43 Mt (31.1%) were then recycled, 11.27 Mt (41.6%) incinerated and 7.4 Mt (27.3%) went to landfill. The percentage of collected waste increased by 10.6%, from 24.5 Mt in 2006 to 27.1 Mt in 2016, and the properly recycled increased by 79% in absolute terms, from 4.7 Mt in 2006 to 8.43 Mt in 2016. The percentage of recycled waste,

over the total collected waste, increased from the 19% in 2006 up to the 31.1% in 2016. With respect to plastic packaging the collected waste increased from 14.9 Mt in 2006 to 16.7 Mt in 2016. In the same period, proper recycled plastic packaging increased by 74% and energy recovery by 71%. In 2016, with respect to the total of plastic packaging waste 40.9% were recycled, 38.8% went to incineration while 20.3% to landfill.

Although it is evident the growth of percentage both of collected waste and of recycled waste, it is also straightforward that the efficiency of the collection and the recycling in EU countries can still be noteworthy improved, simply by comparing the percentage of plastic packaging properly recycled with the total return rate obtained by DRS. Table 1 resumes the Total Return Rate within the countries with a Deposit-Return System regulated by a national legislation versus the plastic packaging RR. Indeed, even if the two data are not directly comparable (one refers to collection rate, while the other refers to recycling rate - it is clear that there is a large opportunities of improvement. In fact, a DRS affects the first three stages, Collection, Separation and Sorting, as depicted in Fig. 2. By multiplying the Total Return Rate with the Processing Rate as indicated in Fig. 2, a first insight on the improvement margin can be obtained (Table 1).

**Table 1.** Estimation of Plastic Packaging Recycling Rate from a Deposit-Return System (CM Consulting, 2016) and Countries Recycling Rate (Plastics Europe, 2017)

| ***Country*** | ***Total Return Rate (collection + separation + sorting), %*** | ***Plastic Packaging Recycling Rate (hp: processing 90%), %*** | ***Plastic Packaging Recycling Rate (EUROSTAT)*** |
|---|---|---|---|
| Germany | 97 (2014) | 87.3 | 48.4 (2016) |
| Sweden | 88.25 (2014) | 79.2 | 50.7 (2016) |
| Estonia | 82.3 (2015) | 74.1 | 24.6 (2016) |
| Denmark | 89 (2014) | 80.1 | 36.1 (2016) |
| Croatia | 90 (2015) | 81.0 | 41.1 (2016) |
| Finland | 92.6 (2014) | 83.3 | 25.4 (2016) |
| Iceland | 90 (2013) | 81.0 | 42.7 (2016) |
| Lithuania | 74 (2016) | 66.6 | 74.4 (2016) |
| Netherlands | 95 (2014) | 85.5 | 51.5 (2016) |
| Norway | 96 (2014) | 86.4 | 44.6 (2016) |

## 4. Results and discussion

A case study, i.e. Plastic Free Movida (PFM), within the city of Turin in Italy is described as an example for a Circular BM for a Deposit-Return System for reusable cups. This example shows how by introducing a new actor responsible for the Deposit and the Clearing System in the MMF for single-use beverage containers described in Fig. 1 it is possible to transform constant material flow into a temporary material stock.

The PFM Business Model has been introduced by an Italian NGO named greenTO in 2019 within the city of Turin in order to create a distributed and integrated retailers network at urban scale. The BM is based on the adoption of reusable cups by the retailers within an urban area and on a DRS managed by the NGO itself. The definition of "integrated" network refers to the fact that the owner of the reusable cups is a third party stakeholder, in this case the NGO, and the retailers have not to pay any deposit in advance, as in existing DRS for single-use containers and the introduced cups can be delivered back by consumers to any retail involved in the network. The case study is analyzed in terms of MMF and BM Canvas, highlighting the involved stakeholders. Finally, results from a survey on consumers' behaviour is pointed out.

### *4.1. Money Material Flow*

In this section, the Money Material Flow is described. The DRS here analyzed is pretty similar to the one described in Figure 1 related to the common single-use containers DRS; the main difference is a new actor, i.e. the Deposit Manager Organization (DMO), who is the responsible for the Clearing System and acts as a man in the middle among the Consumers/Retailers and the Producers/Recyclers blocks by managing the Consumer Deposits (Fig. 3). First, the container supply chain again starts from the Producers who sell reusable cups to one, or more, Deposit Manager Organization (1) who purchases directly the empty cups without adding any deposit to the price of the cups. The DMO is the owner of the materials and the manager of the deposits. Second, the DMO delivers the reusable empty cups to the Retailers through private agreement receiving back an *una-tantum* deposit, i.e. a deposit for each requested cup (2) in the first stock.

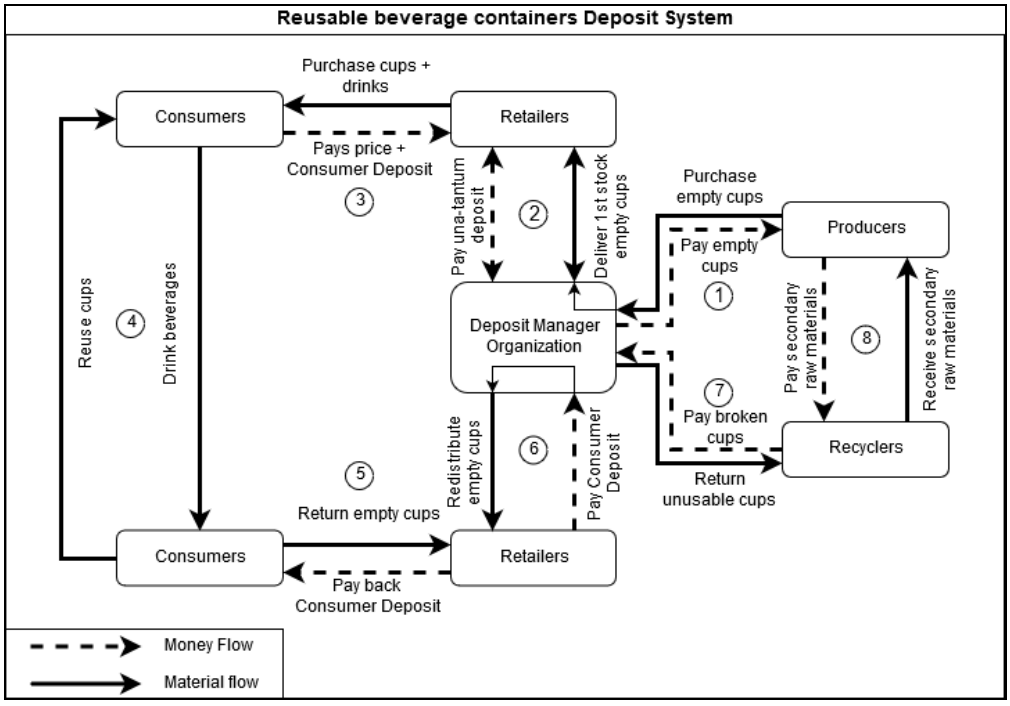


**Fig. 3.** Representation of a reusable beverage containers Deposit-Return System

The double direction of the arrows, at this stage, means that retailers can stop and give back, at any time, the furnishment of cups. The agreement between the DMO and the Retailers can be one, or many, year long and it guarantees to the Retailers, for all the life of the agreement, to have a constant stock of cups. Third, as in the single-use DRS, Retailers deliver the empty cups to Consumers when they buy a beverage by receiving the Consumer Deposit (3) and consequently, Consumers use, and re-use, the cups as many time as they want (4), stacking the cups in a reuse loop. At any time, Consumers can return the empty cups to the retailers by taking back the Consumers Deposit (5). At this point, the DMO takes part again in the supply chain by receiving back, weekly or monthly, the Consumer Deposits and by redistributing empty cups among the network of involved Retailers (6). This step, is necessary to close the reuse loop of the cups. The redistribution, instead, is necessary for an integrated system, i.e. a network of Retailers with the same cup and to guarantee to the Consumers to be able to return empty cups to anyone of the involved retailers and not only in the first one where they buy the cups. More precisely, the redistribution meaning is to balance the number of cups according to the individual agreement between the DMO and the Retailers; in other words, the DMO has to deliver cups to each retail in order to guarantee constantly the same amount of the 1st stock of the step (2).

Finally, when the cups reach their end-of-life, e.g. broken, threadbare or unusable cups, the DMO has to collect them in order to send all the materials to the Recyclers in order to enter in the classical and existing Packaging Supply Chain (7, 8). This Deposit System, in other words, based on the same logic of the single-use containers Deposit System, increases the life of each cup from few minutes to years by stacking the flow of materials within the steps (3), (4), (5) and (6) and transforming a constant flow of materials made by single-use products into a, temporary (a few years), stock of materials.

### *4.2. Business Model Canvas*

In this section, the business model canvas is presented, in order to document the business model with a visual tool which describes PFM's value proposition, partners, resources, customers, and finances. The PFM's mission is to offer a simple and effective solution to encourage the adoption of consumption models related to reuse practices, starting with drinks consumed in bars, cafes and clubs. The experimentation phase took part in Turin, Italy, in 2019 and during the implementation phase many new activities and players came up, transforming the initial business idea in something more integrated with the city. Out of what is described in Fig. 4, a couple of considerations can be made:

- in order to maximize the awareness on single use plastic consumption and its impact, partners engagement is crucial; committed partners can involve other new partners and suppliers, enhancing the resiliency of the entire supply chain; moreover, they can involve and engage all the consumers, creating a real community and supporting an indirect education for consumers;
- the integrated system support is the main advantage of PFM. Consumers can turn back or refill their cups in any point of the network (commercial points);
- in order to scale up the business, increasingly involvement by new partners is crucial; the business needs to scale also in different operations, as already experimented, such as public events, concerts and exhibitions.

### *4.3. Analysis of customer perception*

An online survey has been conducted in the months of June and July 2019 to understand consumers and citizens' drinking habits at night and to explore the perception of users' related to the introduction of reusable cups within the Turin's nightlife. Two hundred

and twenty-eight answers were collected (27 in English from foreigners and 201 in Italian). The survey was composed by three main sections: 1) personal and registry information (profession, age, gender, ..); 2) drinking habits and nightlife routines; and 3) consumers' feelings and perception about reusable cups and Deposit-Return Systems.

*4.3.1. Personal information*

A percentage of 36.6 of the respondents were male and 63.4% were female, 71% were between 18 and 25 years old, 27.5% were between 25 and 40 and 1.5% between 40 and 60. 77% were students, 20% were employed and the remaining 3% were unemployed. Finally, the majority were resident in Turin (61%) or lived in Turin as students/workers (28%) while the rest (11%) was living outside Turin.

**Plastic Free Movida**

| KEY PARTNERS | KEY ACTIVITIES | VALUE PROPOSITION | CUSTOMER RELATIONSHIPS | CUSTOMER SEGMENTS |
|---|---|---|---|---|
| - Consumers<br>- Bars, cafes and clubs<br>- Bloggers<br>- Municipalities<br>- Reuse Business Model Expert<br>- Engineering partner<br>- Regulatory Expert<br>- Other institutionals partners | - Raising awareness of customers and consumers<br>- Selection, customization and distribution of reusable rigid plastic cups<br>- Personalized glass washing service, collection and re-delivery<br>- Redistribution of new cups and deposits<br>- Integrated management system for the customer relations<br>- Graphics and communication<br>- Organization of promotional events | Offer an integrated empty return system for beverages sold, through the use of reusable rigid plastic cups and a customized pay-per-wash service, capable of increase commercial positioning and reduce the waste of single use plastic. | - Direct contact with the customer (email / phone / whatsapp / meeting)<br>- Newsletter | - Bar owners<br>- Event organizers<br>- Catering companies<br>- Public entities<br>- Food and Beverage operators<br>- People sensitive to environmental issues, disposable plastic and social innovation<br>- People who want to save money on the purchase of disposable products and waste generation<br>- People who like to share their experiences through social media |
| | KEY RESOURCES | | CHANNELS | |
| | - Reusable cups<br>- High performance dishwashers<br>- Mobility system and transport for the cups redistribution service<br>- Logistic know-how and integrated systems<br>- Strong staff commitment on environment protection and social innovation issues<br>- Communication skills<br>- Fundraising skills | | - Cups (with customized graphics)<br>- Web site<br>- Social Media (Facebook, Instagram)<br>- Events / concerts / exhibitions | |

| COST STRUCTURE | REVENUE STREAMS |
|---|---|
| - Purchase of reusable cups<br>- Purchase of dishwashers<br>- Purchase of transport vehicles for cups redistribution<br>- Marketing & Communication<br>- HR and salaries<br>- Taxes | - Revenues from the refill of the cups capital for each client<br>- Revenues from the washing and delivery service<br>- Revenues generated by the licensing of the brand<br>- Sponsorships and donations |

**Fig. 4.** Business Model Canvas of Plastic Free Movida case study for a Deposit-Return System for reusable cups

*4.3.2. Drinking habits and nightlife routines*

This section was focused on analyzing the average attendance of users in the nightlife and the average number of drinks per night in order to quantify the possible impact of a Deposit-Return System. Perception on the plastic recycling was also asked, as well as if consumers usually drink their beverages in plastic or glass cups. About the drinking habits there were three questions: 1) "How many times in a month do you drink in the city at night?", 2) "How many drinks do you consume on average in an evening?" and 3) "How often are you served the drink you asked for in a plastic cup?".

With respect to the first question, 30% of the participants at the survey drinks more than 4 times per month, 33% between 2 and 4 times per month and 33% declared between once or twice per month. The majority drinks more than one cocktail per night (70% between 1 and 3 cocktails per night and 26% between 3 and 5 and 3% more than 5 cocktails per night).

These first questions, together with the first section questions, ensured that the answers came from usual attenders of the nightlife in Turin. Finally, with respect to the third question "How often are you served the drink you asked for in a plastic cup?", 60% of the sample declared "quite often", 29% stated "in occasion of big affluence" and only 11% answered "rarely".

*4.3.3. Consumers' feelings and perception about reusable cups*

In this last section, the aim was to understand the feeling of the consumers facing with reusable plastic cups and their perception with respect to the service of recycling of single-use plastic cups. There were 6 main questions: 1) "When you finish your drink, what do you usually do with the plastic cup?", 2) "What do you think will happen to the plastic cup you've used?", 3) "Would you feel uncomfortable consuming a drink in a reusable cup?", 4) "How much are you willing to pay for a reusable cup if the bartender changes it with a clean one every time you get a new a drink?", 5) "If the bartender gave you the possibility to choose between a reusable cup and a plastic cup, which one would you pick?" and 6) "If you find a reusable cup on the floor, would you pick it up and bring it back to the bar?".

The first two questions aimed at understanding the perception related to the recycling of plastics. Surprisingly, the majority doesn't care about throwing correctly the single-use cups. Indeed, the 48% declared to throw it into a generic bin (not the plastic dedicated bin), 10% declared to leave it in the street, 10% to bring back it to the bar/pub while only the 26% declared to deliver the plastic cup into a plastic bin. This behaviour is further confirmed by the scarce trust into the recycling service. In fact, the second question revealed that 70% believed that plastic cups end into a landfill or directly disperse into the environment (12.7%). Only the 17.3% trusts the recycling service. Finally, the last four questions analyzed the users' feeling with reusable plastic cups. Only 4% declared to feel uncomfortable to drink into a reusable cup due to hygiene, while 48% stated both to be adverse if the cups are not properly washed and to not have any problem with reusable cups usage.

With respect to the average price for the deposit, 36% wish to pay less than one euro, 59% between 1 and 2 euros and 5% more than 2 euros. With respect to the fifth question, the majority prefers a reusable cup (93%) against a single-use cup (7%). Finally, the last question analyzed the users' behaviour on picking up empty cups within the street, confirming that the introduction of a Deposit-Return System may solve the littering problem thanks to the deposit. Indeed, 70% declared to collect an abandoned cup, 24% maybe and only the 6% not, I wouldn't.

## 5. Concluding remarks

In this paper, a Product Service System for a Deposit-Return System for reusable cups has been introduced. The pilot project here described, run in the city of Turin in the month of July and August 2019 and still active, allowed to transform a flow of material into a temporary stock of material. The case study has been validated by a survey related to the behavior and the perception of usual nightlife attenders. The results from the survey revealed that night attenders have a scarce trust on the local recycling multi-utility company of the city of Turin. Moreover, answers from the survey pointed out that the majority of nightlife attenders in the city of Turin don't care about correctly dispose single-use plastic cups.

The latter feature can be easily solved by introducing a Deposit-Return System for both, single-use and reusable cups, as highlighted from the survey. 70% declared that with a DRS would collect abandoned cups in the street and 24% maybe. Thus, the described Business Model and the related Material Money Flow shows how introducing a new actor into the classical DRS for single-use cups it is possible to create an integrated network of retailers at urban level and to boost reuse practice within a city for a targeted product (in this case, plastic cups).

Even if, survey's results and preliminary outcome from the pilot project are satisfactory several aspects have to be further investigated. First, a Life-Cycle Assessment must be done in order to compare classical single-use container DRS with the proposed DRS for reusable cups and to identify possible inefficiency, from an environmental point of view, and to reveal the "environmental break-even point". Indeed, the production of reusable cups need undoubtedly more energy and raw materials (the weight ratio between a single-use and a reusable cup is about 1:10), as well as the repeated washing of the reusable cups squanders a large amount of water. Second, current plastic cups producers are selling products, i.e. reusable cups, only tested, in a large scale, during temporary, from a few days up to a few weeks large festival.

Thus, the effective durability of a reusable cup is still to be assessed within the daily life of a bars. It is clear that within bars, restaurant and clubs of a city the usage is much more intensive with respect to a time-limited event. Finally, eventually administrative barriers in different countries have to be analyzed. Existing national, regional or local regulations could stall the scale up of such a model due to hygiene, public safety in the street or to simpler lack of appropriate laws for DRS. On the contrary, a DRS for reusable cups, if implemented at urban scale, could allow to collect information related to social practices, such as social drinking. Merely by developing a smart cups, e.g. a monitoring system which can track drinking habits of citizens and the flow of the cups within the city, it may be possible to collect current unavailable data on several social phenomena related to the nightlife.

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**Conflict of interest**

The principal investigator Dario Cottafava is one of the cofounder of the promoting NGO involved in the case study described.

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# EXPLOITATION AND ENERGY RECOVERY OF FLUFF: SMART SOLUTIONS IN A PROSPECTIVE OF CIRCULAR ECONOMY*

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## Abstract

In recent decades, the electronic equipment business has increased exponentially. At the same time, programmed obsolescence refers to the deliberate shortening of a product's useful life by the manufacturer in order to increase consumption. This also means that the amount of waste derived from electrical and electronic equipment will continue to increase in the coming years. Electronic scrap components, such as CPUs, contain potentially harmful materials such as lead, cadmium, beryllium, or brominated flame retardants. It is crucial to obtain more knowledge about the environmental consequences of the different WEEE treatment options, because political decisions and legal changes will influence development of WEEE collection, recycling or/and disposal. The new technologies in the field of the waste management, provide the possibility of recycling and recovering merchandise fractions previously considered irrecoverable. In line with this, one of the biggest problems in waste disposal is fluff. The term "fluff" refers to the light scraps left over from vehicles and include gaskets, tires, fabrics and plastics. To date, the only possible disposal system is the transfer to controller landfills. This means the loss of material resources due to the lack of recovery, in particular of energy. For this reason, the goal of this paper is to propose possible, but also sustainable, alternatives to landfill disposal. In conclusion, the advantages of thermovalorization are: lowering the total cost of the storage system and the exploitation of industrial waste materials, environmental and community benefits such as reducing the landfilled waste amounts and reducing greenhouse emissions.

*Keywords:* Circular economy, fluff, weee, waste impact

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## 1. Introduction

Circular economy (CE) is emerging as an economic strategy rather than a purely environmental strategy. The concept of a circular economy (CE) was first proposed by scholars in China in 1998 and formally accepted in 2002. The major objective of the government is to promote the sustainable development of economy and society, while it also helps to achieve sustainable environmental protection. Although there is no commonly accepted definition of CE so far, the core of CE is the circular (closed) flow of materials and the use of raw materials and energy through multiple phases. Regarding the circular economy, three is a key number (Yuan et al., 2006). The "3R" principles—reduction, reuse, and recycling of materials and energy are often cited to describe the three possible approaches. In practice, there is a three-layer approach to implementing CE. At the micro or individual firm level, companies are either required or encouraged to conduct CP (Cleaner Production) auditing. At the meso or second level, the main objective is to develop an eco-industrial network that will benefit both regional production systems and environmental protection. At the macro or third level, the main purpose is the development of the eco-city, eco-municipality, or eco-province (Nourreddine, 2006).

It is well established that end-of-life products such as vehicles, white goods or mixed scrap undergo a shredding process. It consists of a heavy hammer mill pulverizing the waste, with a subsequent sorting step separating a heavy and a light fraction. Whereas the heavy fraction predominantly consists of metals, which can be recycled, up until now there has been no adequate solution for the so-called shredder light fraction (SLF). The light fraction can be separated into plastics, fines and fluff. For the plastics, several possibilities for recycling already exist, such as use as a reduction agent for the blast furnace process. There is, however, potential for improving the recycling rate of the fluff fraction. Since this material contains a significant portion of fibers, further usage of the material should be considered (Jaiswal et al., 2012).

**Fig.1.** Fluff

Recycling of shredder fluff is part of CE. It is possible to find it in the nonmetallic content of automobile and other shredded materials, such as refrigerators, dryers and dishwashers. There are two different types of fluff: light fluff (CER 19 10 04) and heavy fluff (CER 19 10 06). Light fluff is the part, where all the lightweight components are concentrated, and it is not dangerous (Cossu et al., 2014) On the contrary, heavy fluff includes the heavyweight components, which are the remains of the separation of metals (glass, plastic). The problem is that the plastic content of shredder fluff is typically 15-20% by weight and it is expected to increase over the next decade. Moreover, at present, shredder fluff is landfilled. For this reason, it is necessary to find a new way to recycle it, in order to reduce the volume and the mass of shredder fluff going to landfills (Andersen, 2006).

The aim of this paper is to analyze the recycling of shredder fluff, in order to reduce the environmental impact. Recycling is complicated because this material is very heterogeneous, density and moisture content change from site to site and from day to day as different types of source materials are shredded. Even though this process is difficult to implement, at the same time, it is necessary for the environment. To improve a Green Economy model, whose purpose is to reduce the environmental impact, the society needs to focus on the growth of one economic system based on sustainable development.

An important innovation to re-use fluff is the new Panizzolo refining plant for fluff waste management, lunched at the beginning of 2019. It consists of a patented hammer mill that is designed to complete the Fluff waste cycle. Solid waste in input are differentiated into the following types: Fluff from mixed, crushed and ground metals, Fluff from floatation systems, car fluff (from discarded vehicles), WEEE recycling fluff and other secondary mixes. The refining system is designed to recover metals with an End of Waste cycle logic. On completion, it obtains granulated aluminum, copper and steel that is completely separated, and classified as secondary raw materials.

## 2. Materials and methods

A waste-to-energy plant is a waste management facility that combusts wastes to produce energy. This can be in the form of steam, electricity or hot water. The electricity is fed into the grid and distributed to the end-users. The hot water, depending on local infrastructure can be sent to a nearby district heating (or cooling) network to heat (or cool) homes, hospitals and offices. The steam can be used by the nearby industry in their production processes. Waste-to-Energy is a hygienic method of treating waste, reducing its volume by about 90%. Modern Waste-to-Energy plants are clean and safe, meeting the most strict emission limit values placed on any industry set out in the Industrial Emissions Directive. Efficient Waste-to-Energy plants thermally treat household and similar waste that remains after waste prevention and recycling (Youcai et al., 2002). In this way they reduce both methane emissions (a potent greenhouse gas that has 25 times greater impact to climate than carbon dioxide $CO_2$) from landfilling and $CO_2$ emissions that would have been produced if the amount of energy was generated in conventional power plants.

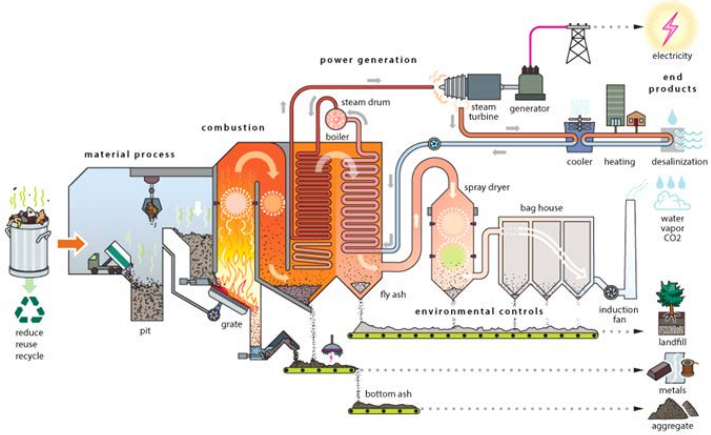
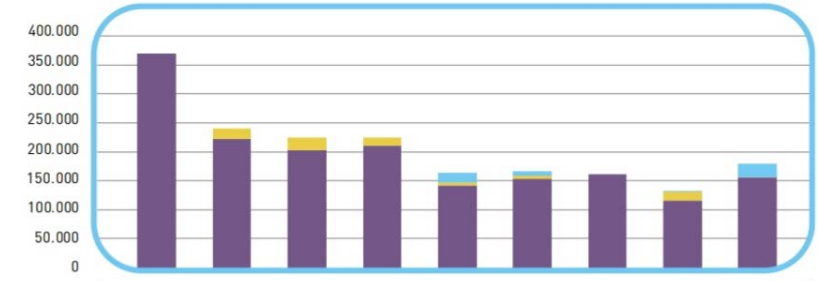



**Fig.2.** Waste-to-energy plant components

The process of generating electricity in a mass-burn waste-to-energy plant has seven stages:

1. Waste is dumped from garbage trucks into a large pit.
2. A giant claw on a crane grabs waste and dumps it in a combustion chamber.
3. The waste (fuel) is burned, releasing heat.
4. The heat turns water into steam in a boiler.
5. The high-pressure steam turns the blades of a turbine generator to produce electricity.
6. An air pollution control system removes pollutants from the combustion gas before it is released through a smoke stack
7. Ash is collected from the boiler and the air pollution control system.

This process of generating energy is related to the recycling of fluff. Until only recently fluff has been largely disposed of in controlled landfill sites. However, in Europe environmental regulations, including the EU Landfill Directive 1999/31/EC and ELV (End of Life Vehicle) Directive 2000/53/EC, have dramatically increased the pressure on all stakeholders to develop alternative solutions. As increasingly stringent legislation forces Shredder Residues (SR) to be diverted from landfilling, newly developed technologies will be in a position to compete for the market value of disposing of the waste. However, the fluff waste stream is so variable that it cannot be automatically assumed that processes developed for one type of fluff will prove to be suitable for other fluff streams.




| | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|---|---|---|---|---|
| RICICLO | | | | | 17.154 | 6.976 | 0 | 1.454 | 23.130 |
| RECUPERO ENERGETICO | 0 | 17.766 | 21.279 | 13.687 | 4.793 | 5.763 | 0 | 14.484 | 268 |
| DISCARICA | 369.495 | 221.962 | 203.204 | 211.005 | 141.786 | 153.493 | 161.331 | 116.417 | 156.310 |

**Fig. 3.** Recovery fluff in Italy

The reference point for In Sicily for the recovery and disposal of hazardous and non-hazardous waste is the company FG S.r.l. Thanks to the knowledge acquired also in the field of industrial, naval and railway demolitions, the FG S.r.l. is specialized in the treatment of electrical and electronic equipment out of use, with the recovery of appliances at the end of life. The meaning of WEEE indicates waste from electrical and electronic equipment. Awareness of this type of waste is greatly increased due to the major dangers associated with its abandonment and environmental impact. In the last decades the amount of WEEE increased exponentially (Baldé et al., 2017). The main causes are to be sought in the increasing commercialization of these products and in their life cycle drastically reduced by the programmed obsolescence. The proper disposal of waste is very important for the environment because it reduces the emission of hazardous substances into the atmosphere such as heavy metals present in electronic boards or ozone gases harmful to the cooling circuits of refrigerators and air conditioners, allows a considerable energy saving for the recycling of secondary raw materials. As we said previously WEEE are the fastest growing

category of waste globally, with a growth rate that varies between 3-5% during the year. The UN estimates between 20 and 50 million tons of hi-tech waste, produced in the world. Waste from electrical and electronic equipment, represents a great opportunity for the circular Economy in both environmental terms (through the reduction of various gases, such as CFC and pentane), and economic (through the reduction of energy impact, the production of raw materials-second such as copper, iron, aluminum and plastic highly influential from the remunerative point of view). The treatment and processing of WEEE, due to the peculiarities of this waste and the presence of non-biodegradable and partly environmentally toxic substances in it, can only be operated by companies that have passed the accreditation processes regulated by Legislative Decree no. 49/2014 (Implementation of the WEEE Directive 2012/1/EU).

The work of FG, using state-of-the-art technologies and equipment, allows a treatment of WEEE environmentally friendly, it allows the recovery of raw materials that make up them. Thanks to this particular specialization in the sector, FG S.r.l. has obtained and maintains the certifications to be accredited to the treatment and recovery of all categories of WEEE.

WEEE are defined by Annex 1 of the Regulation 25 September 2007 n. 185 (Art. 4 paragraph 1 of Legislative Decree 49/2014).

In particular they distinguish 5 types that allow to optimize the logistics and their treatment:

- R1 (Cold and Climates), e.g. refrigerators, freezers, air-conditioners. The presence of GAS and refrigerant fluids in the equipment circuits of this grouping makes their processing extremely complex. FG ensures the safety and remediation of these highly polluting components ensuring that ozone-damaging substances are not released into the atmosphere and that fluids do not contaminate the aquifers. Also, the reclaimed carcasses are conveyed by means of conveyor belts to the grinding area which takes place in a controlled and depressurized environment, avoiding the escape of the volatile components. A series of mechanical separators operate the sorting of iron, plastic, aluminum, copper and polyurethane.
- R2 (Large white), for example washing machines, dishwashers, microwaves. The equipment belonging to this group undergoes a manual pretreatment after this, components such as: cement, motors, cards, plastic, glass (washing portholes) are removed.
- R3 (TV and Monitor), for example old CRT cathode-ray tube screens, modern LED and Plasma screens. Both old and new monitors and TVs contain substances that are harmful to the environment. The production lines of FG provide to operate on these equipment a pretreatment with manual disassembly of the components.
- R4 (CE PED ITC, light sources and all other equipment outside other groupings), for example vacuum cleaners, sewing machines, irons, fryers, blenders, mobile phones, ceiling lights. Small electrical equipment undergoes a manual disassembly process, thanks to which operators separate the individual components and then undergo mechanical crushing.

## 3. Experimental: FG company

FG S.r.l. is a medium-sized company located in Belpasso, a town in the province of Catania (CT) and it deals with the recovery and disposal of hazardous and non-hazardous waste, in particular over time has specialized in the treatment of electrical and electronic equipment and their recovery at the end of their life. The origins of the company date back to 1974, the year in which it was founded by Mr. Failla, the first plant occupied only the disposal of refrigerators that still represent 80% of their core business. In 2001 it moved to the premises where it is currently located where he has a surface of 30000 square meters of which over 6000 are covered.

In 2018 a fire occurred in an area of the company, due to a short circuit in an electrical panel; and so the re-construction process started which has not yet been completed, introducing some precautions such as: inserting the electrical panels in an isolated area and using a flame-retardant rock wool insulation.

**Fig. 4.** The FG company logo

Today the company is run by the Failla brothers, based on the idea of proactivity that the disposal and recovery of waste is essential to safeguard the environment and improve the quality of life. The company has obtained and maintains the certifications: UNI EN ISO 9001:2015, UNI EN ISO 14001:2015, OHSAS 18001:2008; it operates throughout the national territory and the suppliers are both private and public administration. Organization and management structure of the company is closely aligned with a top-down approach. At the top of the company there is the sole director, who guide and monitor the management of the company. FG S.r.l makes use of the collaboration of a specialized team to support the organization.

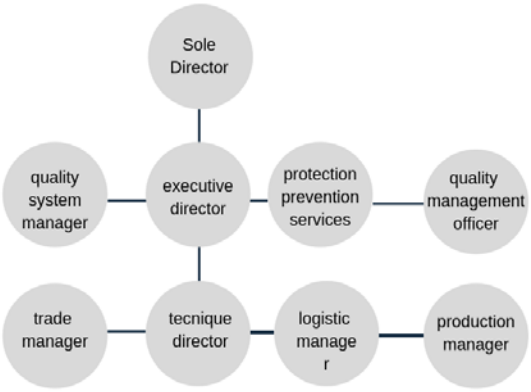



**Fig. 5.** Organizational chart

The production process is divided into several phases:

- Acceptance: this is where the vehicles are weighed through a loading and unloading register.
- Organizational check and sorting: after a brief check, the waste is sent to the various areas where it will be ready for recycling in particular:
  - in the R1 area there are gases and refrigerants, here the safety, reclamation and shredding takes place.
  - in the R2 area the treatment takes place manually to remove certain components such as motors, cards etc.

• in the R3 area there are wastes with harmful substances, here the disassembly takes place and then the aspiration in the R4 area as in the R2 area the separation is done manually.

## 4. Results and discussion

The technology described in this paper demonstrate how the recovery of Fluff fraction still seems a long way off. In fact this material is considered irrecoverable and for this reason it sent to landfill disposal.

Numerous efforts have been made in Europe, the United States, Japan and Australia in an attempt to increase the recovery of fluff for recycling and use, through waste-to-energy, pyrolysis, and combustion in the cement and steel industry. Some of these methods of re-use may represent a starting point for FG S.r.l. These forms of treatment allow an energy recovery of the fluff equivalent to that of traditional fuels. The possible reuse of Fluff through heat treatment has been studied in various pilot research projects, demonstrating high potential. The thermovalorization is a very interesting reality for energy production. A waste-to-energy plant is a waste incinerator, which allows energy to be recovered by exploiting the caloric content of the waste itself. Unfortunately the waste-to-energy plant create smoke and emissions but today, thanks to new technology and a rising ethic, the pollution is under control. In this way, a part of the fluff (on average not more than 40%) properly treated can become an excellent CSS, secondary solid fuel.

In Italy there is still little talk of waste-to-energy and in particular in Sicily, the situation is still backward. Given the lack of waste-to-energy plants, the company FG S.r.l. is forced to send its quantity of fluff to landfills. The company data shows a high quantities of fluff in the categories R1 and in the bulky. More especially FG S.r.l. reaches overall recovery rate equal to 88.10%, derived from WEEE of the R1 group. The remaining 11% is represented by the fluff, in this case polyurethane present in refrigeration systems. The bulky represents another source in which there is a high percentage of fluff (60%) derived from foam rubber. The reason why the waste-to-energy plant may seem difficult to implement is given by the lack of a strategic vision. There are a serious infrastructural gap that affects the entire waste treatment and recycling chain. Companies face the difficulty of making investments due to a complex regulatory framework that effectively blocks innovation and, paradoxically, precisely the growth of the circular economy. In the absence of Community legislation, in many cities achieving the goals set out in the thematic strategy on the urban environment seems a very long way off.

A study shows how the fluff can guarantee a high calorific value and has all the features to be treated. During the analysis various types of fluff were taken into consideration. They were assessed in accordance with the aspects of calorific value and the production of contaminants, they were evaluated. From the results it emerges that the fine fraction is the worst both from an environmental and an energy point of view, in fact it is the richest in metals and has a low PCI (15,000 kJ / kg). The classes with the highest PCI values (around 26,000 kJ / kg), therefore the most suitable for an energy recovery of this type, are those with a grain size between 50 mm-100 mm together with the 20 mm-50 mm fraction for away from the fact that high-PCI substances, such as polymers, rubbers and textiles accumulate in coarse fractions. However, the 50 mm-100 mm class produces a smaller amount of toxic substances.

To conclude we could also get a good fuel, removing the fine fraction because it would increase the LHV and reduce the production of toxic substances. This would allow us to find a new alternative energy production medium, thus reducing the environmental stress caused by landfills and abnormally large quantities of waste now deposited the building sector could have benefits. In fact, cement production requires a very high energy cost,

around 50% of the production cost. Therefore the use of the fluff as an alternative fuel could be a great advantage.

Studies show that by mixing the steel slag dust with the fluff and clinker, a composite cement is formed. It has been observed that the concrete consisting of steel slag dust has a compressive strength of 1.1 to 1.3 times higher compared to common concrete (Guadagnino et al., 2018).

## 5. Conclusions

The strong technological evolution of waste-to-energy plants has shown a considerable increase in the recovery and optimization of fluff fraction. The years of the economic crisis have given further impetus to investments in research on maximizing recovery and improving the efficiency of plants.

The energetic valorization of the fluff fraction could guarantee innumerable advantages. It would allow the decrease in landfills of large quantities of fluff and the increase in more materials placed on the market. Moreover it would allow the achievement of the objectives set by the European Union and can be an excellent substitute of fuel.

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# DISPOSAL AND REUSE IN THE CIRCULAR ECONOMY: REDUCTION OF PLASTIC MATERIALS IN PRODUCTS OF LARGE-SCALE DISTRIBUTION*

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## Abstract

The circular economy promotes a more conscious use of non-renewable materials in order to safeguard the eco-sustainability of production processes. The importance of sustainable development lies in the idea of being able to guarantee future generations a quality of natural resource equal to that available to current generations. Plastic polymers, especially ones that are used for food products, represent the hardest substance to be disposed of, and thus have a serious environmental impact.
This study proposes the application of the "Plastic Free" project in the productive process of a business. It was decided to collaborate with one of the emerging companies of Southern Italy "F.lli Arena Co. Ltd", which deals with a large-scale distribution of food and non-food products, on behalf of major brands. The study will focus on the conversion from plastic polymers to eco-friendly and fully compostable polymers in order to achieve a significant reduction in the amount of plastic waste produced.

*Keywords*: large-scale distribution, packaging, plastic polymers, reuse, waste management

## 1. Introduction

The great changes the contemporary world is facing encouraged the research of a new model of development, capable of relating different dimensions and satisfying various needs (Fusco Girard, 2016). This need brought to the idea of sustainable development that is

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development that meets the needs of the present without compromising the ability of future generations to meet their own needs (https://sustainabledevelopment.un.org/content/documents/5987our-common-future.pdf). The green economy and circular economy are implemented in this field.

The green economy is considered a new development strategy that aims to alleviate the contradiction between rapid economic growth and the shortage of raw materials and energy (Yuan et al., 2006). It operates in the era of the global climate crisis and environmental scarcity. Therefore, it considers the ecological question a vital issue related to new possibilities of development, which take into account not only a more equitable distribution of assets, but also the damages produced by human activities. That means to reintroduce waste in the cycle of production which becomes the second raw material. Thanks to new technologies and new materials, a significant reduction in waste is achieved. A relevant theme is the use of plastic and the damages deriving from it. Only 15% of plastic is recycled worldwide, 25% is subjected to energy recovery, and the remaining 60% ends up in landfills.

Plastic has changed our world, allowing the production of inexpensive, light, and unbreakable goods. It is a material that was planned to have a long life and has become the primary material for the creation of disposable objects. Of all the plastic that is produced, almost half of it is used for the production of packaging. After being used for a short period, it becomes waste and is dispersed into the environment where it remains for a long time (Bunone, 2019).

The circular economy, however, implicates more than the mere recycling of waste: it involves the development of a new model of economy that must be contrasted with the linear economy throughout the whole production process. The following study proposes to highlight the reasons why abandoning plastic materials is important and can bring numerous advantages for human beings. It also intends to analyze why it is convenient to choose other materials that can entirely replace plastics and which are 100% biodegradable and recyclable.

## 2. Materials and methods

Waste is the substance deriving from human activity or natural cycles that are abandoned or which are doomed in time to be abandoned. Concerning its physical composition, waste is made of the same material of the generating product. On the basis of its physical state, waste can be divided into solid, liquid, or gaseous waste. Solid waste can be organized into two categories depending on its origin: waste originating from industrial waste or food waste. They can also be classified according to their physical properties (fuel, compostable, recyclable) or their degree of safety (we distinguish hazardous from non-hazardous waste) (McDougall et al., 2001).

The term plastic is used to describe synthetic materials. The common characteristic of all "plastic" material is their malleability. These materials can be easily used, becoming instruments characterized by high versatility (Bunone, 2019). Plastic is made up of large molecules that are called polymers. These consist of carbon and hydrogen atoms, with possible presence of oxygen, nitrogen or other elements such as chlorine and bromine. There are several types of plastics that can be grouped into three main polymer families:

- thermoplastics, which soften with heat and harden again with cooling;
- thermosettings, which never soften after being shaped;
- Elastomers, have great deformability and elasticity, can be both thermoplastic and thermosetting and are used in a large number of applications.

There are a great variety of polymers, each of which has its own characteristics and fields of application. According to DIN 7728, 16780 and ISO 1043/1, each plastic material is associated with a symbol that uniquely identifies it (Lanz and Gigon, 2018). Last year 280 million tonnes of plastic was produced globally. Only 7% of these became raw materials, 12%

were burned, causing environmental damage resulting from the production of toxic gases such as dioxins[†] and the rest accumulated in landfills or dispersed into the environment. The top 122 polluting rivers (4% of total landmass surface area and 36% of the global population) contributed for >90% of the plastic inputs with 103 rivers located in Asia, eight in Africa, eight in South and Central America, and one in Europe.

Plastics and microplastics are reaching a worrying concentration. Over the last 35 years, Nasa has highlighted the birth of five enormous plastic islands. The largest of these is the "Great Pacific garbage patch", located in the Pacific north and about 700,000 $km^2$ in size. Solar radiation combined with saltwater accelerates the fragmentation of plastics, thus creating the most harmful microplastics. These, confused with phytoplankton, are ingested by fish fauna. The Mediterranean Sea is considered to be the sea with the highest density of plastic. This is mainly due to the fact that it is a closed sea and as a result, the plastics poured accumulate over time until reaching very high concentrations in some areas.

One of the methods for disposing of plastic waste is mechanical recycling. Plastics, at the end of its life, must be disposed of through the use of processes that meet the criteria of environmental sustainability and that allow, in the light of the circular economy, the obtaining of second raw materials[‡]. Amongst these processes, recycling is undoubtedly the most important. All material recovery activities begin with the collection phase. Based on the type of collection pursued, it is already possible to obtain a good quality of the recovered product to start recycling. Over the years, and also thanks to the contribution of common motions, the separate collection of waste has increased considerably (Pietrelli et al., 2014).

Recycling plastics is highly expensive and also has a strong environmental impact. Therefore, environmental pollution is becoming a critical concern for the European Union, which has issued specific regulations, as the UNI EN 13432:2002 (Coletto, 2014), to protect the environment from the damage caused by plastic waste. The solution to this environmental problem can be the introduction of biodegradable and compostable plastics. Biopolymers or bioplastics are polymers prepared by biological processes that give the final material a high level of biodegradability (Bunone, 2019). Scholars claim that biodegradable plastics are a promising solution to this matter because they are environment-friendly. They can be derived from renewable feedstocks, thereby reducing greenhouse gas emissions (Tokiwa et al., 2009).

The term packaging generally refers not only to the material part but more specifically to the underlying production process; it also covers specific technical and qualitative requirements necessary for each type of product. In this regard, three types of packaging are distinguished: primary packaging, mainly for sale; secondary packaging, to multiple purposes and use; finally, tertiary packaging, necessary for the transport of goods. Proper packaging design is the key. In particular, it is essential when it comes to packaging in the food industry, as it requires special processing. In fact, incorrect processing of the materials used could lead plastic to release toxic or dangerous substances for humans. In the 1930s, a new industry was based on polymers obtained from oil that were proposed as an alternative to traditional materials (such as wood, iron, light alloys, silk etc.) in their respective sectors. Since then, polymer materials have become an irreplaceable tool of everyday life, given their infinite uses in the most diverse areas. As a result, annual world production has reached 60 Mton. Such a spread, however, has led to the release of millions of tonnes of plastic waste. The plastics used in Europe account for about 80% of total demand, and one of the main sectors of use is packaging (39.4%).

In Italy, in 2011, the demand for plastics amounted to about 7 Mton addressed mostly to the packaging sector. In 2013, in particular, the number of plastic packaging reached 2,043

[†] Compounds formed during the combustion of waste. The main culprit is chlorine bound to organic polymeric compounds such as PVC (polyvinyl chloride).

[‡] Substances consisting of waste and waste from the processing of raw materials or materials derived from the recovery and recycling of waste.

Mton, marking an increase in those initiated to the trade and industry circuit (Pietrelli et al., 2014). On the one hand, the purpose of packaging is to facilitate containment, protection, handling, shipping and the use of the product; on the other hand, it plays a much greater role which is to prevent damage to goods and the excessive onset of waste. For this reason, the entire packaging system must be able to respond to the critical concept of responsible packaging, which means: optimizing packaging and minimising waste. Different types of packaging address different products, and they also act as a source of information and communication from the company to the consumer. Each company, however, uses the more convenient packaging, usually the most "fashionable" and the one the consumer appreciates the most (Mazzetto, 2013).

European legislation aims to emphasise the processing and use of so-called MOCFs, i.e. Materials and Objects in Contact with Food, which include not only food packaging, but also wraps and kitchen utensils and processing surfaces in contact with food. In the case of MOCFs, there is an alert rate of about 10%. Therefore, it is necessary to redesign the production process in order to reduce its dangerous components or increase its recyclability: this often affects the marketing strategies of companies. In this sense, the Packaging and Waste Directive, 94/62/EC, is a full expression of a new approach that is increasingly required of each individual in these supply chains.

The Directive explicitly provides for the need to take preventive action to help the environment, by acting on the product itself. Its purpose is to adopt processes and technologies that will reduce the use of raw materials, pollution, and the resulting production of waste. The crux of packaging in the 21st century is to reduce the use of plastic polymers as much as possible. Some characteristics of plastic can be a disadvantage for a specific application, and an advantage for a different one. For example, the low water vapour barrier of the bio-based plastic PLA is a disadvantage when making a water bottle, but an advantage in the packaging of vegetables and fruit. Biodegradable plastic packaging and garbage bags can be used to collect a larger amount of municipal kitchen waste. Unclear communication, however, may result in people using non-compostable bags for this purpose, thus increasing the amount of this plastic in the organic waste stream.

The main materials used in packaging are bio-PE and bio-PET; an important new bio-based material for packaging applications is PEF. The properties of PEF are highly similar to PET, but the barrier properties are more favourable: bio-based and biodegradable plastics form interesting packaging materials for food (Oever van den et al., 2017).

The Large-scale Distribution exercises the management of commercial activities in the form of retail products and more, in free-service outlets. The typical feature of this type of action is the use of large surfaces, which range from at least 200 m2 for food products only, to a minimum size of 400 m2 when they are not limited to the scope of grocery. A distinctive element of the GDO is the operation of the stores through "commercial chains", characterized by a single brand recognizable by both suppliers and customers, which therefore allows a certain contractual strength towards the former (Ceciliato, 2017). The importance of large-scale distribution as a food marketing channel in the country is still below the average European values; however, it is experiencing notable growth phenomena, albeit significant territorial differences must be considered.

Compared to other countries, in Italy the market share of traditional retail outlets of food goods represents a significant share, driven in particular by the South. In recent times, there has been an almost exponential increase in hypermarkets and supermarkets, at the expense of small outlets for free-service food. This change, which has taken place over the last fifty years, has changed the consumer's purchasing behaviour (Metelli, 2010).

## 3. Case study

The Arena Group, with more than 150 stores, is a leading Sicilian distribution company. It has several signs: Decò, IperConveniente, SuperConveniente and Non Solo Cash. According to the channels, the outlets are divided in: Superstore Decò, Maxistore Decò and Decò Supermarkets. The group is growing strongly and plans to consolidate the presence of the Decò, IperConveniente, and SuperConveniente signs in Sicily and Calabria. The Arena brothers founded the brothers' company Arena Co. Ltd in Valguarnera Caropepe in the province of Enna, in the mid-seventies, but it was already in 1922 that the family business saw its birth. Gioacchino and Cristoforo Arena, start the business with a wholesale food and two small retail outlets, the "center" and the "jolly" in the country of Valguarnera.

Subsequently, in 1985, the company purchased a building with an area of 900 square meters for the opening of a new larger point of sale, so that it could accommodate the catchment area of the other two smaller ones, which were closing at the same time. With this new point of sale, the company presents itself to the world of modern distribution with the sign STANDA. After a few years, the company implemented the same sales format in other city centers in the province of Enna. This is how the expansion throughout Sicily began. The brothers Arena owns two distribution centers: one in Dittaino for the supply of fresh produce, and one in Catania for non-perishable food and no food. The latter has signed a contract with a platform in Catania for the delivery of frozen products to the stores. Refrigerated vehicles are transported to the points of sale.

The distribution centers are in line with specific regulations; the F.lli Arena Co. Ltd has more than 6000 picking spaces. Proper management of this activity allows monitoring of the inventory flow that is useful for inventory and inventory analysis. In addition, the company has more than 500 square meters of refrigerators.

## 4. Results and discussion

Innovations in packaging are increasing, but a miraculous solution that would allow society to go to the pride, without asking questions or changing habits, does not exist. While the economic mode recommends further research to invent bio-degradable or recyclable products, the political world takes steps to ban single-use plastic products. Single-use plastics have been banned by the European Union through the approval by the European Parliament of the single-use plastics directive. By 2021, all Member States will have to phase out the production and marketing of commonly used items such as plates, cutlery, straws and food containers. All plastic objects that are easily replaceable should be produced using biodegradable and environmentally sustainable materials. The directive aims to impose the use of different materials or merely the reuse of plastic objects.

The principles within this legislation cannot be against the EU principles but may be more ambitious. The Italian government, in the budget law of December 30, 2018, No 145 paragraph 802 reports a commitment signed by the companies producing single-use plastic items, which "on a voluntary and experimental basis" from January 1, 2019 to December 31, 2023:

a) They will adopt differentiated collection and recycling models of plastic tog from fossil sources with increasing rates of the reintroduction of second raw materials into the production cycle;

b) They will produce composting and composting to vegetables made from biopolymers of plant origin.

c) They will use biopolymers by December 2023 as an alternative to fossil fuel plastics for the production of disposable crockery.

The guidelines for joining the plastic free campaign are:
- apply the four R rule: reduce, recycle, retrieve, and reuse
- eliminate the sale of plastic bottles and replace the supply with water dispensers
- delete single-use plastic items
- limit the sale of products with over-packaging and promote the sale of bulk products
- provide employees with cups and bottles that can be reused
- do not use single-use plastic during company events

In Italy, many cities have joined the plastic free project by removing several plastic objects from both public places and municipalities. The company F.lli Arena Co. Ltd, in accordance with the European Directive and the law of 30 December 2018 No 145, aims to reduce the use of plastic materials within the production process. It embraces the "Plastic Free" initiative.

With the "plastic free" project, whose literal meaning is "free from plastic", the Ministry of the Environment has adopted a number of measures with the ultimate aim of abolishing the use of single-use plastics. These include: the elimination of plastic bottle dispensers; installation of water dispensers; free distribution of metal bottles to employees; replacement, in hot beverage dispensers, of plastic cups and scoops with paper and wooden ones.

## 5. Conclusions

Plastic waste that ends up in the oceans is subject to fragmentation. This microplastics can be eaten by large and small mammals, blocking their digestive system and killing them, and these ingested microplastics can also be harmful to humans who eat marine life. Scientists have found plastic fragments in more than a hundred marine species, and more than half of them end up on our boards.

Plastic pollution that ends up in the sea can also travel great distances, which makes its effects unpredictable. The measures proposed with the "plastic free" project will help Europe take a big step towards the circular economy. The European directive is based on existing rules and complements other measures taken to combat sea pollution. The approach follows that of the 2015 Plastic Bags Directive, which changed consumer behavior. The proposed directive will bring many economic and environmental benefits, including: 3.4 million CO2 emissions will be avoided, environmental damage at the cost of EUR 22 billion will be avoided by 2030, savings will be made for consumers 6.5 billion Euros.

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# HEXAVALENT CHROMIUM REDUCTION VIA FERROUS SULPHATE: DOSAGE AND MANAGEMENT OF A GROUNDWATER TREATMENT PLANT*

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## Abstract

The subject study focuses on the ability of a groundwater treatment plant in removing hexavalent chromium, Cr(VI). Cr(VI) is considered to be an extremely dangerous pollutant due to its toxic, mutagenic and carcinogenic characteristics as well as its high solubility in water, making it capable of spreading over large areas. Cr(VI) removal from contaminated water may be carried out in different ways. The present study takes into account the analysis of chemical reduction of Cr(VI) to Cr(III) via ferrous sulphate ($FeSO_4$) as well as filtration via activated carbons of the chlorinated solvents also present in the contaminated water . The reduction of Cr(VI) generates a significant amount of sludge that could impact the activate carbon filters installed downstream to the Cr(VI) reduction section. In order to limit sludge production and therefore avoid high pressure in the filters, a thorough control of the redox reaction is extremely important . The subject study also discusses the batch tests carried out in order to determine the proper dosage factor and consequently maximize the removal of Cr(VI) and minimize carbon filter clogging.
The results exposed may be of great support to all those who have to deal with contaminated water with hexavalent chromium. The general purpose of the subject study was to ensure discharge of unpolluted water whilst reducing operational costs and waste generation.

*Keywords:* chemical reduction, exhaustion carbon time, ferrous sulphate, hexavalent chromium, water treatment

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## 1. Introduction

Treatment technologies used to remove hexavalent chromium in concentrations of milligrams per litre include, amongst others, ion exchange resins, reverse osmosis filtration, granulated iron absorption and chemical reactions followed by filtration, the last of which is object of the present study (Bartlett, 1991).

There are several reducing agents that can be used to carry out chemical reactions, these include sulphur dioxide (Maisto et al., 2017), sodium sulphite, sodium dithionite, hydrogen peroxide and ferrous ion (Metcalf & Eddy, 2006). Reduction via ferrous sulphate is an uncommon treatment technology yet has numerous advantages such as procedure simplicity, pH independence and good removal rate (Franco et al., 2005; Qin et al., 2005). The main disadvantages are related to the definition of the exact dosage of reducing agent and contact time in order to obtain the desired removal percentage.

The water treatment plant considered in the present study is composed of two main sections, a first section in which ferrous sulphate is dosed and a second section in which hexavalent chromium is reduced to trivalent chromium via a reaction tank. After treatment, the water is conveyed into a filtration section, composed of granular activated carbon, and successively discharged into the public sewer as a final step.

The redox reaction which occurs with the ferrous sulphate is based on the oxidation reaction of Fe(II) to Fe(III) with the consequent release of an electron, and the reduction reaction of Cr(VI) to Cr(III) through the acceptance of the previously released electron. For this reason and in ideal conditions, three moles of Fe(II) are necessary in order to reduce one mole of Cr(VI) to Cr(III) (Su and Ludwig, 2005), as illustrated in the semi- (1)(2)(3) and overall redox reductions (4) reported below:

$$Fe^{2+} \rightarrow Fe^{3+} + e^{-} \quad (1)$$

$$3Fe^{2+} \rightarrow 3Fe^{3+} + 3e^{-} \quad (2)$$

$$Cr_2O_7^{2-} + 14H^{+} + 6e^{-} \rightarrow 2Cr^{3+} + 7H_2O \quad (3)$$

$$Cr_2O_7^{2-} + 14H^{+} + 3Fe^{2+} + 3e^{-} \rightarrow 2Cr^{3+} + 3Fe^{3+} + 7H_2O \quad (4)$$

Another interesting application of the Cr(VI) to Cr(III) reduction concerns the combined use of ferrous sulphate and sodium dithionite. In aqueous solutions sodium dithionite dissociates and releases $S_2O_4^{2-}$ ions, which reduce Fe(III) according to the reaction (5) (Marrazzo, 2009):

$$S_2O_4^{2-} + 2Fe^{3+} + 2H_2O \rightarrow 2SO_3^{2-} + 2Fe^{2+} + 4H^{+} \quad (5)$$

With the same mechanism, sodium dithionite can partly reduce the dissolved Cr(VI), however, the reduction speed of Cr(VI) with sodium dithionite and its by-products increase in acidic conditions (Ludwig et al., 2007). The scope of the subject study is to define the proper dosage of ferrous sulphate in order to ensure the reduction of Cr(VI) to Cr(III) whilst optimizing treatment system costs. Stoichiometric dosages do not guarantee a sufficiently safe factor in terms of removal efficiency and, therefore, significant overdosing is a common consequence. The present study has as its main goal the definition of a sufficiently reliable safety factor.

A further analysis, discussed in the present paper, concerns active carbon filtration typically located downstream to the reduction section. In addition to the known absorption functions of the organic compounds presented in the treated water, the activated carbons also act as a depositional shield for Cr(III) and iron hydroxide (by-product), which precipitate due

to their oxidative state. When analyzing the data on the progressive state of the plant, it was possible to correlate the degree of filter clogging to the dosed quantity of ferrous sulphate.

The work outline of the present study may be divided in three main parts:

- bibliographical research and case studies, critical analysis of the data retrieved during the functioning of the subject plant;
- batch test conduction; the tests were performed by varying the boundary conditions, in particular the dosed molar ratio and reaction time;
- result analysis, conclusions and recommendations.

## 2. Materials and methods

Batch tests were conducted in different conditions in order to understand how the kinetic reactions are influenced by boundary conditions. Key parameters include:

- molar ratio between Cr(VI) concentration in polluted water and Fe(II) dosage as ferrous sulphate;
- reaction time.

Due to the knowledge of the stoichiometric ratio – 3:1 – a number of 5 tests were performed at different dosages, respectively 1:9 (factor 0,1), 3:1 (factor 1), 9:1 (factor 3), 30:1 (factor 10) and 90:1 (factor 30). A specific test was performed for each molar ratio. In order to highlight the role of the reaction time, samples were taken and analyzed at specific reaction times for each test. Data was successively collected after 5, 15 and 30 minutes from the dosage addition.

Hexavalent chromium concentrations were measured using a spectrophotometric kit operating according to the Diphenyl carbohydrazide method, with an accuracy of approximately 5% of the reading (± 3 ppb @ 25 ° C) and a working scale between 0 and 300 ppb. At the beginning of each test the Cr(VI) concentration was measured in order to calculate the quantity of reducing agent (ferrous sulphate) needed. Once the ferrous sulphate was dosed, the sample was kept in constant stirring in order to ensure a close contact between the contaminated water and the reducing agent. This was necessary in order to replicate as realistically as possible the conditions of full-scale plants, in which mixing is ensured by dedicated equipment. At set times, samples were taken from the test beaker and analysed in order to determine the concentration of Cr(VI).

Together with the bench test performance, plant functioning data was recorded and analyzed whilst the increase in the pressure of the carbon filters (indicator of the degree of packing) was correlated with the ferrous sulphate dosages.

## 3. Results and discussion

This section includes the results and evaluations of the batch tests and the degree of packing of the activated carbon filters. The first test was carried out with a lower dosage than the 3:1 stoichiometric ratio in order to better understand how lower dosage reactions proceed in comparison to predetermined ones. Figure 1 displays the trend of Cr(VI) concentration over time. The above trend shows how, in case of an under-dosage, and for long reaction times, the dosage does not guarantee a good degree of hexavalent chromium removal. Table 1 reports the removal rate related to the first test described above.

Figure 2 displays the Cr(VI) concentration trend over time when the dosage factor is equal to the stoichiometric ratio. The above trend is discordant with the expected trend, probably due to errors in the measurement procedures. For this reason, the results of the test carried out with dosage factor 1 were not considered in the data processing phase. The following graph (Fig. 3) shows the case in which the quantity of ferrous sulphate dosed is 3 times the stoichiometric one.

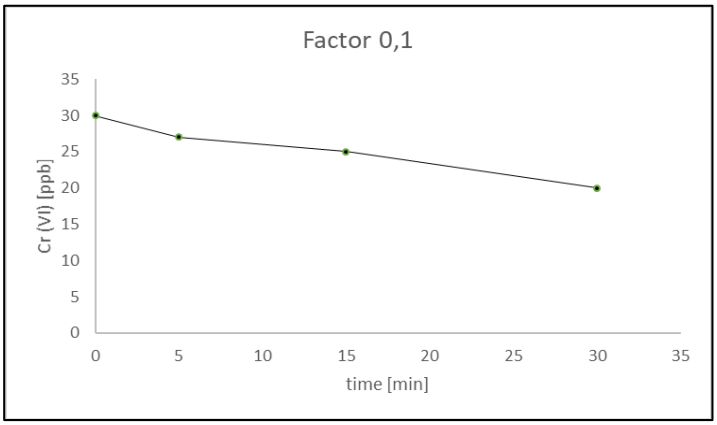


**Fig. 1.** Cr(VI) concentration for Cr:Fe dosage ratio equal to 9:1.

**Table 1.** Removal rates for Cr:Fe dosage ratio equal to 9:1

| | ***Removal, %*** | | |
|---|---|---|---|
| ***time, min*** | 5 | 15 | 30 |
| ***Factor 0.1*** | 10 | 17 | 33 |

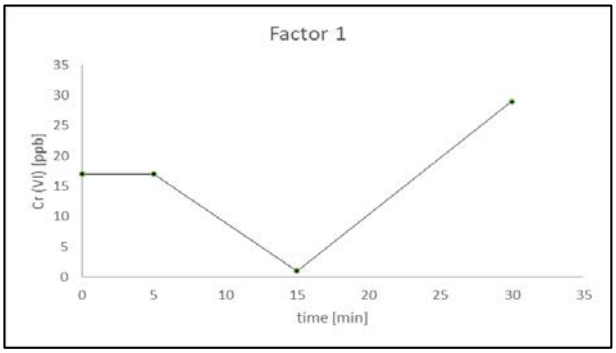


**Fig. 2.** Cr(VI) concentration for dosage ratio Cr:Fe equal to 1:3.

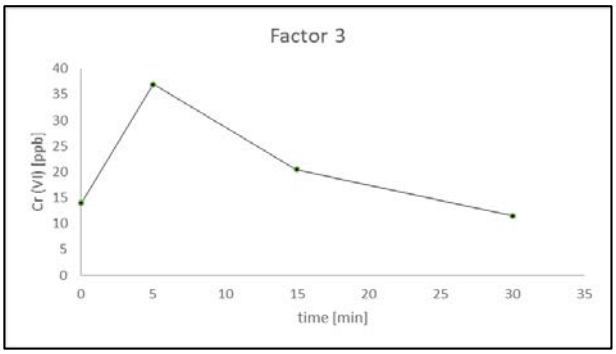


**Fig. 3.** Cr(VI) concentration for Cr:Fe dosage ratio equal to 1:9.

When considering the dosage factor used in this test (factor 3), the initial concentration of Cr (VI), is most probably an out-layer due to a measurement error. For this reason, during the data analysis only the concentrations measured from minute 5 are considered reliable. From minute 5 onwards, the reaction proceeds regularly with a reduction rate higher than the one observed in the under-dosage case (Fig.1). The abetment percentages are displayed in Table 2. Figure 4 reports the Cr (VI) concentration pattern in the case of a high over-dosages. The typical contact time in reaction tanks for plants, in which chemical reduction of hexavalent chromium takes place, is about 30 minutes. For both dosage factors (as shown in Fig.4) the reaction can be considered complete and the reduction target is largely achieved.

**Table 2.** Removal rates for Cr:Fe dosage ratio equal to 1:3

| | ***Removal, %*** | | |
|---|---|---|---|
| ***time, min*** | 5 | 15 | 30 |
| ***Factor 3*** | 0 | 45 | 69 |

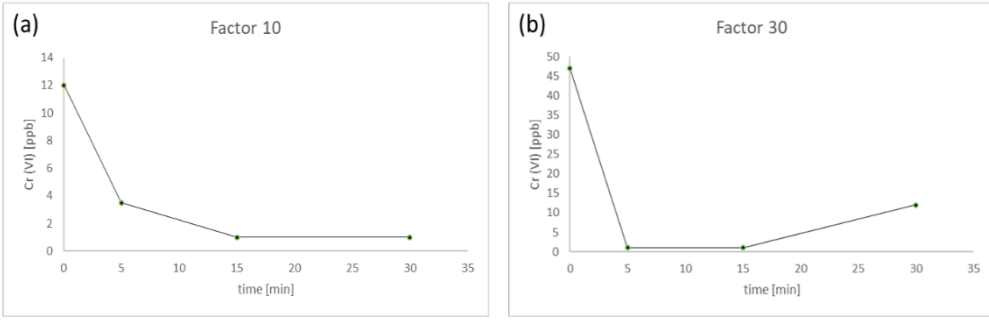


**Fig. 4.** Cr(VI) concentration for Cr:Fe dosage ratio equal to (a) 1:30 and (b) 1:90.

As can be seen from the above trends, the over-dosage ensures removal of the hexavalent chromium for short reaction times (5 minutes) and, as observed in the trend line slope from 0 and 5 minutes, the higher the dosage factor the faster the kinetics. As expected, if the dosage factor increases, both the reaction rates and efficiencies increase. This is due to the increase in contact probability between the reducing agent and Cr molecules. The abatement percentages shown in Table 3 confirm the above considerations.

**Table 3.** Removal rates for Cr:Fe dosage ratio equal to 1:30 and 1:90.

| | Removal, % | | |
|---|---|---|---|
| time, min | 5 | 15 | 30 |
| Factor 10 | 71 | 92 | 92 |
| Factor 30 | 98 | 98 | 74 |

The ideal dosage factor is between 10 and 30: dosage factors lower than 10 may not ensure the desired reduction rate, whilst dosage factors over 30, are over consuming and do not make the exercise cost-effective. Once the optimum dosage rate was evaluated, the clogging effects on the filtration media were analyzed. The data obtained from the monitoring of the treatment plant, conducted over a period of 30 months, showed two different time frames. In the first period, a dosage factor of 7 was maintained for 118 days. This dosage is

correlated to a progressive increase in the inlet pressure of the filter of about 0.35 bar per month. However, the analyses of the samples, taken at the final section of the water treatment plant, showed compliance with the regulatory limits but inconsistency for what concerned mass reduction of Cr(VI). The trend of the pressure described above is illustrated in Fig. 5. During the second period, between days 118 and 149, the dosage factor was increased up to 137 times the stoichiometric ratio in order to obtain more consistent reduction of Cr (VI). Figure 6 illustrates the trend of pressures recorded.

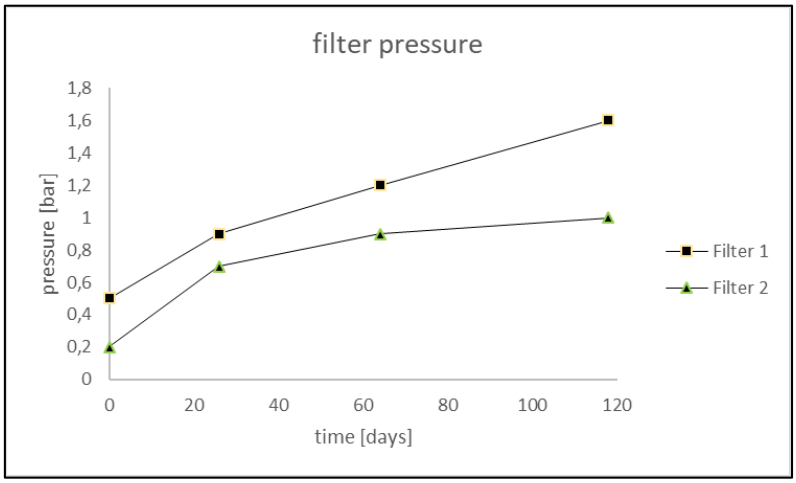


**Fig. 5.** Filter pressure for dosage factor 7

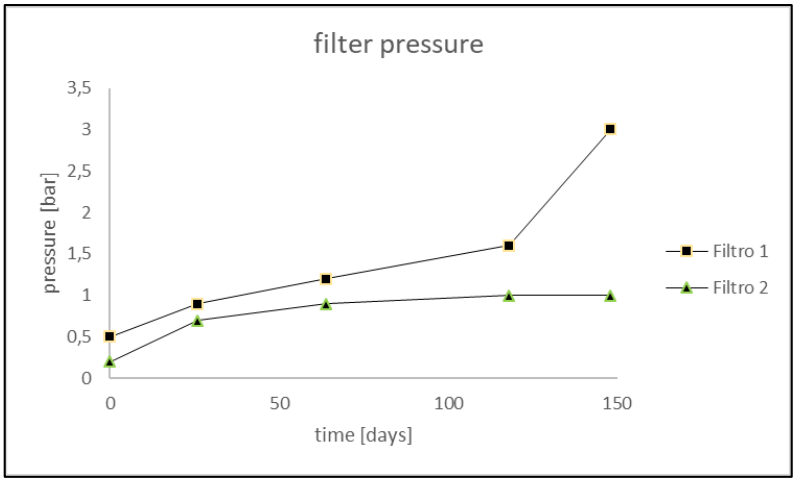


**Fig. 6.** Filter pressure for dosage factor 137

The higher dosage, used during the second period, led to an increase in pressure (of up to 3 bars) and clogging during a single operational month. Consequently, although the discharge limits are in compliance with regulations, the operational costs related to maintenance (filter media substitution) are not optimal for a dosage factor of 137. In the basis of these considerations, compliance between the amount of dosed reagent and the degree of filter clogging can be confirmed.

On the basis of the tests results described above, the optimum dosage has an order of magnitude of factor 7. This should ensure both the removal of Cr (VI) and acceptable clogging times, making the dosage ideal from an economic and management point of view. The batch tests conducted allowed the definition of an optimum molar ratio for the dosage used in hexavalent chromium reduction. If the engaged reagent is ferrous sulphate, a dosage between 10 and 30 times the 1:3 stoichiometric ratio of Cr:Fe is recommended. The following figure (Fig. 7) illustrated the removal rates as a function of time for each dosed ratio:

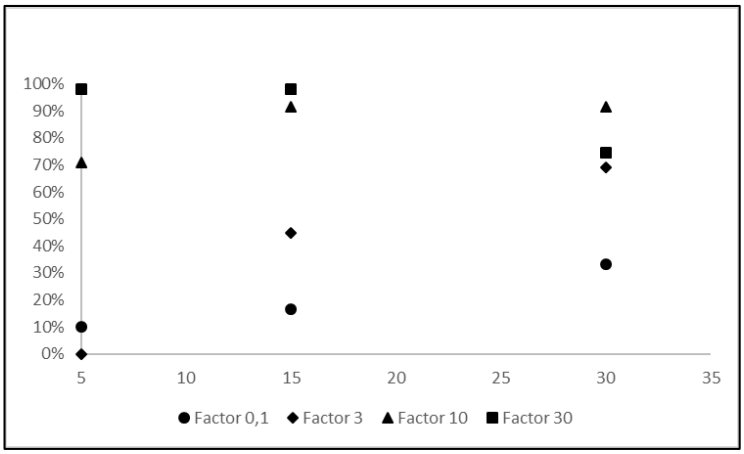


**Fig. 7.** Removal efficiencies over time for different dosages

## 6. Conclusion

Dosages lower than factor 10 do not ensure the complete reduction of Cr(VI) to Cr(III) whilst dosages exceeding factor 30 are incompatible with the practice because of:

- high operational costs related to the supply of the reducing agent;
- high operational costs related to filter media replacement downstream of the dosing/reaction section.

It should also be noted that in the treated water there are no oxidizing agents that could give rise to parasitic reactions with consequent consumption of ferrous sulphate.

The contact time necessary to ensure a sufficient reduction of Cr (VI) to Cr (III) depends on the dosed quantity of reduced agent. If a factor between 10 and 30 is chosen, it is advisable to use a contact time between 15 and 30 minutes because:

- reaction times lower than 15 minutes, in case of relatively low dosage rates, may not be sufficient to ensure a complete reduction of the hexavalent chromium;
- reaction times greater than 30 minutes need very large reaction tanks unsuitable for practical applications.

When considering the filtration on activated carbon, it was confirmed that the degree of clogging depends on the dosed quantity of reducing agent. If a dosage between 10 and 30 is assumed, a filter clogging time between 3 and 4 months is realistically reliable.

In order to verify the above considerations and define more precisely the proper dosage factor, a dosage factor between 10 and 30 will be set and the filter pressure trends will be monitored as described above. This assumption will be validated during plant operation.

## Acknowledgements

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# OXYGEN TRANSFER CAPABILITY IN SFS-H NATURAL WWT STUDIED ON ENGINEERING-UNIBO PILOT PLANT*

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## Abstract

The increasing interest on natural wastewater treatment systems implementation for large flow rates involves to study in detail the process features. Recently, the full scale implementation of horizontal sub-surface flow (SFS-H) phytotreatment systems in irrigation channels is studied. Biological processes in SFS-H phytotreatment systems for wastewater treatment are regulated by vertical profiles of dissolved oxygen which balance and distribute the aerobic/anoxic/anaerobic conditions in filtration bed. Nitrification in horizontal flow systems is strongly influenced by the limited oxygen transfer capability so hybrid systems (vertical and horizontal flow) are frequently implemented to improve the nitrification/denitrification rates. Consequently, the oxygen transfer capability in SFS-H natural ponds is a key point for their efficient implementation. Thus, a monitoring study has been carried on the Engineering-UNIBO pilot plant in order to measure and improve the oxygen transfer capability in SFS-H natural pond. The pilot plant consists of two tanks with the same sand bed and one of them also contain plants (*Phragmites Australis*). The pilot plant was alternatively fed by clean water and wastewater from the University sewage system. Consequently, four work conditions were studied and compared: 1) clean water and tank without plants 2) clean water and tank with plants 3) wastewater and tank without plants 4) wastewater and tank with plants. The Dissolved Oxygen (DO) and Temperature (T) were measured at two levels corresponding to surface and bottom of the tank in order to evaluate the horizontal and vertical variations. As expected, the monitoring results show that in case of clean water inlet the DO variations are very low even if an increase was observed when the hydraulic retention time was 30 h, while in case of wastewater inlet DO increase reach around 30%.

*Keywords:* dissolved oxygen, HRT, natural treatment, *Phragmites australis*, wastewater

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## 1. Introduction

The increasing interest on natural wastewater treatment systems implementation for large flow rates involves to study in details the process features. In the last years, the use of natural treatments has also spread to industrial and agro-industrial wastewaters. Moreover, the full scale implementation of horizontal sub-surface flow (SFS-H) phytotreatment systems in irrigation channels is recently studied (Andreo-Martínez et al., 2017; Tatoulis et al., 2017).

Biological processes in horizontal sub-surface flow SFS-H phytotreatment systems for wastewater treatment are regulated by vertical profiles of dissolved oxygen which balance and distribute the aerobic/anoxic/anaerobic conditions in filtration bed. Nitrification in horizontal flow systems is strongly influenced by the limited oxygen transfer capability so hybrid systems (vertical and horizontal flow) are frequently implemented to improve the nitrification/denitrification rates (Carballeira et al., 2017). Consequently, the oxygen transfer capability in SFS-H natural ponds is a key point for their efficient implementation (Nguyen et al., 2019). In wider terms, the oxygen transfer capacity in a treatment system, as SFS-H, is related to the difference between Dissolved Oxygen (DO) and $O_2$ sat concentration in water both related to the water temperature. The oxygen transfer is harder (low transmission rates) if this difference is low. Consequently, the aerobic processes (oxidation and nitrification) are limited by the oxygen transfer capability.

Therefore, in order to study the biological processes occurring in a SFS-H system, we have considered two key aspects: 1) the effect of plants, in terms of contribution to oxygen concentration in the system, this effect can be investigated considering two conditions: with and without plants; 2) presence of preferential water volumes where the oxygen concentration is higher/lower that involve the DO heterogeneity in the water volume, due to transitory conditions.

In this context, the aim of this study is to evaluate the aeration capability of SFS-H phytotreatment systems. Hence, the aeration of the sand bed in connection with plant roots generate aerobic and anaerobic areas where oxidation/nitrification and denitrification processes are possible. In particular, the oxidation capacity mainly depends on the plant's roots oxygen contribution, but sand bed also contributes to oxygen concentration in the system when the inlet is intermittent.

## 2. Materials and methods

In order to reach the aim of the study, a pilot plant has been implemented in the School of Enginering – Terracini campus of the University of Bologna. The pilot plant is fed by clean water and raw sewage from the campus sewage system and is divided into two lines, named 0 and 1, consisting in two SFS-H tanks. The tanks contain the same filling of sand (diameter = 2-4 mm) and the first is the blank (SFSh – 0) and in the second were planted *Phragmites Australis* (SFSh – 1). A sedimentation tank is placed before the tanks because the sewage path is short and suspended solids that should clog the following tanks gravel bed (Fig. 1).

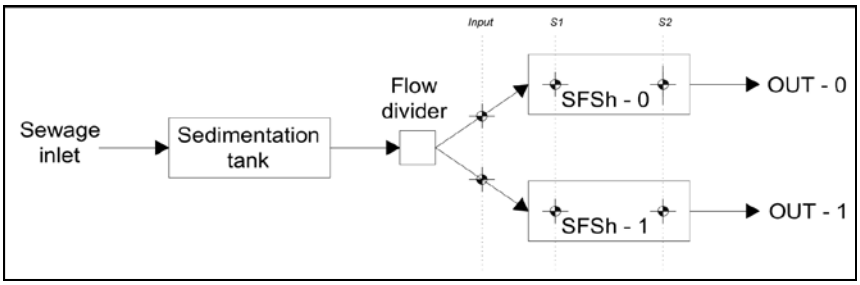


**Fig. 1.** Pilot plant flow diagram with sampling points (black/white dots)

During the experimentation, we considered three Hydraulic Retention Times (HRT): 1.5h, 12h and 30h. Consequently, four work conditions were studied and compared: 1) clean water and tank without plants 2) clean water and tank with plants 3) wastewater and tank without plants 4) wastewater and tank with plants. Two vertical sampling pipes were installed in each tank in order to measure Temperature (T) and DO, in each work condition, along the water column using the multiparameter system YSI 556.

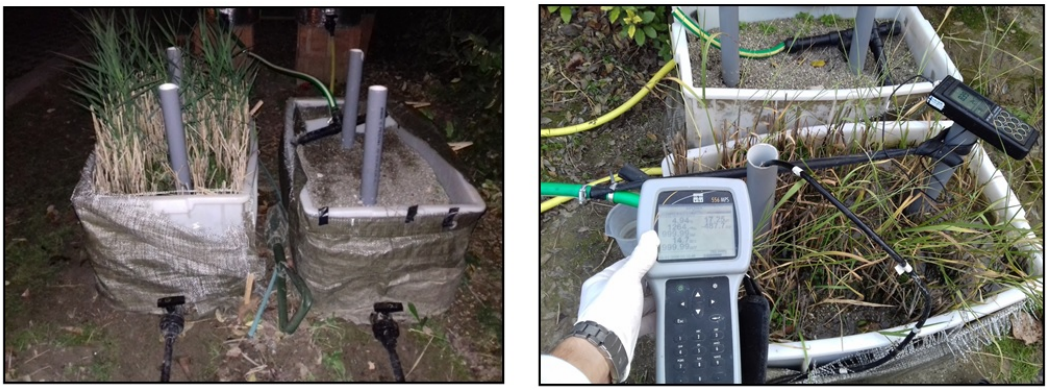

**Fig. 2.** Pilot plant: view from the output (left) and monitoring with YSI in S1(right).

In particular, we identified 8 sampling points placed above and bottom each sampling pipe and named in accordance with the horizontal position ("S1" and "S2") and vertical position ("UP" and "DOWN"). Moreover, it was monitored the inlet of each line and named "Input". The data have been collected from 2016/11/29 to 2017/09/27.

## 3. Results and discussion

The monitoring results concerning Temperature (T) and Dissolved Oxygen (DO) are grouped in Table 1 for each monitoring campaign in each sample point. Table 1 also shows the intermediate measurement from test start to the HRT achievement. Those data permits to discuss the intermediate states. More in details, the second column shows the tank where the test was carried out: tank SFSh - 0 without plants (N) or tank SFSh - 1 with plants (Y). Last column shows the net DO balance calculated between the values measured in S2-DOWN and Input.

To the study aims, we started testing HRT equal to 1.5 h and then we increased the HRT in the following two tests (12h and 30h). Thus it is possible to distinguish three different situations in terms of oxygen transfer in the system when wastewater is treated. Until HRT is under 2h the main contribution to the DO concentration is due to the oxygen already present in the sand bed as shown by the very similar values in tank SFSh - 0 and tank SFSh - 1 (see Table 2). The sand bed effect run out when HRT is 12h, because DO remains practically constant from Input to S2. In this case, there is an equilibrium between Oxygen production and consumption for organic matter degradation (oxi-nitrification). When HRT reach around 30h, we observed that the DO increases in the system because the plants oxygen contribution is higher than the request due to oxi-nitrification process. Indeed, the organic matter concentration is lower and the biological kinetics are slower than the previous cases.

In order to get better understanding of the meaning of the data, we show some of them in the Fig. 3. Observing the OD trends when HRT is 30h we note the increase of DO in the system and its stabilization when HRT is around 30h. This DO increase is due to the plants as confirmed by the almost stable trend in the data collected in tank SFSh – 0, without plants (case 08-Feb-19_NoPlants_S2-DOWN). In all cases, we note an initial DO variation until around 10h. This is

due to DO variations in the system due to the equilibrium between production, consumption and oxygen already present in the sand bed. This result is relevant because allows us to draw some interesting observations about the HRT to be adopted in a system like the one we studied. We also observe some initial OD variations due to the Oxygen already present in the water and consequently OD Input in clean water is higher than wastewater.

The water Temperature plays an important role in the oxygen transfer in the system as shown by the "net DO balance" values. As shown in Tables 1 and 2, the difference between output and input DO in summer is generally higher than winter.

**Table 1.** Pilot plant monitoring data: clean water

| ***Clean Water*** | | | | ***T[°C]*** | | | | | ***DO [mg/l] [%]*** | | | | | ***Net DO balance [%]*** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sampling Date** | **Plants** | **t[h]** | **HRT, [h]** | **INPUT** | **S1-UP** | **S1-DOWN** | **S2-UP** | **S2-DOWN** | **INPUT** | **S1-UP** | **S1-DOWN** | **S2-UP** | **S2-DOWN** | |
| 29-Nov-17 | N | 10:00 | 1.5 | 4.4 | 4.8 | 4.7 | 4.4 | 4.3 | 11.14 (85) | 11.37 (89.1) | 11.4 (89.4) | 10.9 (83.2) | 10.32 (79) | 10 |
| | | 10:30 | | | 4.8 | 5.1 | 5.0 | 4.8 | | 12.39 (97.1) | 11.92 (93) | 11.37 (89) | 11.35 (89) | |
| | | 11:00 | | | 4.4 | 4.5 | 4.3 | 4.8 | | 12.62 (96.4) | 12.71 (97) | 12.09 (92) | 11.65 (91) | |
| | | 11:30 | | | 5.1 | 5.0 | 4.9 | 4.8 | | 12.26 (96.1) | 12.65 (99) | 12.27 (96) | 12.28 (96) | |
| | Y | 10:00 | 1.5 | 1.7 | 1.9 | 2.1 | 3.5 | 3.4 | 12 (86.87) | 12.98 (94) | 12.16 (88) | 12.64 (94) | 12.77 (95) | - |
| | | 10:30 | | | 3.4 | 3.4 | 3.3 | 3.6 | | 13.31 (99) | 12.77 (95) | 12.23 (91) | 12.57 (96) | |
| | | 11:00 | | | 3.4 | 3.5 | 3.5 | 3.5 | | 11.97 (89) | 11.7 (87) | 11.83 (88) | 12.37 (92) | |
| | | 11:30 | | | 5.9 | 5.8 | 5.0 | 4.9 | | 10.07 (81) | 9.95 (80) | 11.48 (90) | 11.48 (90) | |
| 06-Dec-17 | N | 9:00 | 12 | 7.2 | 7.0 | 6.6 | 2.1 | 2.0 | 12.7 (100) | 13.1 (100) | 13.9 (100) | 15.6 (100) | 16.16 (100) | - |
| | | 11:00 | | | 4.7 | 4.7 | 2.9 | 3.0 | | 11.48 (90) | 11.1 (87) | 12.64 (94) | 12.05 (92) | |
| | | 13:00 | | | 4.8 | 4.7 | 3.7 | 3.7 | | 11.48 (90) | 11.35 (89) | 11.78 (90) | 11.39 (87) | |
| | | 15:00 | | | 4.7 | 4.6 | 3.2 | 3.5 | | 10.72 (84) | 11.23 (88) | 11.83 (88) | 11.16 (83) | |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 17:00 | | | 3.9 | 3.7 | 4.1 | 3.8 | | 11.13 (85) | 11.39 (87) | 11.39 (87) | 11.65 (89) | |
| | | 19:00 | | | 4.2 | 4.3 | 4.4 | 4.3 | | 11.39 (87) | 11.26 (86) | 11.26 (86) | 11.26 (86) | |
| | | 21:00 | | | 2.4 | 2.5 | 1.7 | 1.2 | | 12.16 (88) | 12.02 (87) | 11.74 (85) | 12.21 (86) | |
| | Y | 9:00 | 12 | 9.3 | 5.6 | 4.5 | 9.0 | 8.7 | 11 (95.24) | 11.32 (91) | 11.48 (90) | 10.16 (88) | 10.16 (88) | 17 |
| | | 11:00 | | | 9.4 | 9.1 | 9.3 | 9.0 | | 10.39 (90) | 9.93 (86) | 10.63 (92) | 10.28 (89) | |
| | | 13:00 | | | 4.5 | 3.7 | 4.8 | 4.3 | | 11.82 (90.3) | 11.92 (91) | 11.48 (90) | 12.05 (92) | |
| | | 15:00 | | | 5.6 | 4.2 | 4.9 | 4.6 | | 11.54 (92.8) | 12.05 (92) | 11.86 (93) | 12.09 (94.8) | |
| | | 17:00 | | | 5.1 | 4.9 | 4.6 | 4.4 | | 12.12 (95) | 11.74 (92) | 11.61 (91) | 12.44 (95) | |
| | | 19:00 | | | 4.8 | 4.9 | 3.8 | 3.6 | | 11.99 (94) | 11.86 (93) | 12.05 (92) | 12.44 (95) | |
| | | 21:00 | | | 3.2 | 3.1 | 3.4 | 3.2 | | 12.77 (95) | 12.64 (94) | 12.5 (93) | 12.91 (96) | |
| 13-Dec-17 | N | 10:00 | 30.00 | 9.3 | 9.8 | 9.2 | 10.0 | 9.8 | 10.3 (91.3) | 10.37 (92) | 11.09 (96) | 10.15 (90) | 10.04 (89) | 7 |
| | | 13:00 | | | 8.5 | 8.3 | 8.3 | 8.0 | | 9.94 (84) | 9.82 (83) | 9.58 (81) | 9.94 (84) | |
| | | 16:00 | | | 7.6 | 7.7 | 7.6 | 7.6 | | 10.06 (85) | 10.18 (86) | 9.82 (83) | 9.94 (84) | |
| | | 19:00 | | | 7.1 | 7.0 | 7.3 | 7.3 | | 10.31 (85) | 10.19 (84) | 9.94 (82) | 10.07 (83) | |
| | | 10:00 | | | 5.2 | 6.1 | 4.5 | 4.8 | | 10.84 (85) | 10.57 (85) | 10.87 (83) | 10.72 (84) | |
| | | 13:00 | | | 5.0 | 4.9 | 4.5 | 4.5 | | 10.84 (85) | 10.59 (83) | 10.97 (86) | 10.97 (86) | |
| | | 16:00 | | | 5.4 | 5.4 | 4.8 | 4.9 | | 10.84 (85) | 10.72 (84) | 10.97 (86) | 10.97 (86) | |
| | Y | 10:00 | 30.00 | 4.0 | 8.5 | 8.9 | 10.7 | 10.7 | 10.25 (91) | 10.18 (86) | 9.93 (86) | 9.25 (84) | 8.92 (81) | 21 |
| | | 13:00 | | | 6.8 | 7.1 | 7.3 | 7.0 | | 10.43 (86) | 10.43 (86) | 10.43 (86) | 10.19 (84) | |
| | | 16:00 | | | 5.5 | 5.6 | 6.5 | 6.5 | | 10.2 (82) | 10.2 (82) | 10.19 (84) | 10.19 (84) | |
| | | 19:00 | | | 5.4 | 5.3 | 5.4 | 5.2 | | 10.84 (85) | 10.69 (86) | 10.43 (86) | 11.35 (89) | |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 10:00 | | | 4.4 | 5.1 | 3.8 | 3.9 | | 11.78 (90) | 11.61 (91) | 11.52 (88) | 11.92 (91) | |
| | | 13:00 | | | 4.7 | 4.5 | 4.1 | 4.1 | | 11.61 (91) | 11.48 (90) | 11.92 (91) | 12.05 (92) | |
| | | 16:00 | | | 4.2 | 4.3 | 4.5 | 4.1 | | 11.78 (90) | 11.65 (89) | 12.31 (94) | 12.44 (95) | |
| 12-Jul-18 | Y | 10:00 | 1.5 | 23.7 | | 24.8 | | 23.9 | 6.13 (73) | | 6.39 (77.5) | | 6.37 (75.8) | 15 |
| | | 10:30 | | | | 24.7 | | 24.8 | | | 9.2 (100) | | 7.57 (91.8) | |
| | | 11:00 | | | | 26.0 | | 24.9 | | | 9.73 (100) | | 7.53 (91.3) | |
| | | 11:30 | | | | 26.4 | | 25.5 | | | 7.92 (97.9) | | 7.04 (87) | |

**Table 2.** Pilot plant monitoring data: wastewater

| ***Wastewater*** | | | | ***T[°C]*** | | | | | ***DO [mg/l] [%]*** | | | | | ***Net DO balance [%]*** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sampling Date** | **Plants** | **t[h]** | **HRT[h]** | **INPUT** | **S1-UP** | **S1-DOWN** | **S2-UP** | **S2-DOWN** | **INPUT** | **S1-UP** | **S1-DOWN** | **S2-UP** | **S2-DOWN** | |
| 25-Jan-18 | N | 15:00 | 1.5 | 5.1 | 4.9 | 4.8 | 4.9 | 5.0 | 3.7 (29) | 3.57 (28) | 3.19 (25) | 3.32 (26) | 3.44 (27) | - |
| | | 15:30 | | | 6.1 | 6.3 | 5.9 | 6.0 | | 3.48 (28) | 3.36 (27) | 3.36 (27) | 3.23 (26) | |
| | | 16:00 | | | 6.3 | 6.4 | 6.4 | 6.6 | | 3.36 (27) | 3.48 (28) | 3.36 (27) | 3.15 (26) | |
| | | 16:30 | | | 5.9 | 5.3 | 5.4 | 5.3 | | 3.36 (27) | 3.44 (27) | 3.19 (25) | 3.06 (24) | |
| | Y | 10:00 | 1.5 | 5.0 | 4.1 | 5.3 | 2.6 | 3.0 | 3.95 (31) | 4.06 (31) | 3.57 (28) | 3.76 (28) | 3.63 (27) | 9 |
| | | 10:30 | | | 4.1 | 4.0 | 3.4 | 3.0 | | 4.06 (31) | 3.93 (30) | 4.03 (30) | 3.9 (29) | |
| | | 11:00 | | | 4.1 | 4.0 | 3.3 | 3.2 | | 3.93 (30) | 3.8 (29) | 4.03 (30) | 4.3 (32) | |
| | | 11:30 | | | 4.0 | 4.4 | 4.4 | 3.5 | | 3.93 (30) | 3.8 (29) | 3.93 (30) | 4.32 (33) | |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 01-Feb-18 | N | 9:00 | 12 | 5.2 | 5.3 | 5.1 | 5.0 | 4.9 | 3.5 (27.5) | 3.57 (28) | 3.44 (27) | 3.7 (29) | 3.57 (28) | - |
| | | 11:00 | | | 5.4 | 5.2 | 5.4 | 5.3 | | 3.44 (27) | 3.32 (26) | 3.32 (26) | 3.32 (26) | |
| | | 13:00 | | | 5.6 | 6.0 | 6.1 | 6.2 | | 3.23 (26) | 3.11 (25) | 3.23 (26) | 3.23 (26) | |
| | | 15:00 | | | 6.3 | 6.5 | 6.6 | 6.9 | | 3.48 (28) | 3.4 (28) | 3.43 (29) | 3.23 (28) | |
| | | 17:00 | | | 6.5 | 6.7 | 6.8 | 6.6 | | 3.27 (27) | 3.4 (28) | 3.4 (28) | 3.4 (28) | |
| | | 19:00 | | | 6.9 | 7.3 | 7.5 | 7.6 | | 3.4 (28) | 3.27 (27) | 3.43 (29) | 3.19 (27) | |
| | | 9:00 | | | 6.9 | 6.8 | 6.9 | 7.0 | | 3.4 (28) | 3.27 (27) | 3.27 (27) | 3.27 (27) | |
| | Y | 9:00 | 12 | 4.0 | 4.1 | 5.2 | 4.8 | 4.6 | 3.6 (27.5) | 3.67 (28) | 3.44 (27) | 3.7 (29) | 3.57 (28) | 15 |
| | | 11:00 | | | 5.1 | 5.1 | 5.2 | 5.5 | | 3.32 (26) | 3.32 (26) | 3.19 (25) | 3.11 (25) | |
| | | 13:00 | | | 6.4 | 6.3 | 6.0 | 6.1 | | 3.23 (26) | 3.11 (25) | 3.36 (27) | 3.36 (27) | |
| | | 15:00 | | | 6.7 | 7.1 | 5.5 | 5.7 | | 3.4 (28) | 3.27 (27) | 4.35 (35) | 3.32 (27.2) | |
| | | 17:00 | | | 6.5 | 6.5 | 5.5 | 5.5 | | 3.52 (29) | 3.4 (28) | 4.48 (36) | 3.42 (26.9) | |
| | | 19:00 | | | 5.3 | 5.4 | 5.4 | 5.1 | | 4.21 (33) | 4.08 (32) | 5.23 (41) | 3.81 (29.9) | |
| | | 9:00 | | | 4.4 | 4.3 | 4.3 | 4.5 | | 4.45 (34) | 4.32 (33) | 5.11 (39) | 4.15 (31.3) | |
| 08-Feb-18 | N | 10:00 | 30 | 6.1 | 6.3 | 6.3 | 6.2 | 6.0 | 3.36 (27) | 3.48 (28) | 3.48 (28) | 3.36 (27) | 3.36 (27) | - |
| | | 13:00 | | | 7.1 | 7.2 | 7.1 | 7.4 | | 3.27 (27) | 3.27 (27) | 3.4 (28) | 3.27 (27) | |
| | | 16:00 | | | 7.6 | 7.8 | 8.3 | 8.4 | | 3.31 (28) | 3.19 (27) | 3.31 (28) | 3.19 (27) | |
| | | 19:00 | | | 6.4 | 6.2 | 6.3 | 6.0 | | 3.36 (27) | 3.11 (25) | 3.23 (26) | 3.23 (26) | |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 10:00 | | | 6.4 | 6.1 | 6.0 | 6.2 | | 3.48 (28) | 3.11 (25) | 3.36 (27) | 3.36 (27) | |
| | | 13:00 | | | 8.1 | 7.8 | 8.3 | 8.4 | | 3.31 (28) | 3.08 (26) | 3.19 (27) | 3.19 (27) | |
| | | 16:00 | | | 8.1 | 7.8 | 7.7 | 7.9 | | 3.31 (28) | 3.19 (27) | 3.08 (26) | 3.08 (26) | |
| | Y | 10:00 | 30 | 6.0 | 5.9 | 6.1 | 6.0 | 6.1 | 3.8 (30.1) | 3.73 (30) | 3.61 (29) | 3.48 (28) | 3.36 (27) | |
| | | 13:00 | | | 5.8 | 5.6 | 5.5 | 5.9 | | 3.73 (30) | 3.61 (29) | 3.61 (29) | 3.48 (28) | |
| | | 16:00 | | | 5.8 | 5.6 | 4.7 | 4.8 | | 3.61 (29) | 3.48 (28) | 3.83 (30) | 3.95 (31) | |
| | | 19:00 | | | 5.1 | 5.0 | 4.9 | 4.7 | | 3.83 (30) | 3.7 (29) | 4.08 (32) | 4.34 (34) | 14 |
| | | 10:00 | | | 5.4 | 5.2 | 3.4 | 3.3 | | 3.57 (28) | 3.32 (26) | 4.44 (33) | 4.84 (36) | |
| | | 13:00 | | | 4.3 | 4.4 | 3.9 | 3.7 | | 3.8 (29) | 3.4 (26) | 4.06 (31) | 4.71 (36) | |
| | | 16:00 | | | 6.1 | 5.9 | 5.6 | 5.1 | | 3.48 (28) | 3.11 (25) | 4.23 (34) | 4.32 (33.8) | |
| 13-Sep-18 | Y | 8:30 | 1.5 | 20.0 | | 19.8 | | 19.3 | 3.3 (36.3) | | 3.47 (38.2) | | 3.05 (33.6) | |
| | | 9:00 | | | | 20.0 | | 19.5 | | | 3.79 (41.7) | | 2.41 (26.6) | 14 |
| | | 9:30 | | | | 20.1 | | 19.7 | | | 2.84 (31.9) | | 3.7 (40.8) | |
| | | 10:00 | | | | 20.5 | | 19.9 | | | 2.7 (30.9) | | 3.75 (41.3) | |
| 20-Sep-18 | N | 9:00 | 12 | 19.1 | | 18.9 | | 18.8 | 5.56 (60) | | 6.75 (72.9) | | 6.9 (74.5) | |
| | | 11:00 | | | | 20.1 | | 18.7 | | | 7.84 (86.4) | | 6.39 (69) | - |
| | | 13:00 | | | | 21.4 | | 19.1 | | | 5.99 (67.3) | | 5.96 (64.4) | |
| | | 15:00 | | | | 23.7 | | 20.9 | | | 6.15 (73.2) | | 7.07 (79.5) | |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 17:00 | | | | 24.3 | | 24.1 | | | 5.07 (60.3) | | 5.25 (62.5) | |
| | | 19:00 | | | | 24.1 | | 24.0 | | | 4.37 (52) | | 4.41 (52.5) | |
| | | 9:00 | | | | 19.0 | | 19.7 | | | 2.52 (27.2) | | 1.92 (10.8) | |
| | Y | 9:00 | 12 | 20.8 | | 20.9 | | 20.6 | 3.8 (43.5) | | 6.05 (68) | | 7.39 (83) | |
| | | 11:00 | | | | 21.2 | | 20.8 | | | 6.9 (77.6) | | 6.09 (68.4) | |
| | | 13:00 | | | | 23.4 | | 21.4 | | | 4.48 (52.3) | | 4.7 (52.8) | |
| | | 15:00 | | | | 26.4 | | 23.1 | | | 4.25 (52.5) | | 3.61 (42.2) | - |
| | | 17:00 | | | | 26.4 | | 23.1 | | | 3.85 (48.4) | | 2.7 (31.5) | |
| | | 19:00 | | | | 26.1 | | 24.3 | | | 2.34 (29.5) | | 2.31 (27.5) | |
| | | 9:00 | | | | 20.6 | | 21.6 | | | 2.8 (31.5) | | 1.66 (19) | |
| 27-Sep-18 | Y | 10:00 | 30 | 24.3 | | 24.3 | | 25.2 | 2.7 (32.2) | | 4.59 (54.7) | | 6.18 (75) | |
| | | 13:00 | | | | 27.6 | | 26.2 | | | 5.93 (76) | | 7.85 (97) | |
| | | 16:00 | | | | 28.9 | | 27.2 | | | 3.53 (46) | | 3.18 (40) | |
| | | 19:00 | | | | 29.2 | | 27.7 | | | 3.84 (50) | | 3.51 (45) | 29 |
| | | 10:00 | | | | 22.1 | | 22.6 | | | 2.18 (25) | | 1.9 (21.4) | |
| | | 13:00 | | | | 23.4 | | 23.1 | | | 2.31 (27) | | 2.48 (29) | |
| | | 16:00 | | | | 26.1 | | 26.0 | | | 3.5 (43.2) | | 3.48 (44.6) | |

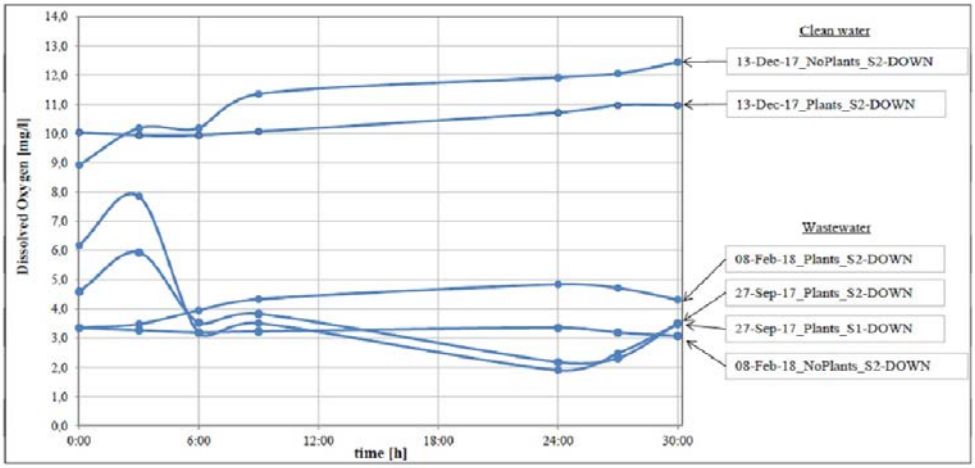


**Fig. 3.** Dissolved Oxygen transitory trends when HRT = 30 h

## 4. Conclusions

This paper aims to study the aeration capability of the horizontal sub-surface flow phytotreatment systems. To this aim a pilot plant has been implemented in the School of Enginering – Terracini campus of the University of Bologna The results from the measuring campaigns in four work conditions, related to the presence of plants with clean water and wastewater, have been studied and compared in this paper.

The DO output trends with wastewater, show that HRT = 30h is necessary to reach the equilibrium between oxygen consumption rate, due to the biological processes, and input rate, due to plants. Indeed, the DO transitory variation end up when HRT is around 10h and the net DO balance reach interesting values when HRT is around 30h. Those transitory variations are due to the oxygen accumulation in the sand bed during the fill phase. Moreover, vertical DO variations have been observed.

Comparing summer and winter data, the data shows a Temperature effect on oxygen transfer capacity because the net DO balance values in summer (from 17% to 29%) are higher than in winter (from 9% to 21%). The results indicate that HRT shall not be less than 30 h in the studied system.

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23th International Trade Fair of Material & Energy Recovery and Sustainable Development, ECOMONDO, 5th-8th November, 2019, Rimini, Italy

# THE "GARANZIA DI ORIGINE": THE MECHANISM TO CERTIFICATE THE RENEWABLE ORIGIN OF THE ENERGY*

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## Abstract

The most common definition is that renewable energy is from an energy resource that is rapidly replaced by a natural process such as power generated from the sun or from the wind. Most renewable forms of energy, other than geothermal and tidal power, ultimately come from the Sun. The Garanzia di Origine – GO is the Italian mechanism to certificate the renewable origin of the energy. The GO is an electronic certificate issued by the Gestore dei Servizi Energetici – GSE in accordance with the European Directive 2009/28/EC. The GO certificates can be commercialized between the qualified operators and currently they are even considered in the business plan of the large scale grid-market projects due to their increasing value. In this sense, we will analyze the case of a Sicilian Olive Oil Producer who just uses green energy in the olive oil production.

*Keywords:* renewable, certificate, grid, business, warranty

*Selection and peer-review under responsibility of the ECOMONDO

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## 1. Introduction

The importance of producing renewable energy is getting higher and higher due to the increasing attention on the green issues and, as much as it does, the economic interests about that have started to grow. This mounting attention has brought to the need of having guaranteed the origin of the energy we buy. Renewable energy potentials are distributed unevenly across Europe. The idea of European trade of GOs for European RE target compliance is to make RE sources in one country available for target compliance in the importing country, if this country provides financial support (Klessmann et al., 2007). The GSE (Gestore dei Servizi Energetici) now has the power to recognize the "green" source of the energy produced and sold, through a new certification called "Garanzia d'Origine" (GO). GO mechanism comes from the "Direttiva 2009/28/CE del Parlamento Europeo e del Consiglio del 23 aprile 2009 sulla promozione dell'uso dell'energia da fonti rinnovabili, recante modifica e successiva abrogazione delle direttive 2001/77/CE e 2003/30/CE" (EC Directive, 2009). This Italian method has given the birth to a new kind of trading, which consists in selling or buying the GO certification in order to guarantee the consumers that the energy they are buying has been produced at the same amount in a eco-friendly way somewhere, but not making sure that what comes in their houses accrues from a renewable source (Peppucci, 2019).

Thus, energy providers guarantee the veracity of the energy mix of the electricity they sell (Codegoni, 2019). Each GO refers to a category which depends on the source: hydroelectric, wind, solar, geothermal, other. ARERA (Autorità di Regolazione per Energia Reti e Ambiente) considers GO certificates as tools to promote the transparency of renewable energy sales contracts to ensure that the same kWh produced from renewable sources is not included in more than one sale contracts (Codegoni, 2019). We will analyze the case of a company which set the goal of making its production more sustainable by taking advantage of this recent mechanism and we will clarify how it works, to show the pros of making the most of the world of GO.

## 2. Materials and methods

Before we explain how we are going to analyze the GO, it's important to say that there are nine major areas of energy resources. They fall into two categories: nonrenewable and renewable. Nonrenewable energy resources, like coal, nuclear, oil, and natural gas, are available in limited supplies. This is usually due to the long time it takes for them to be replenished. Renewable resources are replenished naturally and over relatively short periods of time (Aust, 2014). The Energetic Relation of 2018, a national review drawn up by GSE, shows how the renewable energies are getting way more used than before in Italy, even though the major part of the nation is still covered by the classic energy, which brings pollution and contributes to the discomfort of our planet (Fig.1).

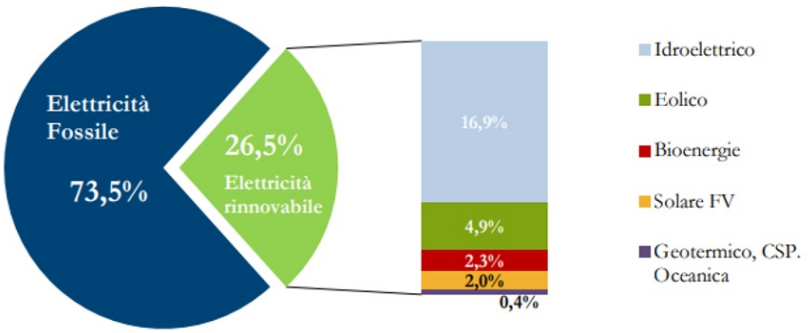


**Fig. 1.** Percentage of use of the different kind of energies in Italy during 2018

As we already said the GO certificate can be traded from the energy producer to the seller, then the trader sells the energy to the consumer by specifying that the energy is 100% green. Having a intermediary is necessary, in fact producers can't sell the energy produced to the final costumer. In our case study we look into a Sicilian Olive Oil producer company, the Trade and Services S.r.l, which called the energy service provider Ambiens S.r.l. to get a new furniture of green energy by purchasing the energy and the certificates they had bought from a green producer. By doing this, they wanted to improve its appearance and its ethic behavior: the basic line of reasoning is spending more money on green energy to reach a higher company standard, which will take its benefits in the long term. Ambiens S.r.l. on the other hand, has chosen to buy only from eco-friendly producers. We can see by the following charts how Sicilian eco-friendly production has increased in the recent years (Fig. 2) and what is its impact in the total production of energy (Fig. 3).

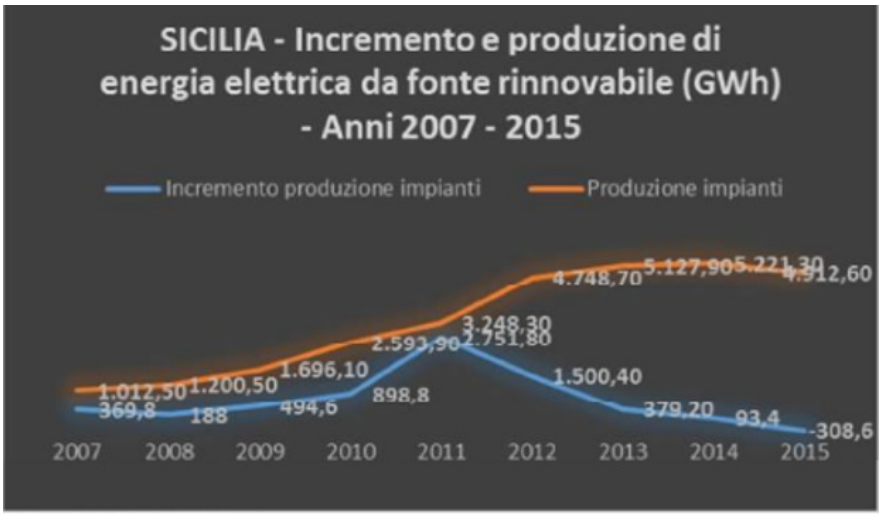


**Fig. 2.** Renewable energy production's increase in Sicilyfrom 2007 to 2015

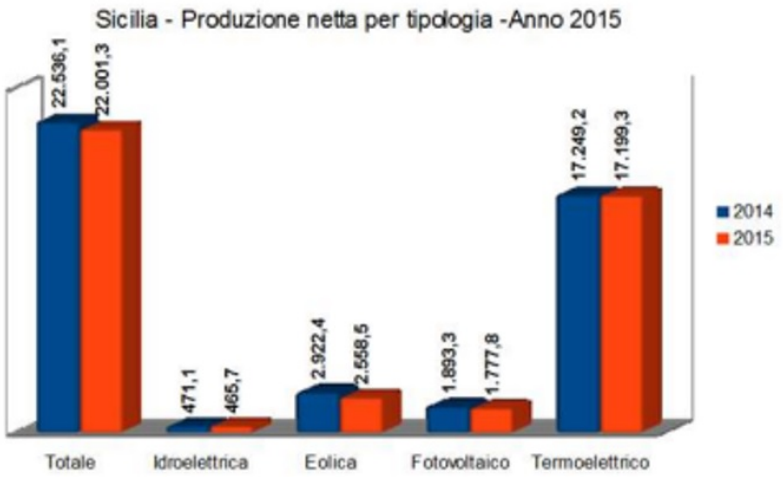


**Fig. 3.** Net production in Sicily for every kind of energy in 2015

Recently the Italian Minister of Environment published in the Official Journal a new decree to facilitate small, medium and big plants producing energy from renewable sources. The incentive of D.M. 04/07/19, also known as Fer1, rates reach up to 150 euros per megawatt-hour for wind power, 155 euros for hydroelectric power, 110 euros for gases produced by purification processes and 90 euros for small solar photovoltaic plants.

## 3. Experimental

Ambiens is a society born in 2006. In 2011 they met the German group ASA Energy which operates in the renewable energy sector and gave birth to a symbiotic process. Thanks to the volume of business achieved, the credibility acquired and the recent developments in the energy market, in 2019 Ambiens S.r.l. initiated the marketing of electricity to end consumers, becoming a company that purchases electricity from regularly authorized traders registered in the ARERA lists and sells them to end customers for the purposes of art. 2, Legislative Decree n. 79 of 16 March 1999 (also known as the Bersani Decree), with its own brand, its offers, its billing and the possibility to customize the offer to the end customer. That's why Ambiens has been chosen as the case study for this paper.

Moreover, the company has voluntarily adopted the UNI ISO 26000 procedure. The company Ambiens wants to provide support to producers of renewable energy and prefers to market exclusively sustainable energy. The typical commercial size of a photovoltaic system of a large plant is 1000 kWp or 1 mWp, a plant of this size located on the ground in the areas of southern Italy produces on average 1450000 kWh or 1450 mWh in a year. The certification system of GO provides for the emission of a single certificate for each mWh of energy produced from renewable sources (IGO), it follows that for each plant of size 1 mWp installed in the southern regions, 1450 certificates will be awarded.

Commercially, a 1 mWh plant selling its certificates on the trading market is able to recover on average between 600 and 1400, depending on the operator with which it operates, instead, when the electricity is sold together with a GO certification the cost of the GO on the final costumer is on average higher. From an analysis made between the various electricity suppliers, the supply price varies from 0.5 to 1 cent. kWh which is 5 / 10euro mWh. The company Ambiens wants to offer assistance to an oil mill that requires energy from renewable sources. It follow the signing of the contract for the supply of energy with GO certification, the oil mill will be able to show a sticker in the final product.

## 4. Results and discussion

The oil mill uses 30000 kWh per year therefore the cost that this oil mill will support at most is 30000 • 0.001. On the other hand, the energy producer who sold the certification to the consumer via the supplier will be able to sell part of the annual certification products for a much higher value than it would have been in the world of trading. 30,000 kWh are 30 certificates, if you decide to sell them to the energy supplier and not to the trading operator, in this case you will be able to earn more than 300 €.

The final supply of the oil mill is 0.26 per 30000, so the annual bill cost will be 7800 and after the stipulation of the renewable energy contract the final cost will be 8100. The added cost that the Trade and Services S.r.l. supported is only 300, which corresponds to the 4% of the total cost. For this reason, GO system can represent an economic sustain for the renewable energy producers, and during these years it has become an incentive for green production (Fig. 4).

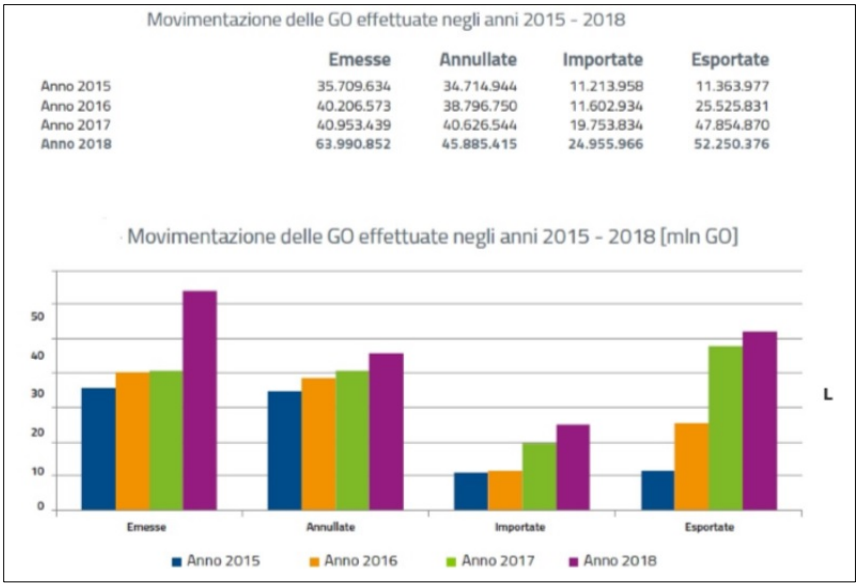


**Fig.4.** Trend of GO certifications from 2015 to 2018

## 5. Conclusions

The mechanism underlying GO certifications is beneficial in economic terms and in terms of Energy from renewable sources is expected to play a major role in the global future energy provision. In the current phase of technology and market development, policy support for renewable energy forms the basis for its market position.

Specific policy support will remain necessary in the coming twenty years to improve the technologies and bring renewable energy supply and demand to a level of maturity at which the sector can compete on a level market with other energy sources. safety, creating an economic advantage for producers and a guarantee of origin for consumers.

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# APPLICATION OF THE CIRCULAR ECONOMY TO CATHODE-RAY TUBE GLASS ECYCLING IN RAEE SECTOR*

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## Abstract

Circular economy is an instrument that allows efficient resources allocation, minimizing the environmental impact by returning waste into the production cycle that is transformed into secondary raw materials. A lower environmental impact implies the use of energy-efficient production systems with a high rate of innovation. This is what the company FG recycling System, in Belpasso (Sicily) aims to do: this is a case of excellence in the field of RAEE recycling, partly thanks to the upcoming execution of a crt glass recycling process deriving from old cathode-ray tube televisions. In fact, the largest percentage of RAEE, about 80%, is represented by televisions and computers (whose functional operation is estimated at about 10 and 4 years, respectively) containing the cathode ray tube or kinescope, which represents two thirds of the total weight of a television or monitor and consists of 85% glass. The treatment and recovery process in the project aims at subjecting certain process outputs to inert matrix, deriving from the already operating production lines, as well as part of inert waste covered by the list of those already authorized by the measures in the possession of FG S.r.l. There are multiple benefits of applying the circular economy model, including reducing the need for new demands of virgin materials and energy, and the creating an economic convenience deriving from a new and cutting-edge pioneering machine.

*Keywords:* recycling glass, circular economy, proactive company, cathode-ray tube.

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## 1. Introduction

The exceptional demographic growth of the last decades, in parallel with the development of the circular economy-based approach, poses a series of problems concerning the quantity of raw materials and the quality of the environment in which we live. In this regard, the need to guarantee a progressive reduction of waste through methodologies that allow its re-use for the creation of new artifacts is increasingly central.

One problem concerning industrialized countries is the management of electronic waste, 80% of which comes from TV and computer (Andreola et al., 2005). Every year the EU produces about 7.5 million tons of electrical waste (Marshall and Henderson, 2001) and this trend is increasing. In fact, an increase of 3.5% per year corresponds to a percentage of 16-28% in 5 years (CEC, 2000). 90% of end-of-life electronic goods (EOL) are disposed of in landfills and cause pollution problems due to the materials it contains. However in Europe operations have already been started for the dismantling of these products and this operation produces different materials and in the case of televisions or computers the CRT (cathode ray tube) represents about two thirds of their weight. In particular for this type of waste, the quantity produced in Western Europe is 300,000 tons/year (CEC, 2000).

A report from "The Global E-waste Monitor 2014: Quantities, flows and resources" revealed a total of an epic 41.8 million tons of e-waste was generated worldwide in 2014 (Baldè, 2015). CRT glass recycling techniques are still under development in countries such as the United Kingdom, Spain and Italy (Doring, 2002). Now, CRT technology for televisions and computers is obsolete and has been replaced by the liquid crystal display (LCD) and light-emitting diodes (LED) flat panel screens (Hischier and Baudin, 2010). Outdated CRT devices are considered an environmental risk if improperly arranged because they contain large amounts of leaded glass which is considered toxic (Oguchi et al., 2013). To give an example, Guiyu from Guangdong province suffered from severe lead pollution due to the funnel glass illegally placed in the landfill, as local workers were worried about their careers and the residents were subjected to severe damage to the body's organs (Xu et al., 2012). Strong points have been raised about the potential of toxic metal leaching from CRTs (Spalvins et al., 2013). Therefore, there is an urgent need to develop effective recycling methods for these difficult-to-treat products.

In general, there are two principal approaches to recycling CRT glass: closed-loop and open-loop recycling. In the closed-loop recycling, CRT glass is generally reused as raw material to manufacture new CRT monitors. For this recycling, it could be profitable only in the case of an absolute separation of the lead-containing and lead-free glass (Hreglich et al., 2001). With the rapid shrinking of demand for new CRTs, most CRT manufacturers have made their own CRT operations. Therefore, a dramatic drop in closed-loop recycling has occurred, and attention has shifted to open-loop recycling (Mueller et al., 2012).

In fact, the objective of the paper is to analyze the advantages and the needs of reusing resources by recycling waste based on methodologies that limit the environmental impact. In particular we will deal with the cycle of the source glass for the production of secondary raw materials. Despite being a perfectly closed cycle, the recycling of glass is full of problems related to its recovery, treatment and conversion in the second raw material. Furthermore, the treatment and disposal of these materials requires the need to adopt innovative and eco-sustainable approaches to achieve energy and environmental sustainability objectives in a perfectly integrated and circular economy.

## 2. Materials and methods

In recent years, Europe has moved towards sustainable development goals linked to the c.d. green and circular economy, in fact we increasingly hear of the circular economy.

Our continent is focusing on the green sector, therefore on the recycling of waste and resources, in fact the term "circular economy" is a generic term for the activities of reduction, reuse and recycling conducted in the production and circulation process (Korhonen et al., 2018). It is a vast and growing market: worth about 2.2 trillion euros for 19 million jobs. In a circular economy the flows of materials are of two types: biological ones, able to be reintegrated into the biosphere, and technical ones, destined to be upgraded without entering the biosphere". In practice it is a zero waste economy, where any product is consumed and disposed of without leaving a trace.

Obviously in the circular economy renewable energies and the modularity and versatility of objects are very important, which can and must be used in various contexts in order to last as long as possible. It is therefore clear that the circular economy presupposes a systemic way of thinking, which does not end with the design of products intended for a single purpose (Ghisellini et al., 2016). It is an economy that not only protects the environment and saves on production and management costs, but also produces profits. In this Italy it is in an excellent position within the European framework, although it does not have a precise law that regulates it (except for some references in the context of the Industry 4.0 plan): it manages to obtain services of 3.4 euros per kg of waste disposed of (Andreola et al., 2003). On 2 December 2015, the European Commission adopted an ambitious circular economy package. It is composed of an EU action plan with measures relating to the entire life cycle of products: from design, procurement, production and consumption to waste management and the secondary raw materials market. The rules aim to have a practical effect on the lives of European citizens. The provision obliges member countries to recycle at least 70% of urban waste and 80% of packaging waste, and prohibits the disposal of biodegradable and recyclable waste. The rules should come into effect starting from 2030 (Murray et al., 2017).

The transition to a model of Circular Economy is a question that also arises for the glass market. Through the recycling of glassy waste for the production of second raw material it is possible to register substantial energy savings in terms of reducing the energy needed to extract the raw materials essential for the production of glass, therefore minerals and sand (Co.Re.Ve., 2012). The generation of second raw material from the glass allows us to guarantee the sustainability of the entire glass business by avoiding the problem of the scarcity of virgin raw materials. To achieve this goal a case study is proposed in: F.G. Recycling srl. The company's objective is to eliminate the concept of waste, waste, so it must be considered a real resource. The company deals with the management and treatment of waste and electrical and electronic equipment (WEEE).

The presence of dangerous components in electrical and electronic equipment is strictly dependent on the presence of heavy metals in the glasses and materials that compose them, as well as the presence of noble metals and other substances that are highly harmful to the environment and human health. These include substances that are harmful to the zono contained in refrigerators, capacitors containing PCBs, harmful ozone gases, components containing mercury or batteries. The dangerousness of the material therefore requires special transports and infrastructures in accordance with the law, capable of handling, receiving and storing WEEE optimally, avoiding damage to the equipment and the dispersion of dangerous substances. The recycling of cathode ray tubes monitors is the one that causes the greatest difficulties connected above all to cone glass, which contains a considerable amount of lead oxides and a coating based on graphite metal oxides. To this end it is necessary to carry out a specific intervention on the cathode ray tube, which requires a suitable treatment to avoid the dispersion of dust and heavy metals, with a consequent operation of reclamation of the cone glass and of the screen glass.

Currently the methods used for the recovery of MNs from waste, specifically contained in the glass of televisions, and components inside electrical and electronic

equipment are essentially of two types: end attacks by means of strong and oxidizing cycles; strong bases or cyanide salts or even heat treatments driven by melting or sublimation in an arc furnace.

Looking specifically at the Sicily region, it is the last in Italy for the recovery of these assets, which sometimes end up in illegal dumps. Despite this, according to data from the WEEE Coordination Center in Sicily in 2018, 14,540 tons of waste were recovered, compared to 13,396 in 2017, for an average per capita of 2.89 kg per inhabitant. The approval of the WEEE decree already signed in 2015 is pending, which would allow the creation of micro ecological areas for the recovery and start-up of new WEEE (www.lasicilia.it).

## 3. Experimental

FG srl is a leading company in the field of recovery and disposal of hazardous and non-hazardous waste. The company was founded in 1974 and is specialized in the treatment of electrical and electronic equipment out of order the CDs. WEEE in fact, the company mission is to manage the treatment, disposal and recovery of waste in eco-friendly terms and, in particular, to derive secondary raw materials from WEEE in full compliance with the environmental and human ecosystem. The company since 2000 is registered in the business register in the ordinary section under the legal form of Limited Liability Company. The FG S.r.l., despite being a large-scale company operating on a large scale, is characterized by a family-type entrepreneurial trait, in fact it owes its name and history to the entrepreneur Giovanni Failla and today to the Failla brothers.

The activity is carried out in the legal and administrative office located in Belpasso (CT), Strada Comunale San Todaro n. 20 CAP 95032, fraction Valcorrente and spread over an area of over 30,000 square meters, of which 6,000 square meters are covered and about 5,000 square meters, however, are expanding. Depending on its objectives, the company FG S.r.l, specialized in the operations of waste, recovery and recycling of hazardous and non-hazardous special waste, logistically speaking, uses services carried out internally and externally.

The vehicle fleet available to the company consists of n. 6 road trains and n. 3 trucks equipped with a demountable body and, in addition, 3 vans. All vehicles are equipped with the necessary equipment to carry out the collection of dangerous goods and are approved in accordance with ADR249 (Accord Dangerous Route).

- obsolete and similar AEE such as faxes, computers, photocopiers, printers
- paper and cardboard packaging
- plastic
- bulky waste

It should therefore be noted that the target customers with whom FG S.r.l. is broad and varied and includes companies (private and public) and consortia relevant throughout the national territory of which the most important not by order of importance are: CMC Ravenna, cobat, isam, item, sibeg, logex remedia tsr. Furthermore, the company has the various voluntary certifications normally provided, specifically FG has ISO 9001, ISO 14001, OHSAS 18001, WEELABEX280. FG S.r.l. it also complies with the requirements of EU Regulation no. 333/2011 of the board, of March 31, 2011, containing the criteria that determine the exact moment in which some types of metal scrap cease to be considered waste pursuant to Directive 2008/98 / EC of the European Parliament and the Council.

## 4. Results and discussion

FG aims to achieve the objective of starting the waste towards a valorization process in industrial sectors in the form of substitutes for virgin raw materials by obtaining the Integrated Environmental Authorization which is subject to compliance with the art. 29 quater and following of Legislative Decree 15/2006 governing the rules on environmental protection. In compliance with the general regulations in force, and in particular those governing the management of electronic waste, FG intends to set up a plant that will allow the processing and recovery of CRT glass within its plant, thus obviating the problem of having to transport tons of dangerous vitreous material at plants located in northern Italy that already has obtained the Integrated Environmental Authorization.

FG recycling has already bought the land adjacent to the current production plant and is still waiting for the integrated environmental authorization of the Sicilian region for starting the new activity. FG Recycling will reduce the environmental impact through new innovative and high-tech plants that allow it to introduce powders and microparticles into the atmosphere for a maximum limit of 10 mg/Nm³. Likewise, the decrease in environmental impact will be enabled by the fact that, within the new Sicilian plant, the only waste that will be produced will be only glass materials that cannot be qualified as secondary raw materials and cannot be sold. It also emerged from the market analysis that the realization of this plant allows to combine the decrease of the environmental impact with the important objective of abating noise emissions because the only fixed source of noise will be represented by the glass grinding line.

Considering economic advantages, with the installation of the plant, the Sicilian company intends to reach an important goal of reducing costs for the transport of dangerous glassy material that cannot be subjected to a recovery and treatment process. In fact, the company accepts waste from electrical and electronic equipment, separates the metal components and incurs significant logistics costs for the transport and disposal of the dangerous fraction, in particular of the CRT screens that is started at the SEA - Environmental Services plant of Vicenza.

FG therefore aims to reduce the cost of € 1,500.00 for the transportation and disposal in Vicenza of the transport and disposal panel in Vicenza of glass and cone panel.

With the creation of the plant, FG Recycling intends to carry out solely the recovery of glassy waste, by means of the grinding technique, deriving from the treatment of equipment out of use with cathode ray tubes and aimed at the production of secondary raw material of glass suitable grain size. The production cycle is characterized by some preliminary and other successive phases. First of all, the input waste to be subjected to a treatment and recovery process are those deriving from the disassembly operations of equipment with cathode ray tubes and treatment of the monitors that are carried out by F.G., as well as waste delivered by authorized transport. The incoming waste is discharged into the special transfer area inside the shed to be subjected to verification operations including checking of transport documents, visual control and radiometer, which are essential for the acceptance in the plant.

Loads that have successfully passed the check and verification phase are sorted by type while loads not deemed suitable are returned to the sender. The next phase is that of the remediation of the removable pollutants that are contained in the cathode ray tube, consisting in eliminating the fluorescent powders which are made up of zinc, cadmium and rare earths. Subsequently, all the remaining metallic or other components that can affect the quality of the glass in the outlet are eliminated, including the removal of the coating from the rear (funnel) consisting of metal oxide and graphite based paint. The process then proceeds to the phase of grinding glass waste which is carried out for distinct campaigns, by means of a double closed cycle plant, since the two categories of glass that make up the CRT screens,

lead glass and barium glass, must maintain different characteristics depending on their destination as a second raw material. The secondary raw material of glass that are produced are accumulated separately in special storage areas to be finally destined for end users. The possibility that the secondary raw material are given loose: this means that the system is set up with a special system equipped with a hopper, a dosing belt and a closed elevator belt, guarded by a suction hood positioned above the discharge point of the secondary raw material.

## 5. Concluding remarks

Considering what has been analyzed in this work, it is possible to assert that The FG recycling system's investment will give rise to a significant turning point in the disposal of WEEE in Sicily.

So far, they have been subjected to disassembly activities with consequent transportation and disposal of plants located in other parts of Italy to assert that FG recycling system srl through the expansion of its own plant finalized to the creation of the cathode-ray glass treatment and recovery plant is able to fully satisfy the objectives contained in the European on environmental sustainability.

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# Ge.S.P.I. Srl: A WASTE TO ENERGY PLANT OF SPECIAL WASTE. ANALYSIS OF THE DIFFERENCES AND SIMILARITIES BETWEEN THE VARIOUS INCINERATION PLANT*

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## Abstract

Waste is unwanted or unusable material: is any substance which is discarded after primary use, or is worthless, defective and of no use. This study is focused on hazardous waste and the differences/similarities between the various "incineration" plant in the world. The characteristic of this type of waste is ecotoxicity. The "Ge.S.P.I. S.r.l." located in Augusta is the leader in the South of Italy for waste reduction that deals with transforming waste into energy, industrial waste and waste from ships. In order to increase the environmental sustainability they decided to present a waste-to-energy plant at Ecomondo in November 2016, that is a waste management facility that composts waste to produce electricity and decreases ash and $CO_2$ emissions but also minimizes the introduction of heavy waste into the environment. This paper is based on the experimental analysis to improve the features of the Ge.S.P.I's plant, in particular the analysis is based on comparison between the most innovative incinerator plant in the world, to analyze the strengths and weaknesses of these plants.

*Keywords:* Ge.S.P.I., incineration, Sicilian company, special waste, waste to energy plant

## 1. Introduction

The concept of waste is the key to the application of the relative discipline. In common parlance, this term indicates several things, which are thrown away in various ways, because they no longer serve their purpose. However the points of view on the same thing

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can be very different: what one person throws away can be used by another until consummation; the unusable residues of a factory can constitute raw materials for another production cycle; a material that everyone today wants to get rid of tomorrow will have an economic value (Di Fidio, 1988).

From the Consolidated Environmental Act are considered urban waste:

- household waste, even bulky waste, coming from rooms and places used for civilian use;
- non-hazardous waste from premises and places used for purposes other than those discussed in the previous point, assimilated to urban waste in terms of quality and quantity, pursuant to Article 98, paragraph 2, letter g;
- waste from exhumations and estumulations, as well as other waste from cemetery activities other than those of the second and fourth points.

They are special waste:

- waste of agricultural and agro-industrial activities pursuant to and for the purposes of art. 2135 c.c.1;
- waste deriving from demolition, construction, as well as waste deriving from excavation activities, without prejudice to the provisions of Article 184 - bis 2;
- industrial waste, [without prejudice to the provisions of art. 185, paragraph 1 letter I)];
- artisan waste;
- waste from commercial activities;
- waste from service activities;
- waste deriving from the recovery and disposal of waste, sludge produced by water purification and other water treatment, wastewater purification and fume abatement;
- waste deriving from health activities;
- deteriorated and obsolete machinery and equipment;
- motor vehicles, trailers and the like out of use and their parts;
- fuel derived from waste;
- waste deriving from the mechanical selection of solid urban waste

This paper is focus of the differences and similarities between the various waste to energy plant. All this waste to energy plants are based on circular economy. A circular economy aims to redefine growth, focusing on positive society-wide benefits. It entails gradually decoupling economic activity from the consumption of finite resources and designing waste out of the system. Underpinned by a transition to renewable energy sources, the circular model builds economic, natural, and social capital. It is based on three principles:

- design out waste and pollution
- keep products and materials in use
- regenerate natural systems

A very clear definition of a circular economy is provided by the European Commission:

*"A circular economy aims to maintain the value of materials and energy used in products in the value chain for an optimal time, thus minimizing waste and resource use. By preventing the occurrence of value losses in material flows, this type of economy creates economic opportunities and competitive advantages on a sustainable basis"*

The characteristics of the circular economy are:

- without waste;
- use resources efficiently;
- preserves natural capital;
- favors the protection, enhancement and restoration of biodiversity;
- low $CO_2$ emissions;
- presupposes economic growth detached from the consumption of resources;
- contributes to creating a safe and sustainable global society.

In order to make the transition to a circular economy, action must be taken at all stages of the value chain. The objective is the implementation of the technological innovation of some cutting-edge waste in a plant in Sicily.

## 2. Materials and methods

The waste can be heat treated through three fundamental processes, each characterized by a different quantity of oxygen present:

• *Incineration* (or waste-to-energy), in which the complete combustion of the organic fraction takes place, in the presence of an adequate excess of air and with the result of obtaining completely oxidized products;

• *Gasification*, in which a partial combustion of the waste is carried out in the presence of an oxygen defect. Only a part of the material subjected to treatment burns, producing enough heat for the thermal decomposition of the remaining one. The final products are not completely oxidized and therefore possess their own calorific value;

• *Pyrolysis*, in which no form of combustion or oxidation takes place but rather a thermal degradation of the material in the absence of oxygen, through the direct or indirect contribution of heat.

Despite only 10% of the waste undergoes the incineration treatment, being the last step analyzed from the perspective of waste management, the latter is the only one to guarantee a substantial reduction in weight and volume of the starting waste, a residue generally sterile final, transferable to landfill and energy recovery (Allegretti et al., 1995). In particular, the use of waste-to-energy as a method of disposing of the waste produced by civil and industrial activities, if on the one hand it has the considerable advantage of a substantial reduction in volume, on the other generates a series of waste, which has as its final destination the landfill controlled. This concerns combustion slag, heavy ash, electro-filter dust, waste washing residues.

## 3. Results and discussion

The company Ge.S.P.I. s.r.l., leader in Southern Italy for the treatment of special waste. It represents the emblem of the new waste-to-energy plants as it is at the forefront in the introduction of numerous technological innovations, first the ash refining grid, implemented exclusively in Germany, Switzerland and France. The core businesses in which Ge.S.P.I. operates LTD are: disposal of special waste by waste-to-energy treatment; medical waste collection and disposal service; services in return in the port area by collecting and transporting the waste produced by ships in transit in the port of Augusta; security / escape service at Esso Italian oil terminals; bunkering services.

The company is a company established in 1984 by the family members of the members of the former Union Marinara cooperative s.r.l. (established in turn in the early 1960s) with which it was initially known and co-owned by mobile vehicles and concessions regarding services performed in the environmental field (port and land). Acquired in 1999 entirely by the Marinara cooperative, the equipment, machinery and human resources necessary to carry out and manage the services for which it is specialized, the Company now carries out its maritime activities in the area of the port of Augusta, managing a plant of incineration site in Contrada Punta Cugno, in the Municipality of Augusta (SR), with authorized potential of 15,000 tons / year.

In particular, the Ge.S.P.I. S.R.L. is a leader in Southern Italy in the sector of disposal through thermal destruction of industrial and port waste. The business segments in which it operates are:

• disposal of special waste by waste-to-energy treatment;
• collection and disposal of medical waste;
• services in return in the port area by collecting and transporting the waste produced by ships in transit in the port of Augusta;
• safety / escape service at Esso Italian oil terminals;
• bunkering services.

The business complex consists of two warehouses used as waste storage, an office building and a building used as a technical control room.

The plant is today, consisting of:

• a section for storing incoming waste;
• a combustion section, recovery of thermal energy with the production of steam used to drive the turbine which, in turn, produces electricity through the production of steam;
• a fume purification section with dry Solvay process;
• a chimney for the discharge of purified fumes in the atmosphere;
• monitoring and control systems for combustion, pollutant concentrations, flue gases and the functionality of the thermal cycle.

Ge.S.P.I. S.R.L., is certified in the year 2018 with the accreditation body Rina Services S.p.A., both for ISO 9001: 2015 and for ISO 14001: 2015. They are ISO 9001 certified in terms of quality for “Delivery of the collection service, transport by land and by sea and incineration of solid urban waste, special non-hazardous, hazardous and animal by-products. Provision of brokerage services without holding hazardous and non-hazardous waste. Transport and delivery of lubricating oils alongside. Assistance services to the piers in evacuation operations” (Ge.S.P.I. SRL, 2016).

They are ISO 14001: 2015 certified regarding the environment for “Delivery of the collection service, transportation by land and by sea and incineration of solid urban waste, special non-hazardous, hazardous and animal by-products. Provision of brokerage services without holding hazardous and non-hazardous waste. Transport and delivery of lubricating oils alongside. Assistance service to the piers in evacuation operations. Production of electricity from waste incineration ".

They are OHSAS 18001 certified in the field of health and safety in the workplace for "Occupational Health and Safety Assessment Series"

Objective for the entire Management of Ge.S.P.I. S.R.L. is to implement in the years 2018/2019 the 231 Law (model pursuant to Legislative Decree No. 231/2001), the latter indicates an organizational model adopted by a legal person, or association without legal personality, aimed at preventing liability penal of the institutions. The responsibility pursuant to Legislative Decree No. 231 joins the criminal liability of the natural person who committed the crime. The introduction of this new and autonomous type of responsibility allows you to directly affect the assets of the institutions that have benefited from the commission of certain crimes by natural persons material authors of the criminally relevant crime, who "impersonate" the company or who however, they operate in the interests of the latter.

Relations with suppliers and customers of goods and services must follow the internal procedures relating to their management, especially regarding the selection, identifying and analyzing:

• the objective criteria (price, quality of the service, assistance), those relating to the soundness and correct execution of the business relationship and full adherence to the contractual conditions, as well as the use, by the suppliers themselves, of procedures that are generally consistent with the regulations in force in the business management. The continuation of the commercial relationship must be subject to a pre-established periodic verification of the minimum requirements required by Ge.S.P.I.;

• the principles of transparency and correctness in the exchange of necessary information, correspondence and formal contacts.

The pursuit of cost-effectiveness of supplies cannot take place without respecting the ethical principles of the code and the general principles of correctness of the activity. The maximization of the advantage to be achieved, in a framework of correct competition, for example, cannot be obtained by using suppliers that do not adopt compatible criteria or resort to unfair or disruptive competition (Giunta et al., 2017).

The GESPI values the human resources patrimony constituted by the employees, protecting the specificity of and the competences of the single collaborators, with the aim of the full attainment of the legitimate aspirations, parallel to the attainment of the business purposes. In fact, forms of employment or collaboration are not admitted, except those provided for by the employment contract and by the regulations in force on the subject. The assumptions and the subsequent contractual relationships must follow criteria of competence and merit, banning all political, trade union, religious or sexual discrimination and finally the interventions of management of the personnel, within the hierarchical relations must be inspired by equity and avoid any possible abuse. Every employee, moreover, must respect his obligations:

• every employee has the obligation to act avoiding any harmful activity of the company's interests, its reputation and image. In the course of his work he has the obligation to maintain an appropriate and respectful attitude to the personal dignity of others;

• each employee is required to take particular care in processing information, news and data acquired in the performance of his or her duties;

• every employee has the obligation to scrupulously follow the company safety regulations and provisions and to take care of the correct use of the available protection devices;

• each employee must act by safeguarding the assets and the instruments assigned according to his / her task, avoiding any improper use, not conforming to the indications provided and, in any case, potentially dangerous for himself or others.

Incineration represents a technique for waste disposal which consists in the complete oxidation of the fuel part of the waste. The heat produced by this combustion can be recovered to produce electricity and thermal energy. This process is carried out in special plants called "Thermovalorizers", i.e. Incineration plants with energy recovery.

The waste energy plant analyzed are (Table 1):

*Dubai:* A disposal capacity of 200 t / h to be able to treat 60% of the waste produced in the Arab Emirates and an electrical power generated by 185 MW capable of satisfying 2% of Dubai's electricity needs the new plant, which will be fully operational in 2020, will have a capacity of 185 megawatts and will be able to dispose of 60% of the waste produced in the Emirate. The project, with a total cost of 2.5 billion Dirham (552 million euros).

The plant's power, which will cover 2% of the city's total energy needs, will be 20MW The new waste-to-energy plant, which cannot be considered a zero-emission infrastructure but is still much greener than an incinerator, fits into a very aggressive energy policy plan with a strong focus on environmental impact. Dubai's long-term goal is to cover 75% of its energy needs with renewable energy by 2050 with investments totaling $ 163 billion. This objective will increase to 25% by 2030 and 75% by 2050, thus establishing the lowest ecological footprint in the world in Dubai.

*Swiss* technology has strongly influenced the construction of the future of incineration in Dubai. Consequently, the greater part of the values registered in the Swiss system is coherent but halved due to the different productive capacity due to the size of the plant. The Swiss system has a Disposal capacity of 16 t / h and an Electric power generated of 67 MW.
Denmark; the waste-to-energy plant has two grate boilers, each with a capacity of 35 tons / hour and a nominal thermal load of 112 MW, two wet fume purification lines with water

vapor condensation and a 67 MWe turbine. The fume condensation system in two steps allows to recover the condensation heat, increasing energy recovery by about 20 percentage points, from which an overall efficiency of 107%.

**Table 1.** Emissions form waste energy plants

| *Country* | *CO (mg/Nm$^3$)* | *NO (mg/Nm$^3$)* | *$SO_2$ (mg/Nm$^3$)* | *TOC (mg/Nm$^3$)* | *HCl (mg/nm$^3$)* | *$O_2$ %* | *Powders (mg/Nm$^3$)* |
|---|---|---|---|---|---|---|---|
| Switzerland | 11.74 | 118.13 | 13.72 | 0.06 | 0.96 | 13.71 | 0.86 |
| Dubai | 8.39 | 98.58 | 11.03 | 0.03 | 0.70 | 12.29 | 0.40 |
| Norway | 20.58 | 131.68 | 22.14 | 0.25 | 3.38 | 15.95 | 1.36 |
| GESPI | 8.13 | 104.1 | 11.69 | 1.63 | 2.5 | | 0.55 |

## 4. Concluding remarks

The analysis from this study was offered to emphasize the strengths and weaknesses of the most important systems in the world. Nevertheless, it is important to underline the values of Ge.S.P.I. they are similar only to those of Denmark since this is an incinerator that incinerates specific waste; therefore, all the other values will be different. The most important variation is energy production (Dubai, Copenhagen and Switzerland).

The Ge.S.P.I. the objective is to direct the business enterprise towards energy production and not on waste thermal destruction. Another important variable appears to be political and bureaucratic, as the timing and social sensitivity are viewed differently based on the location being considered. Moreover, by 2021 the Ge.S.P.I. will seek to strengthen relations with energy "sellers" to create no more self-supporting energy but also sustain energy for the citizens of Augusta. In 2025 the Ge.S.P.I. the objective is to implement a unique zero-emission rotating oven, identical to the one implemented in Switzerland and Dubai.

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# Instructions for authors

## 1. Introduction

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All authors are requested to disclose any actual or potential conflict of interest such as any financial, personal or other relationships with other people or organizations concerning the submitted work that could inappropriately influence, or be perceived to influence, their work.

## 3. Editorial procedure

Maximum 10 pages are accepted (including Abstract, Keywords, References, Figures and Tables), processed with MS editing facilities, using the manuscript template.
Manuscripts should be written in US English and submitted electronically, in .doc format (please do not use .docx) by the Conference Organizers to the Editor-in-Chief, at procedia_esem at yahoo dot com. Please be sure to include your full affiliation address and e-mail address.

## 4. Manuscript preparation

Authors must follow guide for authors strictly (manuscript template), failing which the manuscripts would be rejected without review. Editors reserve the right to adjust the style to certain standards of uniformity.

Manuscripts should be concise, in 1.5 line spacing, and should have 2 cm all over margins. The font should be Times New Roman of size 12 points. The numbering of chapters should be in decimal form. Ensure that each new paragraph is clearly indicated, using TAB at 1.25 pts.

### *Title page will contain*

A concise and informative title (Times New Roman bold, all caps of size 13points); the maximum length of the title should be maximum 150 letters and spaces;
The full name(s) of the author(s) (first name, then last name, with Times New Roman bold 11 points) should be written below the title. The affiliation(s) and complete postal address (es) of the author(s) will be provided immediately after the full name of the authors and will be written with Times New Roman italic 9 points. When the paper has more than one author, their name will be followed by a mark (Arabic numeral) as superscript; for the corresponding author, two asterisks will be added using *Word_Insert_Reference_Footnote_Symbol* sequence.
Also, the full and e-mail addresses, telephone and fax numbers of the corresponding author will be provided in the footer of the first page, as: *Corresponding author*: email..., Only one corresponding author has to be provided.

**Abstract:** each manuscript must be preceded by an abstract presenting the most important results and conclusions in no more than 300 words, written with Times New Roman 9 points.

**Key words:** three to five key words should be supplied after the Abstract for indexing purposes, **ordered alphabetically**, using American spelling and avoiding general and plural terms and multiple concepts (avoid, for example, "and", "of"). Be sparing with abbreviations: only abbreviations firmly established in the field may be eligible. These keywords will be used for indexing purposes.

The text of the paper should be divided into Introduction, Experimental, Results and Discussion, Conclusions, References (or Case-studies presentation instead ofexperimenta).

**The text layout must be on a single column.**

### Introduction

State the objectives of the work and provide an adequate background, avoiding a detailed literature survey or a summary of the results.

### *Material and methods*

Provide sufficient detail to allow the work to be reproduced. Methods already published should be indicated by a reference: only relevant modifications should be described.

### *Experimental*

Provide sufficient detail to allow the work to be reproduced. Methods already published should be indicated by a reference: only relevant modifications should be described.

### *Results and Discussion*

Results should be clear and concise. Discussion should explore the significance of the results of the work, not repeat them. Avoid extensive citations and discussion of published literature.

***Conclusions***
The main conclusions drawn from results should be presented in a short Conclusions section (maximum 100 words).

***Formulae, symbols and abbreviations*** Formulae will be typeset in Italics (preferable with the Equation Editor) and should be written or marked for such in the manuscript, unless they require a different styling. The formulae should be quoted on the right side, between brackets:

$$(x_1+x_2)^2 = x_1^2 + x_2^2 + 2x_1x_2 \quad (1)$$

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Footnotes should be avoided.

***References*** The list of References should only include works that are cited in the text and that have been published. References should be cited in the text in brackets (Harvard style) as in the following example: (Schmidt, 1989), (Schmidt and Walter, 1996), (Walter et al., 1999).

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***Books:***

*Book chapter:* Names and initials of authors; year, article title; editors; title of the book (italic); edition; volume number; publisher; place; page number:

Cutaia L., Morabito R., Barberio G., Mancuso E., Brunori C., Spezzano P., Mione A., Mungiguerra C., Li Rosi O., Cappello F., (2014*), The Project for the Implementation of the Industrial Symbiosis Platform in Sicily: The Progress After the First Year of Operation*, In: *Pathways to Environmental Sustainability,* Salmone R., Saija G. (Eds), Springer Science & Business Media, Cham Heidelberg New York Dordrecht London, 205-214.

*Books:*
Faber K., (2000), *Biotransformations in Organic Chemistry - A Textbook*, vol.VIII, 4th Edition, Springer, Berlin-Heidelberg-New York.

Handbook, (1951), *Handbook of Chemical Engineer*, vol. II, (in Romanian), Technical Press, Bucharest, Romania.

***Symposia volumes:*** Names and initials of authors; year; article title; full title; symposium abbreviated; volume number; place; date; page number:
Masutti D.C., Borgognoni A., Scardovi F., Vaccari C., Setti L., (2014), *Production of Lignocellulosic Enzymes from Different Agro-Food Wastes by Solid State Fermentation*, Proc. of 5th International Conference on Engineering for Waste and Biomass Valorisation - Rio de Janeiro, September 6th-8th, Brazil.

***Journal papers:*** Names and initials of authors; year (between brackets); full title of the paper; full name of the journal (italic); volume number (bold); first and last page numbers:

Setti L., Giuliani S., Spinozzi G., Pifferi P.G., (1999), Laccase-catalyzed oxidative coupling of 3-methyl 2-benzothiazolinone hydrazone and methoxyphenols, *Enzyme Microbial Technology*, **25**, 285-289.

***Patents:*** Names and initials of authors; year; patent title; country; patent number: Grant P., (1989), Device for Elementary Analyses. USA Patent, No. *123456*.

***Dissertations:*** Names and initials of authors; year; title; specification (Ph. D. Diss.); institution; place:

Guikema J.W., (2004), *scanning hall probe microscopy of magnetic vortices in very underdoped yttrium-barium-copper-oxide*, PhD Thesis, Stanford University, Stanford, USA.

Star K., (2008), *Environmental risk assessment generated by natural hazards*, MSc Thesis, Institute of Hazard Research, Town, Country.

***Legal regulations and laws, organizations:*** Abbreviated name; year (between round brackets); full name of the referred text; document type; author; URL address:

JRC European Commission, (2011), *Supporting Environmentally Sound Decisions for Construction and Demolition (C&D) Waste Management*, A practical guide to Life Cycle Thinking (LCT) and Life Cycle Assessment (LCA), On line at: http://lct.jrc.ec.europa.eu/pdf-directory/ReqNo-JRC65850-LB-NA-24916-EN-N.pdf.

EC Directive, (2010), Directive 2010/75/EU of the European Parliament and of the Council of 24 November 2010 on industrial emissions (Integrated Pollution Prevention and Control), *Official Journal of the European Union*, **L334**, 17-119.

EC, (2014), Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions Towards a Circular Economy: A zero waste programme for Europe, European Commission, On line at: http://ec.europa.eu/environment/circular-economy/

Law 152 (2006), Legislative Decree No. 152 of the 03 April 2006, Environmental Regulations, *Official Journal*, No. 88 of the 14 April 2006 – Ordinary Supplement No. 96.

GD, (2004), Governmental Decision no. 1076/2004 surnamed SEA Governmental Decision, regarding the procedure for strategic environmental impact assessment for plans or programs, published in Romanian Official Monitor, part I, no. 707 from 5th of August, 2004.

***Web references:*** The full URL should be given in text as a citation, if no other data are known. If the authors, year, title of the documents are known and the reference is taken from a website, the URL address has to be mentioned after these data.

Web references must not be listed separately, after the reference list.
**All references must be provided in English with a specification of original language in round brackets.**

Lorint C., (2012), *Natural Protected Areas and Biodiversity Preservation* (in Romanian), Universitas Press, Petroşani, Romania.

**Citation in text** Please ensure that every reference cited in the text is also present in the reference list (and vice versa). Do **not cite references in Abstract and Conclusions**

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Define all abbreviations at their first mention in the text. Ensure consistency of abbreviations throughout the article.

***Acknowledgements***
Include acknowledgements in a separate section at the end of the article before the references and do not, therefore, include them on the title page, as a footnote to the title or otherwise. List here those individuals who provided help during the research (e.g., providing language help, writing assistance or proof reading the article, funding supports etc.).

***Footnotes***
Footnotes must be avoided. Do not include footnotes in the Reference list.

*Table footnotes*
Indicate each footnote in a table with a superscript lowercase letter.

***Tables***
Draw the tables in grid format using a basic, solid line style without shadows. Ensure that the data presented in Tables do not duplicate results described in Figures or elsewhere in the article.

***Figures***
Number Figures consecutively in accordance with their appearance in the text. All illustrations should be provided in camera-ready form, suitable for reproduction, which may include reduction without retouching.
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**ALL Figures must be submitted in either .jpg or .tiff format with a very good resolution (but do not submit graphics that are disproportionately large for the content).**

**Figures and Tables must be embedded in the text.**

***Proofs***
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