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Selected papers

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Aims and Scope

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

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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 250 scientific papers, 180 of which on medium/high IF peer-review international journals of industrial and environmental biotechnology and circular bioeconomy. He has 8680 overall citations, a h-index of 55 and an i10 index of 145 (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, ROUTES, MINOTAURUS, WATER4CROPS, ULIXES and KILL SPILL.
F. Fava served and is serving several national, European and international panels, by covering, among others, the following positions:
• Member of the Scientific Committee of the European Environmental Agency (EEA), Copenaghen, for the "Circular economy and resource use" domain (2021-);
• Italian Representative in the "European Bioeconomy Policy Forum" and the "European Bioeconomy Policy Support Facility" of the European Commission (2020-);
• 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-);
• Italian Representative in 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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INTELLIGENT WASTE INFRA MANAGEMENT AS A PART OF CORPORATE CARBON RESPONSIBILITY*

Johanna Alakerttula[1], Mikko Ahokas[2], Outi Laatikainen[3],**

[1]Tampere University, Unit of Industrial Engineering and Management, Korkeakoulunkatu 7, 33720 Tampere, Finland
[2]Macon, Teknologiantie 18, 90590 Oulu, Finland
[3]KAMK University of Applied Sciences, Ketunpolku 1, 87101 Kajaani, Finland

Abstract

The waste sector is in transition. More efforts are being made to improve the separate collection of waste directly from households and to promote recycling, but on the other hand, waste companies are under heavy pressure to keep waste management costs moderate to the customers and limit the environmental impacts of waste management. Carbon neutrality has become a competitive and reputational factor and an essential aspect of corporate responsibility, and therefore companies are setting ambitious targets to become carbon neutral in the future. Still, in the waste management sector, monitoring or mitigating the carbon footprint of waste transportation is not a common practice. Yet, optimizing logistic operations by intelligent monitoring can provide remarkable possibilities to reduce emissions and save fuel consumption and waste management costs. This case study analyzes the implementation of carbon neutrality as a part of CSR in a regional waste transport company. The waste bin level measurement results from one household company are utilized to demonstrate the effects of digital monitoring. The results summarize active measures that companies can take to reduce waste transport emissions and costs. Companies can switch to lower-emission vehicles, optimize logistics, add multi-compartment vehicles, and develop marketing and reporting. In this case, digitalization has been used to renew the operational business model and to provide new innovative data-based waste management. Intelligent remote monitoring in waste container infra has changed logistics planning and a digital marketplace has made the climate and economic benefits of databased waste collection visible to the customers. This research concludes that digitalization will change waste management and that carbon neutrality will likely become a differentiator for waste sector organizations, allowing them to gain competitive and reputational advantage.

Keywords: carbon emissions, CSR, digitalization, waste logistics

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** Corresponding author: e-mail: johanna.alakerttula@tuni.fi

1. Introduction

Municipal Solid Waste (MSW) management plays a crucial role in modern society when building sustainable, environmentally safe, and livable cities (Villalba Ferreira et al., 2022; World Bank, 2020). MSW accounts for 10 % of the total waste generated in the European Union, but it has high political status due to its close link to consumers, complex composition, and increased generation (European Commission, 2022 a; Eurostat, 2021; Ma and Hipel, 2016). In most EU countries, the trend of MSW generation has been upward from 2005 to 2020, but the management of the wastes hasn't been developed at the same pace, and the recycling rate of MSW is still under 50 % (Eurostat, 2021). The European Commission has responded to this with the Waste Framework Directive and set ambitious waste collection and recycling targets for municipal solid waste and specific waste streams, which EU countries need to achieve between 2020-2035 (European Commission, 2022 a).

The sustainable MSW management system consists of mixed and sorted household and garden waste collection, transport and treatment such as recycling of wastes (Jouhara et al., 2017; Li et al., 2021). Traditionally MSW systems have been developed to protect public health and the environment, cut carbon emissions, and respond to resource scarcity (Marshall and Farahbakhsh, 2013; World Bank, 2022). Significantly increasing concern about climate change has encouraged municipalities and organizations to mitigate their greenhouse gas emissions in many sectors (Villalba Ferreira et al., 2022). In fact, the waste treatment sector has been aware of its environmental impacts for a long time (Guzdek et al., 2020), and in MSW treatment, greenhouse gas emissions have decreased by 42 % from 1995 to 2017. The reason is that municipal waste disposal in landfill sites has reduced to a minimum, and landfill gas recovery has increased (Eurostat, 2020). On the contrary, carbon emissions from the heavy-duty vehicles have increased by 25% during 1990-2020 in the EU (EEA, 2020), and transport sector is already responsible for a quarter of the EU's greenhouse gas emissions (European Commission, 2022 b).

It is expected that changes in EU waste legislation will significantly impact waste sorting, separate collection, recycling and logistics of different wastes, such as packaging waste and textiles (European Commission, 2022 a; Óskarsson et al., 2022). In Finland, municipalities are obligated to collect separately different materials, such as packaging waste and biowaste, directly from households (Ministry of the Environment, 2022). This will increase transport performance, waste management costs, and carbon emissions if nothing changes. Therefore, empirical knowledge on how waste transport companies are responding to the urgent need to reduce carbon footprint is needed. This study aims to expand our understanding of technical, social, and economic dimensions of waste logistic companies' climate strategies. Our study is strongly linked to the corporate social responsibility (CSR) policy, where companies take voluntary acts to develop their economic, social, and environmental sustainability and respond to global crises such as climate change (Kadyan, 2016; Le, 2022; Singh and Misra 2021).

2. Materials and methods

This study's main objective is to analyze how carbon neutrality is implemented as a part of CSR in the waste transport sector. The case study method was chosen to explore the studied issue in real-life settings. The first case selected for this research is a waste transport company from Oulu, the Northern part of Finland, which has been a forerunner in climate-neutral transport solutions. The second case is a housing company in the capital region of Finland, whose municipal waste collection has been monitored for two months in July-August 2022.

The study is based on primary interviews, numerical data, and secondary sources (Table 1). Data was gathered during 2021-2022.

To reach the research goal, the study follows a qualitative and quantitative research design. A qualitative method was used to interview the waste transport company, the municipality, and the start-up company and collect data by observing and reading relevant publications. The interview data were transcribed and qualitatively examined with content analysis to provide a picture of the respondents' views and ideas about the research topic. The quantitative research method was used to collect and analyze the numerical data from the housing company.

The results obtained from the interviews were combined with numerical data to get a complete picture of how carbon-neutral targets can be implemented in the waste transport sector and what kind of direct and indirect impacts are found at the company and customer levels.

Table 1. Data type and source

Data type and source	***Description of the data source***
Interviews (semi-structured) with key actors, duration 1h per interview	- CEO and owner, Waste transport company Haurun Jäteauto (10/2021, 01/2022) - Transport manager and owner, Waste transport company Haurun Jäteauto (11/2021, 01/2022) - Foreman, Waste transport company Haurun Jäteauto (11/2021) - CEO and owner, start-up company Wastebook developing Jaete sensors (11/2021)
A group interview (semi-structured), duration 2h	Service manager and Office Secretary / both owners of the Waste transport company Haurun Jäteauto (11/2021)
A general interview with other experts, duration 1 h	The municipality representative responsible of municipal waste management (01/2022)
Observation	Coordinating ISO 9001, ISO 14001 and ISO 45001 management systems to the Waste transport company Haurun Jäteauto (10/2021 -> 02/2022)
Minutes, reports	Waste management company responsibility reports (4 different companies) Waste companies' websites (4 different company sites) Ministry of the Environment publications (2)
Numerical data	A housing company (103 residents) in the capital region of Finland, Southern Finland. Numerical data of the surface level of mixed waste, plastic packaging waste, glass, metal, cardboard, paper and biowaste containers were measured in July-August 2022

3. Case studies

In this study, two cases were studied: Waste transport company actions towards carbon neutral waste logistics and numerical waste collection data from one housing company. Haurun Jäteauto is a local waste transport company in Oulu, the Northern part of Finland. Its service includes comprehensive waste collection from residential, commercial, industrial, and municipal customers and sewer maintenance services. The company is very committed to safe and responsible waste management, and the core of its strategy is to develop and provide carbon-free waste solutions for its customers. Reducing the carbon footprint of waste transport is a strategic goal of Haurun Jäteauto. Therefore, the company has been innovating and

investing in carbon-free vehicles, routing, and waste collection since 2018. In the last two years, Haurun Jäteauto has developed smart waste management services with Wastebook company by equipping waste bins and deep collection containers with surface measurement sensors that measure filling levels from 0 % to 100 %. This enables timely emptying of waste bins. Customers are also offered a Smart Waste Bin mobile application with which they can send a call to empty the waste bin.

The housing company, with 103 residents and 30 apartments, started using sensors to measure the waste bins' surface in July 2022. The reason was to find out the current fill level of a waste bin upon collection and to optimize the emptying of the waste bins. The housing company was chosen for this research to provide numerical data using the sensors. The sensors used to measure the filling level of waste bins are powered by IoT (Internet of Things). This is a network that connects devices and systems through the internet (Fig 1).

Fig. 1. Data from measuring the degree of filling of the mixed waste deep collection container in the housing company (Original picture from Wastebook Oy company).

The waste bins of the housing company were equipped with a smart sensor that measures their fill levels and temperature. Smart sensors collect data on waste generation patterns and send it to the cloud. When the waste bin is full, the waste management company's ERP or route optimization system receives the order to collect the waste bin through an API and transmits the data to the driver. Data collected by smart sensors is ultimately translated into concrete and actionable insights like waste statistics and carbon footprint calculations for the customer.

4. Results and discussion

Measuring the degree of waste bin surface indicates that waste bins can be emptied unnecessarily since not all the waste bins fill at the same rate as others. Based on the sensor data from July-August 2022, four out of seven mixed waste bin emptying were in vain since the degree of the waste bin filling was just 29-43 % (Fig 2). This means that the amount of waste from the first and second emptying would have fitted to the bin, if only the third emptying had been done. This same applies to the 5th and 7th emptying of the bin. If emptying of the waste bins were optimized, it would mean savings in waste costs – in this case, savings in waste management fees would be almost 60 % in two months.

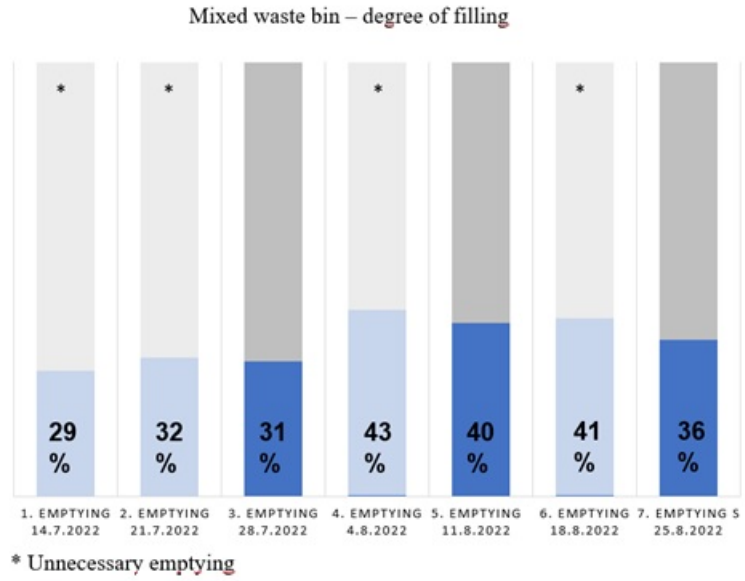

Fig. 2. Data from measuring the degree of filling of the housing company's mixed waste deep collection container.

Our study identifies the spectrum of company strategies enabling the shift towards carbon-neutral waste logistics (Table 2). Changing to green energy is influenced by current fuel prices and the availability of alternative fuels like biogas. Carbon emissions can be reduced by replacing fossil vehicles with lower emission vehicles, and multicompartment vehicles allow for collecting different sorts of wastes simultaneously. Transport optimization can be achieved by digitalization and sensor technology and by using waste bins that can be emptied more scarcely (like an aerated biowaste bin). Online store streamlines customers' choice of waste management services and makes innovative waste management's economic and environmental benefits, e.g., using sensors to measure waste surface levels, visible. Carbon neutral strategies and reporting of the carbon emission reduction achievements present a significant opportunity for companies to become forerunners and gain reputational and economic benefits. In the bigger picture, cooperation between different companies is needed to develop climate-neutral solutions.

Table 2. Different carbon neutrality strategies and their impacts on waste companies and customers

Strategies	*Waste companies*	*Customers*
Green energy	**Green energy for transport:** Using advanced biofuels, electricity, hydrogen and renewable synthetic fuels in waste transport vehicles cut downs carbon emissions.	**Green energy co-transition:** Utilizing biogas filling stations that have been opened in the areas of the municipal waste management companies
Low carbon emissions	**Zero-emission and multi-compartment vehicles:** Procuring low-emission vehicles over original fossil fuel vehicles. Using multi-compartment vehicles in waste collection when the transportation of different wastes (with one vehicle) is profitable for environmental reasons.	**Positive environmental impacts:** Cutting down the waste transport emissions and noise, in the case of electric vehicles.
Optimization of transport	**Efficiency of the transport system:** Saving working hours and fuels by designing the transport routes according to the degree of filling level of waste containers. Piloting new need-based innovations to measure waste container surface and innovating and testing new containers that can be emptied less often.	**Lower waste management costs**: Cutting down the waste management costs since the waste container is emptied only when it is full.
Green marketing	**Electronic marketplace:** Developing an e-marketplace that makes it easier to market intelligent low-emission transport solutions to the customers and compare them to the original ones.	**Value creation:** The e-marketplace is bringing the carbon footprint of separate waste collection and transportation visible to the customers when they are making purchase decisions. This can encourage separate collection of different wastes compared to sole mixed waste collection.
Sustainability strategies and data	**Carbon emission reduction targets and strategies:** Including carbon neutrality into company strategies and making the companies' carbon footprint issues more transparent to the employees and stakeholders. Providing information of companies' carbon footprint in the sustainable reports or including them into the environment management systems**.**	**Digital applications:** Mobile application is allowing customers to follow their waste accumulation in real time and calling for the emptying of the waste container when needed. Waste data and carbon footprint calculations of the waste management can be provided easily for the customer in weekly or monthly periods.

5. Conclusions

This paper summarizes the recommendations on how the waste transport sector can promote a carbon-free future through concrete actions and strategies while ensuring that the impact of the transitioning process for the customers is also taken into account. Results indicate that waste transport companies can take up to five strategies to promote carbon neutrality and implement them separately or together.

The study also reveals that the benefits of developing carbon neutrality are not limited only to positive environmental impacts. Still, the social and economic dimensions of carbon neutrality strategies are often under-represented even though decreased traffic load, savings in fuel and waste management fees, creation of innovations and jobs, and an emission-free environment can be apparent results of climate neutrality.

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TECHNICAL AND ECONOMIC FEASIBILITY ANALYSIS OF THE PILOT PROJECT IN MARSILI, SICILY*

Sergio Arfò[1], Federica Marino[1], Agata Matarazzo[1] , Francesco Italiano[2] Cinzia Caruso[2], Alessia Arfò[3]**

[1]Department Economics and Business, University of Catania, Corso Italia 55, 95129, Catania, Italy
[2]NTLINK S.R.L. Via A. Volta 33 – 95028 Valverde(CT) Italy
[3]Department of Law, University LUISS Guido Carli, Viale Pola 12, 00198, Roma, Italy

Abstract

The implementation of the NRNP in our country has become a prerogative for companies wishing to plan their production processes with a view to the circular economy, in order to achieve the decarbonization inside economy. The case study proposed here investigates the current events of the Environmental Energy Plan envisaged in the Sicily region, and then focuses on an experimental project born in Sicily, focusing, in particular, on the potential of geothermal energy that can be exploited by the volcano Marsili. It is a volcanic layer composed of 80 minor eruptive centers, located in the subsoil of the Mediterranean, near the Sicilian coasts. The contribution of this paper is the analysis of the technical-economic feasibility of the project and the technological innovations involved, evaluating the costs and hypothetical future revenues, inherent in the installation, maintenance and properties related to the production of geothermal renewable energy.

Keywords: economic and financial indicators, environmental sustainability, geothermal energy, renewable energy sources

1. Introduction

In Sicily, the growth of renewables has been inexorable in recent years both in terms of installed power and energy production (Scuderi et al., 2022). Apart from a slight decrease in hydroelectricity (-0.8%), all technologies have increased their electricity production (Cappello et al., 2018). The PEARS is the Regional Environmental Energy Plan, an intersectoral plan

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** Corresponding author: e-mail: arfosergio@gmail.com

that contains the measures relating to the supply and demand system of Sicily's energy planning, which are justified for much more complex reasons than just energy reasons, framing them in the context of a sustainable economic planning In view of the new European Directives regarding renewable sources, energy efficiency and performance of buildings and their national implementation, this Environmental Report is the first update of the previous PEARS, launched in 2009 with strategies and objectives for 2012 The PEARS identifies five macro-objectives, distinguishing them between two vertical macro-objectives and three transversal macro-objectives. The two vertical macro-objectives are: to promote the reduction of energy consumption in end uses and the use of RES by minimizing the use of fossil sources. The three cross-cutting macro-objectives, on the other hand, are: to reduce climate-altering gas emissions, to favor the strengthening of energy infrastructures in a sustainable key, to promote clean technologies and the green economy to favor the increase of the competitiveness of the regional and new production system job opportunities (Armani and Paltrinieri, 2013; Clini, 2022).

In the localization choices we intend to proceed in compliance with certain criteria and guidelines, such as:

- Promotion of the use of chemical, electrochemical and hydraulic storage systems to stabilize the electricity grid;
- Use of attractive areas (Sites of National Interest, abandoned dumps and quarries, appropriately defined and mapped) and "degraded" agricultural land, that is, unsuitable for use in the agricultural sector;
- Amendment to the regulations for the issuance of the authorization title, subject to the maintenance of a minimum level of performance, certified by the GSE;
- Development of both high and medium voltage electricity networks;
- Encouragement of smart grid-type technological solutions;
- Promotion of interventions for the exploitation of wave and tidal energy, in particular for the tidal currents of the Strait of Messina;
- Promotion of interventions for the exploitation of the solar source, through thermodynamic solar plants, near and / or on industrial areas, for the direct exploitation of the heat produced;
- Promotion of interventions for the exploitation of biomass (through anaerobic conversion processes), in particular through the organic fraction of municipal solid waste (FORSU) with prudent and efficient management policies of the forest heritage, paying the utmost attention in the authorization phase to emissions of particulate matter;
- Activation of privileged routes for the Sicilian “minor” islands, starting from Salina, Pantelleria and Favignana. As for the prospects for new plants from geothermal sources in Sicily, they are developing more slowly than imagined compared to the profound potential offered by the area.

The main objective of this paper is to verify the feasibility of an off-shore geothermal energy exploitation project, less exploited and known than its on-shore variant. To achieve this goal, in the third chapter the analysis of a case study was carried out, the Marsili Project, thanks to the collaboration with Doctor Rosario Tomarchio, on behalf of the company Ntlink S.R.L.S, who provided the opportunity to work with INGV, the National Institute of Geophysics and Vulcanology.

These experiences have made it possible to learn about the reality of the Marsili volcano, the largest active submarine mountain in Europe and the Mediterranean, from which

it is possible to obtain off-shore geothermal energy by building a special platform for its exploitation.

3. Materials and methods

So far, the classic geothermal medium-high enthalpy has found, on a global scale, a greater development where there are important thermal anomalies in the subsoil, but it must be taken into account that there is a geothermal potential of low enthalpy in any place on Earth (Torsello, 2021).

Medium-high enthalpy geothermal power would have great potential in Sicily, considering the geological context made peculiar by the presence of numerous volcanic areas (Etna, Aeolian Islands, Pantelleria). But the slowness in the development of the new plants is attributable to the presence of limitations from an environmental-landscape point of view mainly related to the installation of the production plants, and to the long times for issuing the concessions to carry out the research activities preparatory to the start of the sustainable exploitation of the resource. Low enthalpy geothermal energy offers important opportunities due to the fact that, since in Sicily the subsoil temperature up to 150 meters deep is included in the range of 15-18º, an optimal condition is configured to have the maximum efficiency in the heat exchange when the outside temperature is around 5-10º in winter or higher than 25-30º in summer (Santacolomba, 2015).

Geothermal energy in the Sicilian Region includes hot springs, fumaroles, mud volcanoes and many other phenomena that testify to the endogenous heat of the Earth. In Sicily there are manifestations of active and surface hydrothermal volcanism (Aeolian Islands, Pantelleria, Castellammare del Golfo, Calatafimi, Acireale, Sciacca, Etna, Montevago, Terme Vigliatore, Termini Imerese, Alì Terme, Trabia, Cefalà Diana), which occur , at least on the surface, with low enthalpy characteristics and therefore not very suitable for producing electricity (Clementi, 2021).

The thermal complexes in Sicily that use waters with an average temperature at the point of extraction (springs or wells) above 28°C are: Acqua Pia Montevago, Alì Terme, Calatafimi Segesta, Terme Segestane di Castellammare del Golfo, San Calogero di Lipari, Sciacca, Termini Imerese, Vulcano. There are also other unused thermal events, testifying to a strong presence of geothermal sources on the regional territory.

Possible initiatives on the use of low enthalpy geothermal energy can be aimed at applications of systems with heat pumps, which exploit endogenous heat or low temperature heat from groundwater, lake water and land. In fact, a technology is spreading that makes it possible to exploit the natural endogenous heat of the subsoil with heat pumps connected to vertically buried geothermal probes (heat exchangers), in which a heat-conducting fluid circulates that uses the heat contained in the low-temperature bodies. (soil, shallow aquifers and surface water masses) to air-condition the environments (Massari et al., 2021).

But since the temperature in Sicily is less cold than in the countries of central and northern Europe, there are few examples of geothermal probes, which, on the contrary, are more common in European countries with a cold climate.

The most advanced technologies for the use of geothermal resources foresee the exploitation of springs at different temperature levels, with or without natural aquifers:

- Low enthalpy (15°C <T <90°C): in this temperature range, different types of exploitation are possible, both for air conditioning and for heating homes and greenhouses. High-performance air conditioning is obtained with geothermal heat pumps (or probes).
- Medium enthalpy (90° <T <180°C): the sources are ideal for producing electricity with small / medium plants (100 kW-10MW) of the binary type. The geothermal fluid is circulated, in a closed circuit, in a heat exchanger to vaporize a low boiling point

fluid (50ºC-80ºC), and put it in a circuit for heating buildings and greenhouses, making "cogeneration" possible of electrical and thermal energy, before being fed back into the subsoil to return to the groundwater.

- High enthalpy (180° <T <390°C): electricity is generated with medium / large plants (10 MW-100MW) which are based on the separation of the steam, which is introduced into the turbine from the residual water, which can be introduced into a binary cycle to produce further electrical and thermal energy, and then re-introduced into the water table.

The steam leaving the turbines can also be recondensed and the liquid thus obtained put into a further binary cycle for electrical and thermal co-generation, before being re-injected into the groundwater. Geothermal energy, with its plants, allows to reduce the production of carbon dioxide, fine dust and other toxic substances that cause the greenhouse effect and contribute to climate change.

4. Case study

In the Tyrrhenian Sea, the submarine volcano - seamount - of Marsili is the largest and highest active volcano in the Mediterranean and in Europe, located in the central part of the homonymous ocean basin.

It is a stratovolcano with an elongated structure in the NNE-SSW direction, and is made up of several aligned fractures and over 80 minor eruptive centers, called adventitious cones. It covers an area of 2100 km^2, and measures 70 km in length and 30 km in width. The Marsili base is located in the Tyrrhenian bathyal plain at a depth of about 3400 meters, within a back-arc basin about 75-85 km north-west of the Aeolian arc volcanoes, and its apex is at 508 meters deep. The state of the volcano is active: its first eruption is between 0.7 and a million years ago. Therefore, it is clear that the evolutionary history of Marsili is very long, but little is known about it, given its inaccessibility. During its activity, and taking into account the available data, the liveliest eruptive period can be placed precisely between 0.78 and 0.1 Ma, a period during which the Marsili gave rise to mainly effusive and, to a lesser extent, explosive low-energy eruptions.

5. Results and discussion

The all-Italian idea of exploiting the energy of the Marsili volcano was born some time ago, but only a few years ago the possibility of actually landing the geothermal in the sea has begun to materialize (Paltrinieri et al., 2022). The draft project was presented in 2010 at the geothermal conference in Bali, Indonesia.

The extensive oceanographic campaign that began in 2006 represents the first step of the Marsili Project, the first global offshore geothermal exploitation project. It involves the private company Eurobuilding and various Italian public institutions such as ISMAR-CNR (Institute of Marine Sciences - National Research Council), INGV (National Institute of Geophysics and Volcanology), University of Chieti. Eurobuilding, after an initial monitoring phase, received an exclusive research permit from the Ministry of Economic Development. This project, which aimed to build the first off-shore geothermal plant in the world, plans to install the power plant in the Marsili area. The drilling of the well could be carried out in the next few years and the data collected in the previous phase have defined its characteristics.

The drilling site could be positioned along the crest of the volcano in correspondence with the maximum values of the anomalies and, to intercept the center of the reservoir, the depth of the well was prudently set between 1.5 and 2 km. The drilling of the well will give

the opportunity to test the data and models developed in the exploration phase: the temperature gradient, expected around 150ºC/ km, the fluid temperature up to 500ºC, the enthalpy and composition of hydrothermal fluids , a major problem of geothermal environmental impact. The water samples collected around the seamounts did not show the presence of heavy metals and dispersed pollutants; this should be related to the deep asthenospheric origin of the magma body due to the low thickness of the lithosphere and the consequent low crustal contamination. Another major problem regarding the drilling site is related to the stability of the rock and the risk of submarine landslide of the volcanic structure which will be carefully evaluated. The last phase concerns the actual production of electricity from the offshore geothermal source. The planned infrastructure represents a prototype of a 200 MWe power plant. The offshore well will be connected to steam turbines which together with the condensation system, current generators and voltage elevators will be housed on a suitably constructed platform. Considering the volcanic nature of the rocks and the high depth of the basin, semi-submersible platforms could represent an interesting solution.

The electrical connection will be made with a high-capacity submarine cable that will connect the platform to the electricity grid located on the Italian coast about 150 km away. If the pilot plant is successful, the project involves the construction of three other platforms of the same power size. Taking as a reference the average equivalent hour at full load of on-shore geothermal plants, equal to 7324 h, the total energy produced by the 200 MWe prototype platform would be up to 1.46 TWh / year. All things being equal, the total production of 800 MWe on four platforms would reach 5.87 TWh/year, almost double the share of Italian geothermal energy.

The total estimated cost is estimated at around 730 M€ and 2 Bn€, respectively for one platform and four platforms (Fig. 1). Therefore, at the moment, the costs of the plants are quite high, despite being justified by an overall saving, due to the fact that it is renewable energy. The costs of the plants vary according to various factors, such as the subsoil or the thermal needs, but as regards the Marsili, according to the forecasts made, the project could have reached 1 Gigawatt of power, for a total investment of 1.9 billion euro, over a five-year time horizon (Scilletta et al., 2020).

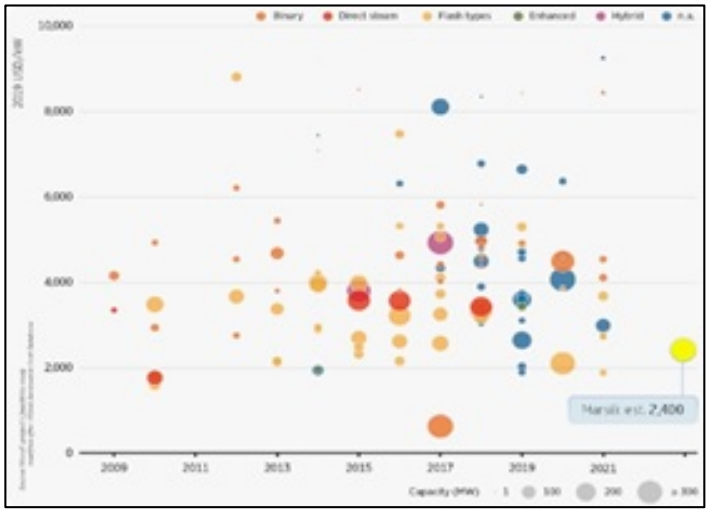

Fig. 1. Total installation costs by project, technology, and geothermal energy capacity

Analyzing specifically the components estimated with the support of table 1, it can be noted that the costs of surface exploration and exploratory drilling alone already amount to

27,000 euros. Gross efficient production in Italy, at the end of 2020, was 120.42 GW, of which 56.59 from renewable sources, to the extent of 47%, and 64.78 GW from non-renewable sources, to the extent of 53%.

The exploitation of the Marsili geothermal field was estimated at 6.4 TWh / year-1, taking as a reference the average capacity factor of the on-shore geothermal plants of the high enthalpy fields, estimated between 85% and 90%, depending on the site and plant conditions (Caruso et al., 2021).

6. Concluding remarks

Offshore geothermal energy could provide sufficient base load electricity to replace fossil fuels and nuclear energy as primary sources of electricity and transport energy, as in offshore geothermal resources, with up-to-date technological measures, not there are emissions into the atmosphere. However, the low environmental footprint of the Marsili project, which can be seen from the technical-economic feasibility analysis carried out, must also be considered with respect to other renewable energies.

It should be borne in mind that, to produce the same amount of energy hypothesized in the first phase of the Marsili project (6.4 TWh / year-1), it would be necessary to use an area of 100 km^2 for a photovoltaic system, while about 1900 wind turbines would be needed from 1.5 MW to produce the same amount of energy with wind. From what has been discussed so far, it is clear that geothermal energy has high development prospects, but at the same time, conventional exploitation for energy production requires fundamental needs of thermal anomaly and water availability that cannot be met everywhere.

Acknowledgements

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CONTROLLED PHOSPHATE PRECIPITATION – SIGNIFICANT OPTIMIZATION. POTENTIAL IN ENHANCED BIOLOGICAL PHOSPHORUS REMOVAL SLUDGE TREATMENT APPLYING THE AIRPREX®-PROCEDURE

Rudolf Bogner[1], Davide Perduca[2]**

[1]CNP CYCLES GmbH, Karlstein am Main, Germany
[2]Perduca Ambiente S.r.l., Piazza Cavour 19, 27045 Casteggio, Italy

Abstract

In the past few years more and more sewage treatment plants have implemented enhanced biological phosphorus removal to treat their wastewaters as this procedure can be realised easily from the technical point of view and offers several advantages compared with chemical phosphate precipitation. The switch from chemical phosphate precipitation to enhanced biological phosphorus removal however frequently leads to undesired consequences:

- Undesired deposits due to the formation of magnesium ammonium phosphate (struvite)
- Poorer sludge dewatering and, simultaneously, rising polymer consumption
- High phosphorus recycle load due to the separated sludge water in biology

Very often, deposits lead to plant equipment and parts failures that push up costs substantially. On top, additional costs incur due to the increase in sludge volumes which must be disposed of. The article will explain in more detail the backgrounds and mechanisms of the struvite crystallisation processes and why they occur as well as provide solutions of how to prevent such problems. When describing the individual processes, our key focus will be on how they can best be applied in practice; we will however also try to provide the necessary chemical background information.

Keywords: phosphate fertiliser, phosphorus recovery, wastewater treatment

** Corresponding author: e-mail: rudolf.bogner@cnp-cycles.de; davide@perduca-ambiente.com

1. Introduction - Effects of phosphates on sludge treatment

Phosphorus is a nutrient needed by all microorganisms; it forms part of their biomass. Although microorganisms consume phosphorus to a limited extent only within the scope of biological wastewater treatment, it is possible to increase the uptake of phosphorus if the treatment procedure is adapted accordingly. The literature mentions a value ranging from 1% to 2% of P/DSC. In the case of increased phosphorus assimilation ("luxury uptake") some bacteria fix energy in the form of long-chain polyphosphates in the aerobic environment. In the anaerobic zone there is no dissolved and/or bound oxygen available, and microorganisms draw on their energy reserve (polyphosphate) so to be able to easily mineralise degradable substrate. In other words: in this stage the phosphate content first increases because of the release process (Bunce et al., 2018). Enhanced biological phosphorus removal, which becomes more and more common, therefore does not lead to a final fixation of the phosphorus but to an exchangeable biologically structured compound. Due to release processes in the anaerobic environment (digestion), the stored polyphosphates are released in part and are present in the sludge water system as orthophosphates.

Values ranging from 50 - 250 mg/L PO_4-P in the sludge water of the anaerobic sludge treatment process are not unusual, and they show that there is a high struvite crystallisation potential. Crystallisations happen in particular if and when pressure differences caused by pumping processes occur, and especially so if the sewage sludge is dewatered by way of centrifugation. Furthermore, crystallisations may already occur in the digester drainpipe (reduction of the hydrostatic pressure) and further on in the pipe system. After all, even small pH leaps, caused by the labile buffer system, can trigger the crystallisation process. The precipitation limit for struvite in a synthesized bicarbonate (hydrogen carbonate) buffer system was determined (Fig. 1) depending on the pH value and the PO_4 concentration applied. As the critical precipitation limit for struvite shows, precipitations already occur from pH values of <7 onward if the phosphorus concentrations are accordingly high. High precipitation rates can therefore be observed in the anaerobic reactor too (Lorick et al., 2020).

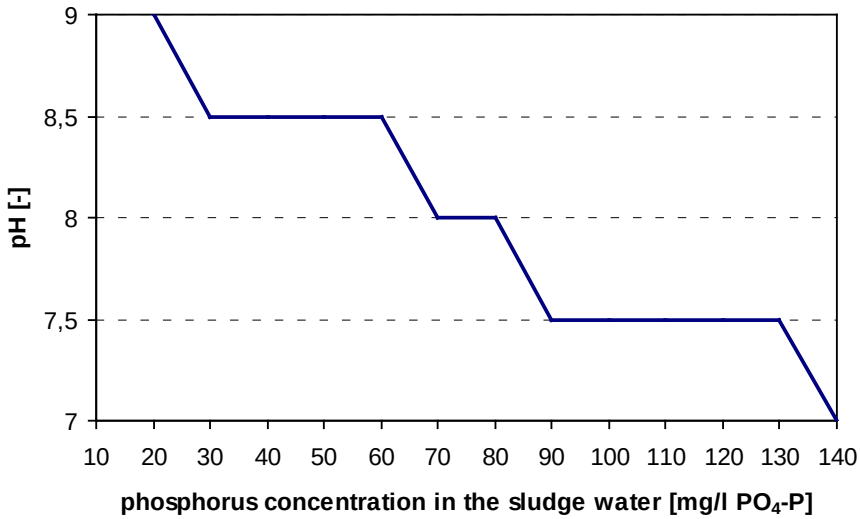

Fig. 1. Critical concentration range for Struvite deposits

In addition to the problems caused by struvite deposits as described above, phosphate stabilises the highly water absorbing colloid system present in the sludge, which causes the

sludge dewatering rate to deteriorate significantly. This has an impact on both the dry solid content discharge and the polymer requirement. The food chemistry industry, in particular the fish and meat processing sector, is already familiar with the correlation between phosphate and water absorbing capacity (Jayathilaka et al., 2012). In order to prevent proteins from dewatering, phosphates are added to food containing proteins to stabilise the structure. Based on the evaluation of data this correlation could already be observed in communal sewage treatment plants (Fig. 2, Fig. 5).

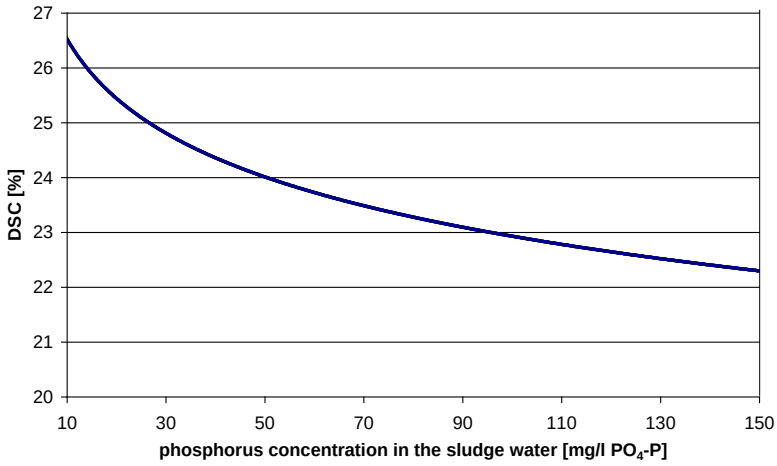

Fig. 2. Correlation between phosphorus concentration in the sludge water and dry solid content after the dewatering process

2. Targeted phosphate precipitation

Economic factors and technical safety aspects usually determine how the problem is solved. Following aspects have to be taken into account:

- Cleaning of the plant equipment and parts
- Prevention by using consumables such as crystallisation inhibitors
- Lowering of the pH values
- Process-engineering measures (reduction of ion concentrations or targeted precipitation)

The technical expenditure required to implement the above may be huge and very costly. The decision of which action to take usually depends on the severity of the failures that occur. We have already mentioned that after the implementation of the biological phosphorus procedure, high phosphate inputs of up to 250 mg/L PO_4-P can be observed due to the remobilisation of these ions in the anaerobic reactor. So if we principally want to continue applying the biological phosphorus procedure, phosphate ions can only be reduced if the procedures, that take place prior to the anaerobic reactor, are completely changed.

The targeted phosphate precipitation procedure achieved by way of increasing the pH value and adding a magnesium-based product after the digestion process has been developed and patented by the Berliner Wasserbetriebe *[Berlin Water Supply and Wastewater Disposal Company]* for sewage plants deploying enhanced biological phosphorus removal. Under the name of AirPrex® this process is marketed by CNP CYCLES, a company active in the field of energy and nutrient recovery.

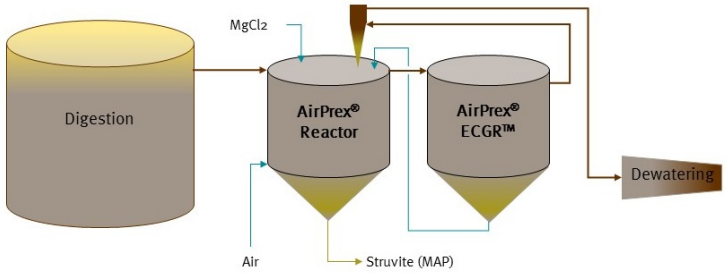

Fig. 3. Schematic flow sheet of the AirPrex® Macro process

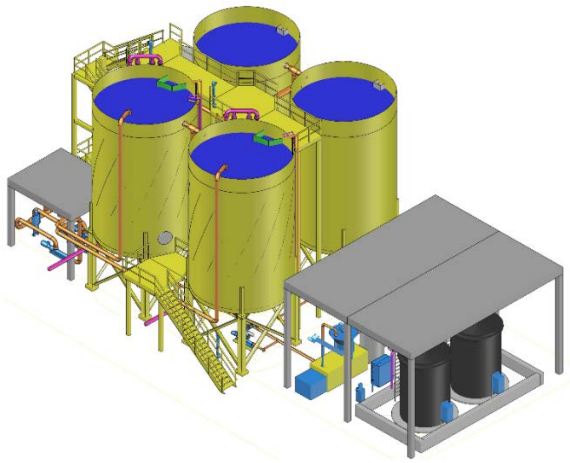

Fig. 4. Picture of an AirPrex® Macro installation

The targeted precipitation reduces the PO_4-P content to values < 15 mg/L which, in turn, considerably reduces the phosphorus recycle load. The reduction of the phosphate ions and the increase in the proportion of bivalent metal ions simultaneously reduce the sludge's water absorbing capacities, lead to a stable, less hydrous floc and usually result in 3% to 6% higher dewatering rates (e.g. previously: 22% DSC, after precipitation: 27% DSC). The AirPrex procedure therefore is a sensible supplement to enhanced biological phosphorus removal. The targeted integration of a "phosphate lowering mechanism" in the sludge treatment process compensates for potential disadvantages of the biological phosphorus process and provides the following advantages:

- Significant improvement of the sludge dewatering rate;
- Reduction of the phosphorus recycle load by 80% to 90%;
- Struvite prevents crystallisation problems in the sludge and centrate area.

This measure therefore achieves a lot more than simply rectifying crystallisation problems. It presents significant optimisation potential and investment and operating equipment costs are normally far below the saving potential. The large-scale tests carried out so far proved the enormous cost effectiveness of the procedure. Figure 5 shows the development of the DSC values in relation to the orthophosphate content determined within the framework of the tests carried out at the Moenchengladbach-Neuwerk sewage treatment plant. The dashed black line shows the DSC value of the struvite -precipitated sludge. Surprisingly, the development of the

DSC content in the sludge dewatered at the same time but not treated is positive too (dashed grey line). The decreasing phosphate content in the digested sludge principally has a positive impact on the dewatering behaviour. The dashed black line shows the full impact of the AirPrex® procedure with regard to a markedly increased DSC discharge value.

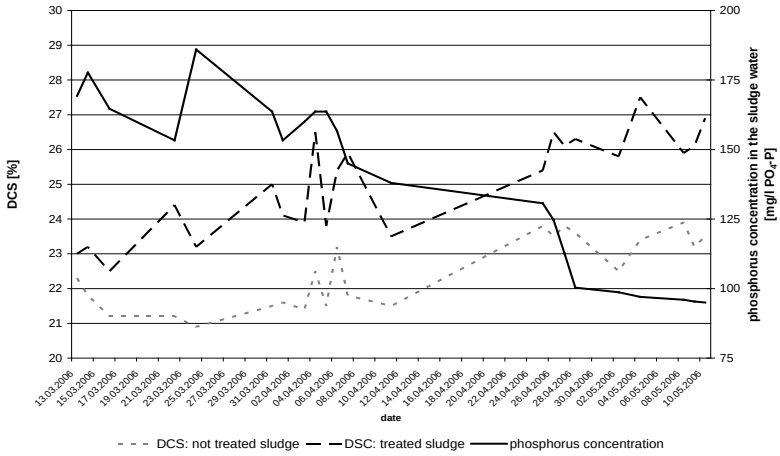

Fig. 5. Correlation between DSC discharge and phosphate content

Figure 6 illustrates the cost effectiveness of the AirPrex procedure compared with the enhanced biological phosphorus removal process as well as phosphorus removal by way of ferric precipitation. The dry solid content, determined after the dewatering process, could be improved on average by 4% to 5%. In this case the combination of the enhanced biological phosphorus removal procedure and the AirPrex procedure resulted in huge cost savings.

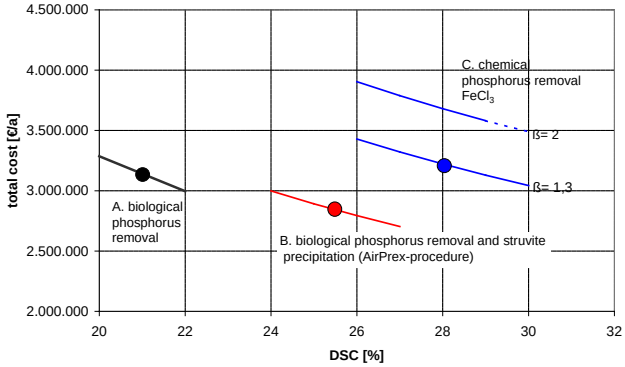

Fig. 6. Comparison of the annual costs incurred for chemical and enhanced biological phosphorus removal as well as integration of the AirPrex procedure (full cost calculation)

3. Usage of phosphate

One of the many advantages of the AirPrex procedure as described above is that it is highly economical. On top the struvite generated in the process is a side product which has the potential to be recycled. The combination of the elements Mg, P and N creates a highly suitable plant fertilizer and is available for use on plants as has been proven. Large-scale tests have been performed to examine in how far struvite can be extracted, i. e. how well it can be cleaned

of sludge and other components such as fibrous and organic materials. After it has been washed out, struvite can be used as a valuable component in fertilizer formulas. Numerous analyses confirmed its suitability as defined by the DüMV *[use of fertilizers ordinance]*. The measurements carried out so far showed that heavy metal values were far below the limiting values. As the price for P_2O_5 has increased four-fold in the course of last year, the equivalent price for struvite currently ranges from about €150 to €200/t. Cleaned roughly struvite won from sewage sludge can be sold at about €50/t.

4. Conclusions

The increasingly deployed enhanced biological phosphorus removal procedure is more cost effective and simpler from the process-engineering point of view compared with the chemical phosphorus removal procedure. However, the resulting higher phosphorus concentrations, which arise in the anaerobic environment of the digestion process within the framework of the sludge treatment due to the phosphorus release, may have a negative impact on the further treatment process:

- Struvite crystallisations in pipes, conduits, pumps, dewatering aggregates;
- Lower dewatering rates;
- Phosphorus recycle load.

In order to improve dewatering rates and to prevent struvite crystallisations, the targeted precipitation of phosphate ions is an effective means to optimise sludge treatment. Furthermore, the phosphorus recycle load in the sludge water is considerably minimised. The targeted precipitation of struvite takes place after the AirPrex procedure, between digestion and dewatering process, where the pH value is raised by way of air stripping so that the crystallisation potential is increased.

As magnesium is not available in sufficient quantities, magnesium chloride is added to reduce the phosphate content to values < 15 mg/L PO_4-P, which reduces the water absorbing capacities of the sludge and considerably improves the dewatering rate. The precipitated struvite is removed from the system and can then be used as a supplier of nutrients in the fertilizer manufacturing industry.

The analyses carried out so far confirm that struvite is suitable within the meaning of the DümV. Due to rising phosphate prices, struvite is gaining in importance and used increasingly by the fertilizer industry.

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PREPARATION OF UNDERFLOOR HEATING PANELS WITH POLYLAMINATE SHEETS AND CAPS FROM RECYCLED PACKAGING*

Gregorio Buonocore[1], Pierantonio De Luca[2]**

[1]Department of Civil Engineering, University of Calabria. Italy
[2]Department of Mechanical, Energy and Management Engineering, University of Calabria. Italy

Abstract

This work shows the design and construction of a prototype of an insulating panel for underfloor heating. For this purpose, only recycled materials were used, such as polylaminate sheets and caps from discarded Tetra Pak containers. For the assembly of the polylaminate sheets, the thermal method was used which does not involve the use of glues or adhesives. The prototype created represents an example of low-cost manufacturing that promotes responsible sustainability by aiming at the reuse and enhancement of discarded materials.

Keywords: eco-sustainability, green building, insulating panel, recycling, Tetra Pak

1. Introduction

As is known, underfloor heating is a particular system consisting of pipes within which hot water or electric resistances circulate. These types of systems are able to allow a uniform distribution of heat from the bottom to the top. The floor system can be considered eco-sustainable, both due to the lower energy requirement compared to traditional radiator systems, and because it can be powered by innovative sources, given the low temperatures required (Bauman et al., 2001). In these systems the piping must be placed over an insulating panel in the shape of a serpentine. Usually, the latter has a predefined design and some joints that facilitate the laying of pipes. Environmental sustainability and the recycling of materials are now very important issues in today's society. The impelling pollution and the high production

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** Corresponding author: e-mail: pierantonio.deluca@unical.it

of waste is pushing research towards the study of new eco-sustainable materials with low environmental impact thanks to the use of natural or recycled raw materials (De Luca et al., 2017; De Luca et al., 2018). The packing of food products is largely responsible for a large production of waste and therefore researches aimed at their recycling or strategies for their reduction are increasingly encouraged (Magnone et al. 2014). Recent studies have reported the possibility of creating panels with insulating characteristics, using polylaminate sheets obtained from discarded Tetra Pak containers (Buonocore et al. 2022). Tetra Pak is a widely used material for packaging food products such as milk, wine, beverages and more (Marsh et al., 2017). Worldwide, its production is very high in spite of still underdeveloped recycling processes (Martinho et al., 2015; Zawadiak et al. 2017).

This study aims to design and manufacture prototypes of insulating panels for underfloor heating systems, through the use of exclusively recycled material. The proposed project involves the creation of prototypes using polylaminate sheets and caps obtained from decommissioned Tetra Pak containers. The assembly of the polylaminate sheets was carried out through the application of the thermal method which does not involve the use of glues. The classic pins present in commercial panels for underfloor heating, which are used for the allocation of the serpentine circulation pipes, were made using the caps of the same decommissioned containers.

2. Materials and methods

The research activity involved three consecutive phases: procurement of materials; prototype design; prototype realization.

2.1. Procurement of materials

The materials used for the preparation of the insulating panel prototype for underfloor heating were polylaminate sheets and caps, recovered from decommissioned Tetra Pak containers (Fig. 1a, b). The containers chosen are those that are generally used for storing milk. In particular, the Tetra Pak, which makes up the selected containers, is made up of six layers, one of which is of aluminum, one of cardboard and four of polyethylene. Once the containers were recovered, after careful washing, they were opened with cutters and sheets of polylaminate with dimensions of about 27x20 cm were obtained (Fig.1c).

2.2 Prototype design

After the phase of procurement of materials, the design phase followed, in which the dimensional characteristics of the panel were identified, such as thickness, surface and positioning of the caps. The position of the caps was considered taking the panels used on the market as a reference. The caps of the disused containers were used to obtain the classic pins that are present on the common insulating panels intended for underfloor heating.

2.3 Prototype realization

Once the polylaminate sheets were obtained, they were assembled using the thermal method, already presented in a previous work (Buonocore et al.; 2022). In particular, a selected number of polylaminate sheets were superimposed on each other in such a way that the aluminum face of the sheet always overlapped with the cardboard face (Fig. 2a). Subsequently these sheets were blocked by wrapping them with baking paper to prevent them from slipping (Fig. 2b). Finally, this block of sheets was subjected to a selected pressure, through the

application of a weight on it, and placed in a thermo-ventilated stove, with programmed temperature and times. Once the heat treatment time had elapsed, the block was left to cool and kept under pressure until it reached room temperature.

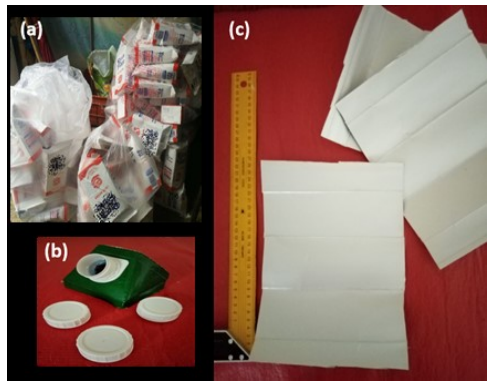

Fig. 1. (a) Decommissioned Tetra Pak containers; (b) caps and (c) polylaminate sheets recovered from discarded Tetra Pak containers

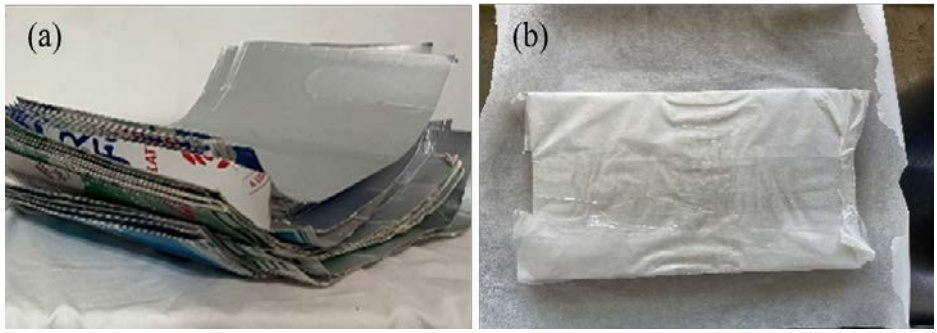

Fig. 2. (a) Overlap of the polylaminate sheets; (b) block of polylaminate sheets wrapped in baking paper

3. Results and discussion

The underfloor heating is usually installed on a surface that has pins arranged at a programmed distance and below it there is a vapor barrier and the screed. The function of the prototype of the insulating panel, on which the coil where the water flows is inserted, is that of not allowing the heat to be dispersed even in the sub-screeds. Thanks to the results obtained in a previous work (Buonocore et al.; 2022), the best experimental conditions to be used in the application of the thermal method have been identified, such as number of polylaminate sheets, temperature and pressure, to obtain a prototype panel well compacted and resistant.

Below are all the details of the design and preparation of the prototype intended for underfloor heating. The design involved the creation of a small-sized panel base module, manageable and easy to position on the screed. Therefore, the dimensions foreseen for the base module were about 27cm x20cm and with a thickness of around 3cm. For the realization it has been calculated that 36 sheets of polylaminate are required to be assembled together.

The design involved the preparation of two components for the construction of the underfloor heating panel

Specifically, the two components are:

- A pinned top layer that serves as housing for the heating coils, 0.5 cm thick. This component is formed by a panel of polylaminate sheets assembled with the thermal method and on the surface of which a system of pins is created. The latter is made through the caps of the polylaminate containers. The design involves 15 pins. Each pin is made with two caps. In particular, a pin was allocated for every 36cm^2 of surface (Fig.3a).
- A lower layer that acts as a base and performs the function of insulation allowing the heat to spread mainly from the bottom up. The function of this layer is also to release heat once the heating system is turned off, extending the effects of heating. The design of this layer foresees a thickness of 2 cm (Figure. 3b). This component is also made by assembling the polylmaninate sheets using the thermal method.
- Finally, the two components are assembled together by subjecting them to heat treatment again.

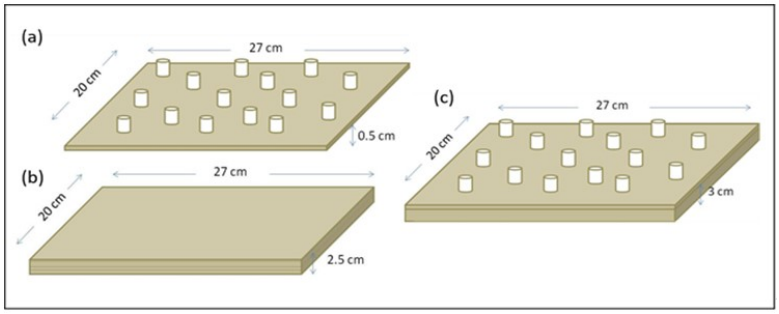

Fig. 3. (a) Upper layer with deposition of caps; (b) lower base; (c) design of the prototype of the insulating panel for underfloor heating

Table 1 summarizes the characteristics and experimental conditions used for the realization of the prototype.

Table 1. Characteristics and experimental conditions for the realization of the prototype

Surface	***Total thickness***	***Total number of polylaminate sheets***	***Number of caps***	***Number of pins***
540 cm^2	3 cm	36	30	15
Experimental conditions:				
Temperature: 200°C Cooking time: 15 min Pression:7.85*10^4 N/m^2				

Figure 4 show the basic unit of the prototype built. It is well compacted and adequately manageable for its installation. The last problem to be pursued is the assembly of the different units built during their installation. For this reason, joints have been provided between one unit and another, made simply by overlapping components (a) and (b) in a slightly staggered way (Fig. 3a, b).

Fig. 4. Images of the basic unit of the prototype of the insulating panel for underfloor heating made using a polylaminate panel and the caps of discarded containers

Their staggered overlap creates joints of dimensions that can be easily varied, depending on the operational needs. These joints make the union of the different base units very stable and easy to make. The following Fig. 5 shows the design of the prototype units with the joints.

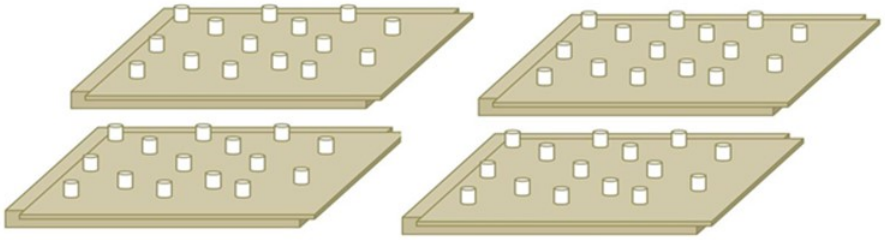

Fig. 5. Basic unit of prototype insulating panel for underfloor heating, with the creation of joints for a more effective and stable installation

6. Concluding remarks

This work has no particular claims other than to show how, through the use of very simple and economical processes, it is possible to create artifacts from recycled materials that have important characteristics that are comparable with those artifacts that are normally present on the market.

It should be noted that polylaminate containers are widely used worldwide and their recycling process is not yet highly developed and therefore most of them end up in landfills.

This work wanted to show how the decommissioned Tetra Pak represents an important resource through which it is possible to create artifacts of particular interest.

It should be emphasized that the preparation method used is sufficiently cheap and the most important aspect is that it does not require the use of glues or adhesives to make the panel. In fact, the adhesion between the different polylaminate sheets occurs thanks to the presence of polyethylene films that are already present on the surface. These soften at high temperatures and thanks to the simultaneous action of pressure during cooling causing a strong compaction of the layers.

The manufactured product is entirely obtained from recycled material and with a very simple process and therefore represents a synergistic encounter between sustainability and economy.

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INNOVATIVE FOOD SUPPLY CHAINS AND NEW BUSINESS MODELS FOR SLAUGHTERHOUSE WASTE: BS GREEN CASE-STUDY

Maria Francesca Caratzu[1], Paola Antonia Deligios[1], Luigi Ledda[2], Daniele Marceddu[1], Filippo Gambella[1], Fabio Correddu[1], Andrea Massidda[3], Giulia Filippini[4], Giuseppe Pulina[1]**

[1]Department of AGRARIA, University of Sassari, Viale Italia 39a, 07100 Sassari, Italy;
[2]Department of Agricultural, Food and Environmental Sciences, Polytechnic University of Marche, Via Brecce Bianche 10, 60131 Ancona, Italy
[3]BS Green srl, Piazza Deffenu 12, 09125, Cagliari, Italy
[4]Anaergia srl, Via Bassa di Casalmoro 3 I-46041, Asola, Italy

Abstract

The disposal of animal by-products (ABP) has been an operational cost for companies in meat supply chains. The use of biodigestion with the production of an organic pellet and nitrogen-rich liquid effluent, as well as the production of heat in the form of steam, can enable this process to be enhanced. BS Green has elaborated a strategy of total sustainability of meat production chains, extended to horticulture chains as well, with the aim of obtaining products with zero climate-changing gas impact, placing ABP disposal at the center of the system. Organic pellets are used to offset surplus emissions from beef and lamb farms, provided they are used with conservation and regenerative farming techniques that allow permanent storage of carbon in the soil. Nitrogen liquid effluent is used in horticulture for the purpose of reducing its nitrogen footprint. Heat is utilized in sericulture and animal feed to reduce the fossil emissions associated with these two processes. All of this is certified with a registered carbon-neutral *NeutryFood*® label. This paper illustrates the engineering of the BS Green system for sustainable agriculture and animal husbandry.

Keywords: animal by-products, environmental impact, net_zero, regenerative agriculture

1. Introduction

Considering the new EU policies (Green Deal, Farm to Fork, certification of impact of animal products and animal welfare etc.), agriculture and livestock farms will be required to

make a transition to a more sustainable production model. Therefore, it is crucial to conduct balances between emissions and removals to ultimately assess the possibility of certifying local productions. In recent years, a growing number of consumers are showing increasing interest in the environmental impact of the food they consume. For this reason, the environmental certification of productions and the creation of "carbon neutral" labels to be affixed to foods of vegetal and animal origin would allow companies to provide transparency and value to their product; moreover, it would allow them to spread awareness about environmental sustainability as well as incentivize their consumption (Rokotyanskaya, 2022).

The disposal of animal by-products (ABP) has been an operational cost for companies in meat supply chains. The use of biodigestion with the production of an organic pellet and nitrogen-rich liquid effluent, as well as the production of heat in the form of steam, can enable this process to be enhanced including these end products within an architecture of regenerative agriculture and animal husbandry. This activity, which until recently represented the outcome of ABP, now stands at the center of regenerative processes to achieve neutrality of environmental impacts by horticultural and livestock supply chains. The system, with BS Green at its center, brings together livestock and horticultural companies that want to reduce or zero their environmental impact, measured by balances between emissions and carbon and nitrogen sequestration, including the use of effluents (organic pellet, nitrogen liquid effluent, heat steam) from the ABP treatment plant.

This paper illustrates the engineering of the BS Green system for sustainable agriculture and animal husbandry as case of study.

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2. Reducing livestock footprint

BS Green approaches the reduction of the environmental impact of livestock sector by different strategies: to achieve neutrality of environmental impacts, by the use of organic pellet and nitrogen-rich liquid effluent originating from the biodigestion of ABP; to promote the valorization of agro-industrial coproducts (AIC) for the feed industry, thanks to the energy provided by the heat steam produced by the ABP biodigestion process, that can be used to stabilize these materials.

2.1. Assessment and reduction of CFP of livestock farm

The main objective of this part of the project is to achieve carbon neutrality of farms products. This objective will be realized by i) estimating environmental balance of ruminant farms involved in BS Green project, and ii) by using organic pellet arising from BS Green activity to offset surplus of emissions.

i) *Estimation of environmental balance of ruminant farms involved in BS Green project*. The methodology chosen to quantify greenhouse gas (GHG) emissions was the Carbon footprint (CFP), being a global warming potential indicator (Pandey et al., 2011). As defined

by Wiedmann and Minx (2008), carbon footprint is the total amount of carbon dioxide emissions released in atmosphere directly and indirectly by an activity or accumulated in the life cycle of a product. The estimation will focus on suckling lamb and beef meat productions; the latter one is mainly derived by cow-calf system widespread in all the region. Sheep milk production plays an important role in most of Mediterranean countries (Pulina et al., 2018), as well as in Sardinian economy. Suckling lamb is the secondary product of dairy sheep breeding in the Island (Battacone et al., 2021), and it is strongly related to Protected Geographical Indication (PGI) production. Although several studies assessed the environmental impact of milk sheep (Atzori et al., 2015; Batalla et al., 2015; Sabia et al., 2020), a lack of studies concerning CFP of lamb meat is highlighted (Battacone et al., 2021; McClelland et al., 2018).

The emission model of IPCC Tier 2 (2019) will be employed to quantify the total amount of CO_2 equivalents of a functional unit of a product, following an LCA approach by considering cradle to farm gate as system boundaries; moreover, the functional unit of 1 kg of suckling lamb meat for sheep farms, and 1 kg of live weight or meat carcass for beef farms will be considered. Different studies assessed EI of livestock products by using IPCC Tier 2 emission model and by expressing emission intensity as CO_2 equivalents per kg of energy corrected or fat and protein corrected milk (Atzori et al., 2015; Batalla et al., 2015; Sabia et al., 2020); while most of the other studies concerning sheep industry used as functional units 1 kg of wool and 1 kg of meat (Cardoso, 2013; O'Brien et al., 2016; Toro-Mujica et al., 2017). Besides GHG on-farm emissions, an estimation of carbon sequestration potential, both from soil and trees of total farms area will be conducted. For each crop and species constituting cropping system of livestock involved, the carbon sequestration rates available in literature will be considered. To achieve carbon neutrality certification of farms products, a complete balance, accounting for both emissions and removals, should be conducted. However, few studies until now have considered carbon sequestration in the estimation of environmental impact (EI) of farms (O'Brien et al., 2016; Toro-Mujica et al., 2017).

ii) *Using organic pellet arising from BS Green activity to offset surplus of emissions*. The results of the first step of evaluation will be useful to characterize the farms depending on the emission balance. Then, the farms will be classified in: farms where the emissions are higher than the removals (positive balance); farms where the removals are higher than the emissions (negative balance); farms where the emissions are equal to the removals (carbon neutral). A calculated amount of organic pellet of BS Green will be given to the positive balance farms to be used as organic fertilizer.

2.2 Agroindustrial co-products

Most AIC are currently used in animal feeding, such as distillers' grain, beet pulp, wheat bran or corn gluten (Lindberg et al., 2021), and including them in livestock feeding is a promising strategy to reduce feed cost - which is the largest in dairy farming - and to minimize competition with human food supply chain. The availability of the surplus of energy (in form of steam) produced by the BS Green activity could be used to reduce the cost of dehydration process, thus making these products available as feed ingredients.

The first step of this part of the project was already conducted and regarded the characterization of some AIC, to estimate the amount of nutrients potentially available to be included in animal feeding, with particular interest in beef cattle and dairy sheep as the main representative species of Sardinian livestock.

A systematic literature revision and analysis of official database were carried out to obtain data on amount of AIC (Table 1) and their chemical composition (Table 2), focusing on some agro-industrial processing industry in Sardinia: winery and olive oil, processing of tomato, artichoke and beer industries. To estimate the amount of each AIC produced annually,

data from ISTAT (2021) and percentage of co-products available in literature for each industry processing were employed.

Table 1. Estimated amount of some agro-industrial coproducts (AIC) in Sardinia in 2020

	Grape pomace	***Olive cake***	***Arthicoke by-products***	***Tomato pomace***	***Brewers' spent grains***
Primary product, t*	83,780	34,473	38,107	31,958	149,000
AIC[a], %	21	41	73	5	19
AIC, t FM	18,432	14,134	27,628	1,598	28,683

**ISTAT, 2021.*

[*]Caratzu et al., unpublished data, means elaborated from current available literature

Table 2. Chemical composition (mean ± standard deviation, SD) of some agro-industrial co-products (AIC)[1]

	Grape pomace	***Olive cake***	***Artichoke***	***Tomato pomace***	***Brewers' spent grains***
Moisture, %	71.2 ± 9.5	44.4 ± 11.0	83.8 ± 4.0	87.7 ± 13.2	79.0 ± 3.1
Dry matter, %	88.9 ± 7.7	84.9 ± 5.6	92.0 ± 0.4	69.0 ± 38.1	90.3 ± 0.6
Dry matter (100-moisture)	28.8 ± 9.5	55.6 ± 11.0	16.2 ± 4.0	12.3 ± 13.2	21.0 ± 3.1
Protein, % SS	11.8 ± 1.8	8.0 ± 1.1	13.3 ± 2.3	19.4 ± 1.2	22.4 ± 4.0
Fat, % SS	6.3 ± 2.5	10.2 ± 5.2	2.6 ± 2.0	9.1 ± 0.9	8.9 ± 1.5
NDF, %SS	43.3 ± 5.6	63.8 ± 2.1	50.2 ± 10.3	55.5 ± 0.0	46.5 ± 5.8
ADF, % SS	37.3 ± 5.9	51.9 ± 2.2	35.0 ± 7.0	43.2 ± 0.0	20.6 ± 4.5
Ash, % SS	7.6 ± 3.2	7.6 ± 5.4	8.9 ± 3.9	4.5 ± 0.2	3.5 ± 0.7

[1]*Caratzu et al*., unpublished data, means elaborated from current available literature

This revision allowed the estimation of the amount of protein available from these AIC (Table 3), which can be potentially used to fed sheep or cows.

Table 3. Estimation of crude protein (t of CP) available from agro industrial co-products in Sardinia

Source	***Crude protein (t)***
Brewers' spent grains	1,319
Grape pomace	658
Olive cake	613
Tomato pomace	37
Artichoke	595
Total	**3,223**

3. Precision agriculture and SOA distribution with spreaders fertilizer

The BS Green project involved the production of a Soil Organic Amendment (SOA) with characteristics such as being used as a fertilizer in crops in a perspective of circular

economy and regenerative agriculture. It has been hypothesized that the solid fraction to be mechanically and uniformly distributed in the field, in compliance with the recommended doses and the principles of precision agriculture, could be transformed into pellets by the BS Green. Moreover, increasing the use of organic amendments would help to reduce the application rate of N fertilizers which is recognized as the most effective measure of reducing N_2O emissions (Rees et al. 2013). For the distribution of SOA, the use of centrifugal spreaders was assumed. Centrifugal fertilizer spreaders dominate the market in most agriculturally developed countries; their main advantage is their low price, wide application width, and high output. Their main disadvantage is the sensitivity for spread characteristics to change with environmental conditions and the material being spread (Ball et al., 2004; Martín-Lammerding et al., 2021; Romano et al. 2014). A study was initiated on the types of spreaders used for the distribution of solid fertilizers in the companies involved in the same project. In total, 21 interviews were conducted with different companies to identify (i) companies adopting PA technologies, (ii) the most type of fertilizer spreader used, and in future work (iii) determine the uniformity of the distribution of different bulk organic fertilizers on the soil surface by evaluating the influence of the physical-mechanical properties of the fertilizers by spreader test. The results of this first survey are reported in Table 4.

Table 4. Precision Agriculture Technologies (PAT) utilized in the farms and the most type of fertilizer spreader utilized

Machine Guidance		***Interviews***	***PAT+ISOBUS***		***%***
		21	**yes**	**no**	
Driver assistance on Tractor	Light bar			21	100
	Autosteer			21	100
				21	100
Tractor + ISOBUS for Variable Rate application		21		21	100
Inorganic, solid granules	(N, P, K, lime, manure)				
	Spinner spreader	21		21	100
	Double disc	10		11	48
	Single disc	11		10	52
	Pneumatic spreaders (airflow)	.			
	Fertilizer drills	.			
Organic, Solid	Solid manure spreaders	11		21	52

The limited use of PAT, VRA, and ISOBUS tractor-fertilizer spreader connection requires the adoption of techniques for verifying the correct dose distribution of the pelleted SOA in the field with spreaders test and UNI standards to characterize the SOA produced by BS Green and to correctly return the dose in the field.

4. Sequestering carbon in soil and reduce nitrogen footprint

Within the context of the BS Green case-study the agronomic investigation aims to determine the i) feasibility to use organic pellets and nitrogen liquid effluent as organic fertilizer by focusing on the amount of each fertilizers type that can be provided; ii) quantitative and qualitative traits of the harvested products; and iii) ability to maintain a stable or increasing soil organic matter content. The pursuing of these challenging goals must take into account the

variability of different factors such as farm typologies, soil fertility variability, crop species, and nutrient management. In Sardinia horticultural systems, addressed to grow globe artichoke, potato, tomato, melon and watermelon (ISTAT, 2021), are often carried out as intensive systems, therefore, relying on frequent tillage and on the massive use of chemical fertilizers. Furthermore, the soils used for this kind of cropping systems are usually poor in soil organic matter and subject to progressive loss of fertility (Deligios et al., 2017; 2021). The availability of high-quality nitrogen liquid effluent would therefore allow its systematic use as a soil improver in many horticultural farms (Campos et al., 2019). Moreover, in most of livestock farms, fodder is partially or totally satisfied by on-farm cultivation. In particular, grasslands with a grass species (barley) or with a grass-legume mixture (e.g. oats, ryegrass, vetch and different species of clover) in rotation with autumn-winter cereals for the production of grain and straw, summer grassland (e.g. sorghum), summer cereals, such as corn, alfalfa meadows and natural pasture, commonly occur in the livestock farms. In livestock farms where rotations include a winter cereal for grain production, straw is partly used as bedding and partly sold outside the farm, while the stubble is grazed and subsequently soil incorporated. Conservation practices, such as zero or minimum tillage, are not very frequent. Some of the mixed crop-livestock farming and horticultural farms, representative of each macro-category, that expressed interest in joining the BS Green case - study have been identified and selected to be configured as Demonstrators.

Agronomic investigation will be carried out within these Demonstrators to achieve the abovementioned objectives, but above all Demonstrators are going to be functional to the development of a management model suitable to be extended to other farms potentially interested in a transition towards circular and conservation agriculture. Agronomic activity is divided into three different sub-actions: 1) chemical characterization of organic pellet and liquid effluent; 2) soil characterization; 3) open field experiments set-up. Experiments will be organized as a complete randomized design and replicated at least twice. Three fertilizers treatments will be compared: optimal dose (in fertigation or broadcasted incorporated if organic pellets), dose usually adopted by the hosting farm (Control treatment), and without fertilizers. Plant growth and development will be evaluated through physiological, biometric and phenological parameters. Height and diameter of the plant, number of leaves, concentration of chlorophyll will be monitored during the crop cycle of the species under study. Plant growth and development will be evaluated through destructive parameters: aboveground and belowground biomass (fresh and dry weights).

The expected benefits are related to the i) enhancement of soil organic carbon sequestration (quantitative and qualitative improvement of the soil organic matter); ii) soil fertility recovery and improvement of production efficiency (by lowering energy inputs); iii) reduction of greenhouse gas emissions from agricultural soils; iv) economic and environmental enhancement of waste from recycling of agricultural production. Furthermore, the issue of environmental resilience outlines an important opportunity for the whole agricultural sector by developing a new business model, a green business one, which would be able to guarantee a reward for the commitment put in place by farmers to contribute to the adaptation to climate change.

5. The BS Green plant

The BS Green plant is designed to treat 30,000 tons/year of ABP having the operational standard reported in Table 5. The material is loaded entirely into the two hoppers placed at a level below the ground in the shed provided for pretreatment. In case of excess incoming material, it will be stored in special enclosed cold rooms to prevent decomposition and odor

spillage. An auger system will convey the material to the special shredding system where the size and lump size of the organic matrix will be reduced. The shredding stage shreds ABP finely, increasing the surface area of the substrate, accelerating fermentation while protecting the plant from snags, damage, and costly repairs.

Table 5. Operational standard of BS Green plant

Substrate	***Input (Fresh matter FM)***	***TS***	***TS***	***VS***	***VS***	***Biogas***	***Biogas***	***BMP***
	[t/y]	***[%]***	***[t/y]***	***[%]***	***[t/y]***	***Nm^3/t FM***	***Nm^3/y***	***Nm^3/t VS***
Slaughter waste	10,152	20	2,030	90	1,827	126.0	1,279.52	700
Entrails content	19,848	13	2,580	85	2,193	55.3	1,096,602	500
Total	**30,000**	**15**	**4,611**	**87**	**4,021**	**79.2**	**2,375,754**	**591**

The shredding material is sent to a two-tank pasteurization system complete with heat recovery exchanger to remove salmonella and Escherichia coli as required by regulations. After being pasteurized, the organic pulp is pumped to the storage tank, which is used for 24h/7d continuous feeding to the anaerobic digestion system. This tank is mixed and can be temperature controlled. The mixed suspension is then sent to the Helios anaerobic digestion system, which consists of one properly sized tank considering the amount of biomass fed and the required degradation times. Due to the digester's unique design, high efficiency mixing system and heating system, the biomass is homogeneous and at a constant temperature inside the tank.

From the point of view of chemical kinetics and reactor selection, the functional scheme of "Complete mixing reactor with digestate recycling" (CSTR) was adopted. The organic matter transformation process is carried out through 4 stages in which 4 different bacterial groups participate, respectively. The degradation stages are respectively: hydrolysis, acidogenesis, acetogenesis, methanogenesis. Through these stages, complex organic matter is broken down by successive steps into simpler compounds, yielding on the one hand biogas, a gas of biological origin composed mainly of methane and carbon dioxide, and on the other hand a stabilized organic compound in which fertilizing compounds such as nitrogen, potassium and phosphorus are present.

Anaerobic digestion can operate in different thermal regimes; each different range corresponds to a different operating bacterial flora. As for the project under consideration, it is planned to operate anaerobic digestion in mesophilic, that is, at a temperature between 37°C and 42°C. By operating the digestion in the mesophilic regime, the conversion of ammonia nitrogen contained in the liquid substrate to gaseous form is reduced, resulting in a double benefit. The nitrogen that remains in ammoniacal form in the fluid constitutes a fertilizer base that increases the agronomic value of the digestate obtained at the end of the process. The sizing of the digester was done with the aim of maximizing the specific biogas production of the ABP. Controlling the biological process, based on literature data substantiated by numerous research and empirical verifications, it is state that almost all available materials see their technically valuable BMP depleted in an HRT of about 30 days.

To properly balance the chemical conditions (pH and concentration of volatile fatty acids) in the digester, ensuring that the bacterial flora can properly digest the material, an index called Organic Loading Index OLR, defined in kg of volatile matter per m^3 of digestion volume per day ($kgVS/m^3g$), must be respected. Wanting to ensure maximum stability and reliability of the biological system, the plant is sized respecting an OLR between 3.0 - 5.0 kg $VS/m^3/g$.

The gasometer located at the top of the digester allows the gas to be stored for a long time and is advantageous in the case of maintenance of any downstream biogas line component. The biogas is then dehumidified and final H_2S polishing takes place in an activated carbon filter. Now the conditioned biogas is combusted in a gas motor CHP to produce heat and electricity.

Substrates that have reached the end of the anaerobic digestion process are sent to a digestate separation system. The solid fraction will be separated from the liquid fraction using the Sludge Screw Dewaterer machine, a solid-liquid separator patented by Anaergia that separates the digestate into a solid and a liquid phase; the latter can be partially recycled within the process for dilution purposes. Solid digestate and greenwaste picked out from the waste are composted in this project. Additional structure material in the form of woodchips must be mixed in to ensure good composting.

The materials to be sent for composting are subjected to a mixing operation, by means of chopping-mixing. The purpose of the chopping-mixing is to create a material that can ensure compliance with process parameters - moisture, density, C/N ratio, porosity, etc. - considered a priority for subsequent biological treatments, as well as for obtaining a qualitatively satisfactory final product. Compliance with the correct mixing ratios is verified by measuring with a special portable probe the moisture content of the mixture; this value is expected to be between 40% and 60%.

The mixture obtained (solid digestate + green fraction + recirculated compost) is stored, picked up and transported, by means of a wheel loader, inside 4 biocells, where the biological fermentation phase takes place. To ensure aerobic conditions inside the biocells and to guarantee proper heat exchange by allowing temperature control, the biocells are equipped with an air insufflation system that draws in air from the adjacent section of the shed via fans and injects it via perforated piping included in the floor of the biocells.

At the end of the process, the extracted material undergoes screening, from which two streams are obtained, the finished compost to be sent for recovery and the recirculation surplus, stored respectively. Atmospheric emissions generated by plant operation are captured by dedicated suction lines and sent for treatment in a special biofilter.

6. Conclusions

The case study of BS Green highlights the potential of innovative food supply chains and new business models in effectively managing and reducing slaughterhouse waste. Through the implementation of sustainable practices and the adoption of circular economy principles, BS Green has demonstrated the feasibility of transforming slaughterhouse waste into valuable resources, thereby promoting environmental sustainability and creating economic opportunities.

BS Green's innovative food supply chain model exemplifies the principles of the circular economy by adopting a holistic approach to waste management. By implementing strategies such as waste segregation, recycling, and resource recovery, the company has minimized waste generation and maximized the utilization of by-products, transforming them into valuable products and reducing environmental impacts.

The utilization of slaughterhouse waste as a resource in various industries, such as biofuel production, animal feed, and organic fertilizer, demonstrates the potential for value creation and resource efficiency. BS Green's business model effectively captures the inherent value of waste materials, turning them into revenue streams and reducing the need for virgin resources.

The implementation of innovative food supply chains and new business models in managing slaughterhouse waste contributes to environmental sustainability. By minimizing waste disposal in landfills and reducing greenhouse gas emissions, BS Green has showcased the environmental benefits of adopting sustainable practices in the food industry.

The success of BS Green demonstrates the economic viability of innovative waste management practices. By capitalizing on the market demand for sustainable and eco-friendly products, the company has created new business opportunities and enhanced its competitiveness in the industry. This case study highlights the potential for other slaughterhouses and food processing facilities to explore similar business models that can yield economic benefits while reducing waste.

Therefore, BS Green case study of ABP recovery after anaerobic digestion and nutrient recycling in agriculture demonstrates that the ecological transition must be accomplished through rethinking disposal cycles toward total recovery of waste value in subsequent production processes.

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MANAGEMENT STRATEGIES OF CONTAMINATED SEDIMENTS IN A SITE OF NATIONAL INTEREST (SIN)*

Nicola Cardellicchio[1], Francesco Cardellicchio[2]**

[1]University of Basilicata, Dep. of Science, Viale dell'Ateneo Lucano 10, 85100 Potenza (Italy),
[2]CNR, Institute of Methodologies for Environmental Analysis, Contrada Loya, 85050 Tito, Potenza (Italy)

Abstract

The management of contaminated sediments represents one of the most critical problems in coastal marine ecosystems. In recent years, many efforts have been devoted to the development of green and sustainable decontamination technologies that can also be used also in situ. Marine sediments, derived from dredging, have increasingly been considered a source of materials for both civil and industrial uses. The management of contaminated sediments in marine areas with high environmental risk, such as that of Taranto, is however largely linked to the objectives to be achieved. For example, the expansion of the port area in the Mar Grande basin to deepen the seabed involved the dredging of large volumes of sediment, especially contaminated on the surface. For the latter, appropriate treatments have been used to reduce the load of pollutants. For less contaminated deep sediments, deposition in a storage tank was chosen. Dredging actions have a strong impact on the marine environment and affect biodiversity. Until a few decades ago, it was thought that the removal of contaminated sediments would be the preferred solution to be applied in various environments. The volumes to be removed, and the treatment costs, have suggested that removal can sometimes have a significant anthropogenic and economic impact. At present, there is a growing awareness of the fact that if not necessary, sediment dredging can have other valid alternatives, especially in ecosystems where important biological communities are present. In confined marine basins, environments such as the Mar Piccolo of Taranto, it is evident that extensive dredging could represent a risk due to the resuspension of contaminants with influences on mussel farming. Capping and/or Monitored Natural Recovery (MNR) could represent an alternative. This work illustrates these various alternatives.

Keywords: dredging, Mar Piccolo basin, sediment remediation, Taranto gulf

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** Corresponding author: e-mail: f.cardellicchio@gmail.com

1. Introduction

With increasing environmental awareness, combined with more restrictive legislation, traditional solutions for the management of contaminated sediments have become increasingly insufficient. In order to improve the management of marine sediments deriving from dredging, alternative solutions have been proposed for the reuse of materials in the civil and environmental fields (Amar et al., 2021). Reuse solutions must generally meet economic, technical, and environmental criteria. At present, the proposed solutions are relatively expensive and not adaptable to all types of sediments. In particular, fine-grained sediments are difficult to reuse compared to sands, due to their high water content, the presence of organic substances, their mechanical characteristics, and the presence of pollutants.

Dredging is now a necessity in the maritime transport sector: therefore, in consideration of the high volumes of sediment to be removed from the ports to deepen the seabed, the recovery of materials has been the subject of various research. The various directives of the E.U. on Environmental Impact Assessment (97/11/EEC), the Habitats and Species Directive (92/43/EEC), the Water Framework Directive (2000/60 / EC), that on the Priority Substances (2008/105/EC) and the Marine Strategy Framework Directive (2008/56/EC) (Smith et al., 2016), have placed over the year potential constraints on dredging operations, including the disposal of polluting dredged sediments. In marine ecosystems where there are ecologically important biological communities, mariculture activities, and at the same time high contamination of sediments, the planning of dredging activities must be carefully evaluated especially for the environmental impact due to the resuspension of sediments. About this, the Taranto seas marine area represents an interesting case study in which all the problems described above are encountered.

The main objective of this work is to illustrate both dredging projects concerning the development of the harbor area of Taranto (Ionian Sea, Southern, Italy), and the prospects for remediation of the sediments in the Mar Piccolo basin of Taranto, where the ecological characteristics of the marine area also require a choice of alternative solutions. In this context, possible technologies are illustrated for the reduction of the environmental impact and/or reuse of dredged materials.

2. Study area

Taranto seas (Mar Piccolo and Mar Grande basins) (Fig. 1) represent a coastal marine ecosystem example, whose biological balances have been modified step by step, in relation to anthropic development and, in particular, to the big industry settlement. The Mar Piccolo basin reflects the negative effects of pollution because of its semi-enclosed shape with remarkable problems of water exchange, which are mainly due to moderate sea tides. Mar Grande basin is a wide roadstead, which lies in the North-Eastern area of the Taranto Gulf with a maximum depth of about 35 m and a mean salinity of 37.8‰. Mussel farming in the Mar Piccolo and Mar Grande basins covers 61 and 4 % of the total surface, respectively. Mussel production is estimated to be approximately 64,000 t/year, but it is prevalent in the first inlet of the Mar Piccolo, where production amounts to 52 %.

Marine coastal areas are influenced by different anthropogenic pressure: urbanization, industrial wastes, agriculture, commercial fishing, and aquaculture. In particular, industrial areas include the most important steel production plant in Europe, an oil refinery, and two power thermoelectric plants. Moreover, the city hosts an important commercial port as well as the main naval base of the Italian Navy located in the first inlet of the Mar Piccolo and in the Southern area of the Mar Grande. For these reasons, the Taranto area has been classified as a

Site of National Interest (SIN) by National Law n. 426 (1998) and included in the National Environmental Remediation Projects. The SIN of Taranto was founded in January 2000 both regard the areas on land and as regards the sea areas; it covers a total area of approximately 115,000 ha, of which 83,000 ha of the marine surface (Italian Ministry of the Environment, 2011).

On 26 July 2012, the Ministry of the Environment, the Ministry of Infrastructure and Transport, the Ministry of Economic Development, the Ministry for Territorial Cohesion, the Apulia Region, the Province of Taranto, the Municipality of Taranto, and the Commissioner of the Port of Taranto have signed a memorandum of understanding to identify the remediation strategies of the Taranto SIN and develop the infrastructural interventions complementary (ISPRA, 2009; 2010). In particular, interventions were started for the dredging of 2.3 Mm^3 of sediments and creating a functional fill tank for the expansion of the Port of Taranto.

For the Mar Piccolo, it was necessary to review the various remediation options given the problems and fragility of the ecosystem and the presence of mussel farming activities. The Mar Piccolo, in fact, is a closed sea made up of two inlets called the first and the second inlet. Within the basin, the presence of species protected according to the protocol of the Barcelona Convention (United Nations, 1977) should also be noted. There are various pressures that have weighed on the entire ecosystem for years: the abandonment of waste, the increase in eutrophication, the poor exchange of water, and the presence of pollutants on the seabed (PAHs, PCBs, Hg). For these reasons, after the various characterizations aimed at defining the conceptual model of the basin (Arpa Puglia, 2014), the experimentation of different technologies aimed at establishing the most suitable for the basin, according to the lower environmental impact was proposed.

Fig.1. The coastal area of Taranto

3. Results and discussion

3.1. The dredging of Taranto port

The dredging of the port of Taranto was aimed at the environmental redevelopment of the areas in the basin of the Great Sea and the development of port infrastructures (Italian Ministry of the Environment, 2012). The dredging aimed both to deepen the seabed up to 16.5

meters to facilitate maritime traffic, and to operate environmental remediation in the areas of the multi-sectoral pier, given the degree of contamination of the sediments. The area subject to dredging, in fact, is affected by discharges from the industrial area of Taranto. Chemical investigations have highlighted a state of relevant contamination mainly due to the high levels of organic compounds, such as polycyclic aromatic hydrocarbons (PAHs) and heavy hydrocarbons. About the PAHs, the investigations showed also concentrations higher in some areas than the limit defined by Law 152/06 (2006). The exceedances mainly affected the first two meters of sediment. Among the PAHs, the most critical compound was benzo(a)pyrene, a carcinogenic hydrocarbon. The investigations also highlighted contamination linked to heavy metals (in particular Lead, Cadmium, Zinc, Mercury, Copper, and Arsenic) and to polychlorinated biphenyls (PCBs), especially in the superficial layers of sediment. Following the characterization carried out by ISPRA (2009), a quantity of approximately 420,000 m^3 of sediments was estimated, that have concentrations of pollutants above the intervention limits.

The deeper sediments had concentrations below the intervention limits (hiips://www isprambiente gov.it/en/publications/handbooks-and-guidelines/manuale-per-la-movimentazione-di-sedimenti-marini-1): the removal of these was necessary to reach the depths established by the Port Authority. The superficial dangerous sediments were the first to be dredged and temporarily accumulated in a special storage tank to be subjected to mechanical dehydration by means of a filter press, and then disposed of in landfills of the appropriate category.

The project, therefore, involved dredging 2.3 million cubic meters of materials and the build a backfill basin for the expansion of the multi-sectoral pier of the port. The modernization project of the Taranto Port also stands out for sustainability-related aspects. The project includes, in fact, the realization of a filling tank containing the dredged sediments to become an area for the storage of the containers. Once the work is completed, the port will also become accessible to 100,000-ton-container ships, allowing a relaunch of the port's activities and the development of commercial traffic and international logistics, also thanks to a port's quay, with a surface of over 1,100,000 square meters.

From a technical point of view, the project identified different dredging techniques: dredging with an environmental mechanical dredger, and dredging with a mechanical dredger with a bucket for the removal of dangerous sediments. Mechanical dredges of the "environmental" type adopt simple construction measures, aimed mainly at preventing the loss of material along the water column and the addition of water to the dredged material. For mechanical removal systems, the degree of filling of the bucket is a determining factor for the success of the process of minimizing environmental impacts. In fact, it is necessary to minimize the resuspension of contaminated sediments, material losses, and high water content of the dredged material which affects the management of the material itself in the subsequent stages of the process.

The dredging process, in fact, often adds a significant amount of water to the removed sediment, making the subsequent management phases difficult and burdensome (for example dehydration, water treatment, etc.). Hydraulic dredgers, on the other hand, can be used for the removal of non-hazardous contaminated sediments: these lift and pump away the removed material mixed with water hydraulically by pumping. However, the dredged material loses its original density and is spilled into the discharge site along with a large amount of water.

Over the last years, however, special environmental dredges have been designed, which aim to prevent the material from being released into the environment and to increase the density of the dredging mud. Significant improvements have been achieved also in relation to monitoring activities of the dredging process. The most modern environmental dredgers can

count on a high accuracy of the positioning system and on automated processes that allow the visualization of the process in real-time.

3.2. Backfill basin

The dredging project has envisaged the construction of a backfill basin near the fifth pier with an estimated capacity of approximately 2.3 Mm^3, covering an area of approximately 30 ha. This backfill basin was the first of a larger basin with a total capacity of 9.0 Mm^3, which, at the end of the works, will constitute a port yard for container storage and handling purposes. According to the project, sediments that were not dangerous at their origin or which became such as a result of treatments aimed at removing pollutants have flowed into the filled tank. The sediments which, after characterization, were considered dangerous, on the other hand, were managed outside the reclaimed area and sent, after treatment, to an appropriately authorized landfill.

In anticipation of the construction of new port docks, in order to ensure the due mechanical strength and to obtain an immobilization of contaminants, solidification/stabilization treatment processes with suitable binders (lime, cement) have been planned inside the filled basin. The construction of the backfill basin predicted preliminary studies in the marine area to evaluate the regime of currents and the bottom biocenosis. The seabed handling activities, in fact, must be conducted in such a way as to minimize the environmental impacts mainly due to the increase in turbidity linked to the resuspension of sediments and the dispersion of contaminants.

More specifically, the effects of dredging on the biological communities are produced by the turbidity of the water, the temporary decrease in the concentration of dissolved oxygen in the water column, the solubilization of contaminants following the change in the chemical-physical conditions of the sediment, and by the entry into the food chain of contaminated particles with the possible alterations of the biocenosis. In sensitive areas, the activities to remove contaminated sediments, therefore, require a particular approach, aimed at minimizing the impacts on the surrounding environment. Dredging is therefore defined as "environmental" if it meets certain requirements, such as high selectivity and precision in the positioning of the instrumentations and cutting, prevention of material loss, optimization of the quantity of water in the dredged material, also in relation to its final destination.

3.3. Treatments of dredged sediments

The treatment technologies have been selected according to the different uses of the dredged material. For less contaminated sediments, both dehydration and particle size separation processes have been envisaged. In the case of coastal reuse of dredged material, the most suitable process is that of particle size separation aimed at separating all the sands for reuse in projects for the environmental recovery of disused quarries, landfill, etc. In order to reduce the volumes of sediment to be transported, a dehydration process of the dredged material has been envisaged both in a natural way (sedimentation basin) and mechanical with centrifugal systems.

An important aspect to verify is the chloride content within the material to be reused which can be reduced by appropriate washing processes. In the case of very contaminated sediments destined for landfills, the project envisaged treatment systems aimed at reducing the pollutant content and downgrading the dredged material for transfer to lower-category landfills. The treatments considered were those of washing with chemical additives and of the thermal type, for the removal of organic contaminants. Depending on the type of contamination,

different washing solutions can be used ranging from water to acidic or basic solutions, to extractions with oxidants or reducing agents, or to treatment with chelants in the case of metal contamination.

Thermal treatments, on the other hand, make it possible to remove, destroy or immobilize a wide range of organic contaminants present in sediments by volatilization of species characterized by high vapor pressure, oxidation, or transformation into less dangerous compounds, trapping within the material.

3.4. The remediation of Mar Piccolo basin

The Mar Piccolo is a typical semi-closed polluted basin of the Mediterranean Sea characterized by poor water circulation (De Serio et al., 2007): this condition favors the sedimentation of organic matter which plays an important role in the transport and accumulation of pollutants in sediments. The Mar Piccolo hosts the largest mussel farm in Italy. The high urbanization and industrialization of the Taranto area have caused, over the years, the contamination of sediments by toxic organic compounds and heavy metals with concentrations that often exceed the legal limits.

Therefore, in the basin, contaminated sediments represent a significant source of contaminants for both the water column and biological organisms. The chemical characterizations effected over time (Arpa Puglia, 2014; ISPRA, 2010) and research conducted by the various Extraordinary Commissioners for remediation since 2013 have confirmed high levels of priority contaminants such as heavy metals (lead, cadmium, mercury, copper, zinc, etc.) (Calace et al., 2005, 2008; Petronio et al., 2012) and organic pollutants (polycyclic aromatic hydrocarbons - PAHs, polychlorinated dibenzo-dioxins and dibenzofurans - PCDDs/Fs, polychlorinated biphenyls - PCBs) (Cardellicchio, 2020). Furthermore, high levels of organic compounds (eg PCBs) were also found in farmed mussels with a significant risk for human health.

As regards organic compounds, the exceeding of the limits set by the European Commission regulation (EC, 2011) of dioxins and dioxin-like PCBs has led, since 2011, to a ban on the marketing and consumption of adult mussels in the first inlet of the Mar Piccolo. In relation to this scenario and for the environmental recovery of the basin, various hypotheses for sediment remediation and protection of the biological communities have been considered with the identification of the best technologies with low environmental impact.

The environmental situation that emerged from all the characterizations carried out made it possible to reconstruct the conceptual model of the basin by identifying the still active sources of contamination (primary and secondary), the transport routes of contaminants, and the impacts on the biological component and, in particular, the bioaccumulation of pollutants in mussels. Naturally, the characterization of the sediments has identified the priority pollutants and the most contaminated areas of the Mar Piccolo such as those near the former Tosi shipyards (north of the first Inlet) and the area of the Italian Navy shipyards to the south of the first Inlet (called Area 170). The sediments of the latter area had significant levels of mercury and PCBs. In relation to this environmental situation, possible remediation interventions were considered such as dredging or capping in the most contaminated areas or monitoring programs to evaluate the natural restoration of acceptable conditions in the sediments.

3.5. Scenarios of remediation in Mar Piccolo

The environmental picture that emerged from the characterizations of the sediments in the first inlet of the Mar Piccolo has highlighted the complexity of the problem relating to remediation: the phenomena of resuspension of polluted sediments represent a non-negligible secondary source of contamination: therefore, the operations of seabed handling should be carefully evaluated.

The definition of the conceptual model of the basin (Arpa Puglia, 2014) has demonstrated the presence of areas with different contamination and the need to adopt different intervention strategies for the various areas also in consideration of the presence of mussel farms and biological communities. The various strategies, therefore, require sharing with the various stakeholders and defining the intended use of the areas to be reclaimed in order to reflect the criteria of sustainability and cost-effectiveness (Extraordinary Commissioner, 2018).

In this context, the remediation project for the first inlet of the Mar Piccolo envisaged the experimentation of three different technological approaches: environmental dredging or capping for the most contaminated areas and the assessment of the natural evolution of contamination (Monitored Natural Attenuation) for the less contaminated ones. In consideration of the particular ecological situation of the basin, the activities of moving the seabed by dredging involve a series of impacts on the biological components linked not only to the increase in turbidity of the water column but also to the possibility of dispersion of contaminants. This is an impact factor on mussel farming.

Therefore, in the case of dredging of sediments in the most contaminated areas, the best technologies should be adopted, for example, "environmental dredgings" and measures aimed at preventing the dispersion of sediments in the water column. The technologies currently available include both mechanical and hydraulic removal systems. Hydraulic environmental dredging systems are based on the suction of the sediment mixed with the process water.

Capping, on the other hand, is a sediment isolation technology, made with a cover consisting of a layer of suitable material to avoid contact between contaminants and the surrounding aquatic environment (Förstner and Apitz, 2007; Palermo et al., 1998). An innovative capping, defined as "reactive", is made up not only of layers of "clean" materials but also of adsorbents to reduce or eliminate the possible spread of pollutants. The thickness of the capping and the composition of its components must be suitably designed according to the physical and chemical characteristics of the seabed and the possible presence of biological communities.

In general, capping is an effective technology for contaminants strongly associated with sediment including hydrophobic organic compounds, such as high molecular weight polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), dioxins, and heavy metals (Gomes et al., 2013). Heavy metals are present in sediments as insoluble sulphides, under strongly reducing conditions. Since oxygen penetration into a capping layer is typically limited, the cover serves to generate strongly reducing conditions in the underlying contaminated sediment and the formation of insoluble metal sulphides (Peng et al., 2018). The low solubility of these promotes metal retention and makes capping an extremely effective technique for sediments with high concentrations of heavy metals, such as those present in the Southern part of the first inlet of the Mar Piccolo.

A further methodology for remediation, especially in less contaminated areas of the Mar Piccolo, is based on the so-called Monitored Natural Recovery (MNR). This term refers to the case in which the remediation of a contaminated site is linked to the ability of natural processes to reduce contamination through physical, chemical, and biological processes that

act without human intervention. However, the Environmental Protection Agency (EPA) attributes an important role to MNR when the sources of contamination have been removed. The technology can also be associated with the other technologies described above (eg capping) and applied to more contaminated areas. However, natural recovery over time must be constantly monitored to verify that the effectiveness of the degradation processes, especially for organic pollutants, proceeds at the expected speed.

Often some degradations of the contaminants can lead to the formation of more toxic compounds: therefore, the processes related to the environmental fate of the pollutants must be well understood. The development and application of predictive tools are therefore essential to evaluate the natural recovery speed and estimate the time required to achieve the remediation objectives. The adoption of different technologies for the recovery of the Mar Piccolo basin must therefore reflect the overall strategy of revaluing the basin both on an ecological and productive level.

4. Concluding remarks

From the analysis of the different remediation technologies, it is evident that according to the characteristics of marine areas and especially their intended use, different types of remediation must be adopted.

The techniques must be such as to respect the criteria of sustainability and cost-effectiveness but must also be aimed to safeguard the ecological environment. This is the case of the Mar Piccolo of Taranto, which has been used for some time for production purposes and whose recovery must necessarily reflect the ecological values present.

From the point of view of the circular economy, the dredging of high volumes of sediment must be associated with the recovery of materials to reduce both environmental impacts and the use of landfills.

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QUANTIFICATION OF SOCIAL PERFORMANCE INDICATORS IN A COMPANY MONITORING ENERGY FROM RENEWABLE SOURCES *

Carrabino Rosario[1,2], Matarazzo Agata[1], Arfò Sergio[1], Massaro Simone[2], Falzone Giuseppe[2]**

[1]Department of Economics and Business - University of Catania
[2]BaxEnergy Italia S.r.l

Abstract

In the context of an economy increasingly based on the ecological transition of individual companies, fundamental importance is given to sustainable management tools in a circular economy perspective. Sustainability, in its most modern sense, also implies a quantification of social, as well as environmental and economic benefits for the company that decides to innovate its technological paradigm.
This paper aims to quantify environmental and social indicators to a young company, BaxEnergy, located in the province of Catania. The company has ten years of experience in monitoring the electricity generation from renewable energy sources. In particular, as an experimental case, social performance indicators relating to the company's market presence and GRI indicators were quantified, which can be used to draw up the company's sustainability report. For BaxEnergy, the implementation of the social report would represent a further step towards transparency and the sharing of the company's values, even to stakeholders, who have always, historically, have treated and have been treated partners in a cold and purely economic way.

Keywords: corporate social responsibility, global reporting initiative, renewable energy sources, social accountability, social performance indicators

*Selection and peer-review under responsibility of the ECOMONDO
** Corresponding author: e-mail: rosariocarrabino2@gmail.com

1. Introduction

The behaviour adopted by companies, from large multinationals to SMEs, has always exerted a strong influence on the configuration and balance of the current economic, political and social context. They shape everyday life, market equilibrium, working conditions and the value system that guides our society (Molteni, 2007).

Businesses, therefore, in an environmental context that is increasingly dense with social and political conjunctures, are no longer seen solely as profit-oriented and wealth-creating entities, but must play the role of actors, responsible engines of development capable of producing environmental and social value. It is precisely in the wake of this capacity to interact with the environmental context and with a view to continuous improvement that the glue between the two worlds comes into being: Corporate Social Responsibility (CSR) management. According to this vision, companies cannot disregard their social responsibility, which is considered a strategic tool that can bring major benefits to society and at the same time strengthen the company's competitive advantage.

Clearly defining Corporate Social Responsibility is certainly not one of the easiest issues to solve. This is because the concept of CSR has in recent years taken on increasingly complex ramifications within its narrower meaning, linked to recent evolutions in the economic and social landscape of the contexts in which it is increasingly taking hold. If we want to further analyse the definition of Corporate Social Responsibility, we can consider the aspect of 'voluntariness'; as CSR, it goes beyond the simple mandatory parameters imposed by law and thus succeeds in defining a strategy in response to the sign of the times, to the social pressures that are increasingly permeating the European and global economic fabric (Garriga and Melé, 2004).

After having given various nuances and points of view regarding the definition of Corporate Social Responsibility, we finally study the official one, contained in the Green Paper published by the European Commission in 2011, where CSR is defined as: "A concept through which companies decide on a voluntary basis to contribute to the improvement of society and to a cleaner environment" and "an integration of social and ecological concerns, through a voluntary process of self-regulation, in the business operations of companies and in their relations with their stakeholders".

In the wake of what the European Commission has set out, it also dwells on how Corporate Social Responsibility should not be a substitute for compulsory regulations, but rather a road to be travelled together with them, with the common goal of achieving mass accountability on the issue that is becoming increasingly important in recent years. In countries where such regulations do not exist, efforts should focus on creating an appropriate regulatory or legislative framework in order to establish a fair basis from which socially responsible practices could be developed.

The objective of this paper is precisely to analyse the role of CSR in a constantly evolving context that brings to the attention of the company the legitimate social and environmental, as well as economic, expectations of the various stakeholders, through the performance of its business activities; in particular, we wish to hypothesise the application of the social report within an innovative business reality in Sicily. BaxEnergy, boasts an innovative corporate structure and thanks to this technological innovation, it has succeeded in gaining important customers in various geographical contexts. The company's main business is therefore the control of a large number of renewable energy plants by means of software, which allows this control to be carried out remotely, even thousands of kilometers away.

2. Research methodology

Having introduced the path in which the social balance sheet intersects, we now analyse its definition and all its parts in corporate reality.

The three main functions performed by the social balance sheet, the main document summarising the social reporting process, are:

- Intensification of the relationship with the various stakeholders, active (financiers, suppliers) and passive (local communities);
- A tool that allows the union of relations between the external environment and the company;
- It is the main tool enabling the application of stakeholder engagement.

For the company, the social balance sheet, therefore, represents the main method to collect the 'sentiment' of the target of customers to which it refers, thanks to which it will be able to continue to maintain that consensus and reputation that are fundamental for the long-term view; while, from the stakeholders' point of view, the accounting document represents the easiest way to make them participate in company life (Di Giandomenico, 2008).

One can now analyse the main task that the board of directors and top management are called upon to perform, namely that of drawing up a document that succeeds in satisfying the different needs of the various stakeholders. It is therefore a complex challenge for the company to meet, on the one hand to satisfy the demands of the various stakeholders, which may differ markedly from each other, and on the other hand that there is no getting away from the fact that satisfactory behaviour on the part of a company, if not communicated, may be seen as a lack of attention and application on the subject (Friedman M.,1970).

In today's annual reports or financial statements, one finds information of various kinds that can roughly be grouped into the following six areas:

- the corporate governance system;
- the operating strategy;
- the company's results;
- the dynamics of the reference context;
- the strategic direction pursued by top management;
- stock market performance (Sartor et al., 2016).

In order to achieve a real concretisation of a corporate policy inspired by the principles of inclusion, social responsibility and transparency, it is therefore essential to start from the consideration of the social report tool not as an end in itself, but rather as a process that is able to involve all corporate levels, no one excluded. After having analysed process standards in the first chapter (AA1000, SA8000, ISO 26000) we now want to focus on content standards, including: the GBS model and the GRI. The social report, according to GBS, has several objectives (Göbbels and Jonker, 2003):

- Giving all stakeholders an overall picture of the company's performance, opening up a dynamic communication process;
- Finding and disseminating useful information on the quality of the company's activities in order to extend and improve stakeholders' knowledge and possibilities of evaluation and choice (Castka and Balzarova, 2008).

"The Commission of the European Community on 30 May 2001 issued Recommendation No. 453 "on the recognition, measurement and disclosure of environmental information in the annual accounts and annual reports of companies".

The reasons for the intervention of the "Commission" can be summarised as follows: the assessment of environmental expenditures and risks in annual accounts contributes to increasing companies' awareness of the environment, in line with the 5th Environmental Action Programme "for sustainable development" and the implementation of the principle of integrating environmental protection requirements into other Community policies is

considered a fundamental choice for the promotion of sustainable development (Moon et al., 2011).

This recommendation clarifies the role of companies with regard to environmental issues, which can be applied by all corporate entities, such as banks, and various financial institutions, to which the rules on Annual and Consolidated Accounts provided for in Directives IV and VII on company law can be adopted, not forgetting that the financial implications do not change as production varies (Becket and Jonker, 2002). In Fig. 1, we propose an example of what the new civil law balance sheet and income statement might look like after the implementation of the recommendation.

The accepted view is that the statutory classification should be retained in the original classes, splitting the content into a) non-environmental and b) environmental, when necessary (American Accounting Association, 2006).

Fig. 1. a) New Balance Sheet; b) New Profit and Loss Account

3. Case study

After having presented the various Corporate Social Responsibility tools in the previous chapters and having illustrated the social balance sheet, with its indicators, we now wish to examine the hypothetical application of the social balance sheet in one of the most innovative realities in Sicily and the entire peninsula, BaxEnergy, which is part of the innovative business hub Free Mind Foundry. This is a young company with ambitious goals, such as playing a leading role in the near future in terms of digitisation, sustainability and technology. The Free Mind Foundry hub hosts many companies, including the other companies of the Massaro group: BaxEnergy, Intellisync, Wisnam and the new entry, Digital Atom.

Let us look in detail at the most decisive company of the entire group. BaxEnergy's main business is therefore the control of a large number of renewable energy plants by means of software, which allows this control to be carried out remotely, even thousands of kilometres away. Energy Studio Pro: a system for all conventional and renewable technologies; it allows

an infinite amount of data to be analysed and stored in real time throughout the life cycle of the plant in question. The main advantages of using this technology are:

- Eliminating human intervention by 90%;
- Reducing intervention time to a few seconds;
- Automating control, thousands of kilometres away;
- Minimise economic and energy losses;
- Maximise ROI.

BaxEnergy can boast the application of two voluntary certifications that are essential for greater sensitivity and respect on these issues, bringing increasing credibility to the entire company ecosystem and to its stakeholders.

The two certifications in question are:

- ISO 9001;
- ISO 27001.

A survey on ISO 9001 certification at the end of 2020 shows that, despite the negative implications brought about primarily by the Covid-19 pandemic, the number of companies that have implemented the voluntary standard is growing.

This system allows for the final collection of policies, processes, documented procedures and records; this set of documents defines the internal rules that define how the company creates, delivers the product or service to its customers. Certification must also be tailored to the needs of the individual company and the product or service it offers, but the standard provides a set of guidelines to ensure that no important element fundamental to the success of a Quality Management System is overlooked.

The second equally important certification that BaxEnergy has decided to implement is ISO 27001, an international standard that describes and integrates an Information Security Management System within the company. Obtaining this certification demonstrates that the company is following the guidelines for proper information security management and provides an independent and professional check on whether security is being managed in line with the international standard's indications and geared towards the company's objectives.

The main benefits of the correct implementation of this standard are:

- Gain a competitive advantage by satisfying customer and supplier requirements;
- Identifying, assessing and managing the organisation's risks by formalising information security processes and procedures;
- Ensure the constant monitoring of the company's performance and activate the necessary improvement actions.

4. Results and discussions

For a proper implementation of the sustainability report in BaxEnergy, a four-point approach can be taken according to the GRI parameters:

- The BaxEnergy case: Mission and corporate values guide;
- Environmental sustainability: "renewables" vs. traditional energy consumption;
- Social sustainability: recruitment and terminations, employee training and development, and occupational health and safety;
- Economic sustainability: customers, quality and customer satisfaction and suppliers: selection and evaluation.

The GRI (GRI, 2016), being a useful tool for Social Report reporting, for companies active in totally different sectors, needs performance indicators that can be used for all of them, in order to achieve greater comparability of actions and results. With reference to the standard

information that characterises the Social Report of all companies that draw it up according to the guidelines of the Global Reporting Initiative, below is a summary divided into two parts:

- **Strategy and Profile**; in this part, the company makes explicit, through the declaration of the highest authority in the decision-making process, the strategic description of the various company choices and how they affect the sustainability of the entire company system, with particular attention given to the impacts of actions already meditated upon, to the description of future risks and opportunities always from the point of view of sustainability. It is also important to introduce basic information that determines the profile of the company, such as: brand, name, operational structure, location of the registered office, number of countries in which it operates, legal structure, mission, vision, size of the organisation, awards received and more.
- **Performance indicators**; they are identified by an acronym consisting of two letters and a sequential number, they are divided into Core (mandatory and universally applicable) and Additional (optional, not universally relevant) and report information on the organisation's economic (acronym: EC), environmental (EN), social (LA), human rights (HR), social (SO) and product responsibility (PR) performance.

As far as economic and environmental sustainability is concerned, it is intuitable how much the focus is on the company's core business: the control and management of exclusively renewable energy plants, and thus a clear contrast to traditional energy sources. It is now necessary to give an overview of the third aspect of sustainability, the one that many scholars believe is most incisive in day-to-day business: social sustainability. With regard to this issue, the main reference indicators that can be used are the economic performance (EC) and social performance (LA) indicators, which are analysed in Fig. 2.

Fig. 2. GRI indicators used in the drafting of the sustainability report

In applying a social sustainability policy, BaxEnergy focuses on the following aspects:

- **Staff training and education**: employees, of all importance, are fundamental and indispensable in order to achieve the company's objectives, and it is precisely for this reason that BaxEnergy invests a great deal of resources in the continuous training of its staff, starting with courses on Safety and Health in the Workplace, passing through seminars on, for example, "Time Emotional Management" and "Communication and Body Language".
- **Staff recruitment and selection**: with a view to continuous investment in young talent in the area, the innovative company has developed a detailed staff selection plan that guarantees fair treatment among potential hires. So-called 'Recruitment Days' are planned and organised punctually, allowing candidates for a specific job position to meet, introduce themselves to the company, proceed to a group interview and then move on to the individual interview and communication of the results.

5. Conclusions

The implementation of the social balance sheet would represent a further step forward for BaxEnergy towards transparency and the sharing of corporate values, even to stakeholders who have always, historically, been treated and have treated partners in a cold and purely economic manner.

The social balance sheet brings with it an objective of fundamental importance that must be achieved by all corporate realities and not in the shortest possible time: shifting the focus from "Profit at any cost" to "Profit, but at what cost?"; thus accompanying the traditional statutory balance sheet, the sustainability balance sheet must no longer represent an optional action applied by a few realities, but a fundamental, compulsory document that thus benefits the entire global economic ecosystem. The advantages that the social balance sheet brings are varied, but the most important one, and the one on which more attention has been paid, is respect for the individual human resource; in the long term, the company that will assert itself in the market and gain an ever greater share of the market will be the one that has definitively understood the importance of human resources as a fundamental key to its business success.

The social balance sheet makes it possible to bring investors and all stakeholders in general closer to the company's reality, touching on and embracing the theme of sustainability from many points of view, from the environmental, social and economic ones. In our case study, we have focused above all on social sustainability, analysing some categories of possible economic and social performance indicators, with a view to the increasing implementation of such tools in the vast majority of companies.

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TREATMENTS OF WATER CONTAMINATED BY ORGANIC DYE TREATED WITH CARBON NANOTUBES*

Pierantonio De Luca[1], Anastasia Macario[2]**

[1]*Department of Mechanical, Energy and Management Engineering, University of Calabria. Italy*
[2]*Department of Environmental Engineering, University of Calabria. Italy*

Abstract

The object of this research activity was the treatment of water contaminated by the organic dye Blue Patent V, through the use of carbon nanotubes.
To optimize the adsorption process, a system containing simultaneously carbon nanotubes and titanium oxide was also studied, followed by periods of exposure to sunlight for programmed times. As is known, titanium oxide is an important photo catalytic agent. In the latter case, the aim was to verify whether titanium oxide, in a first phase, could photodegrade the dye molecules into smaller components, which could subsequently be more easily adsorbed by carbon nanotubes. The system containing only carbon nanotubes proved highly efficient in reducing the concentration of dye, while the system containing carbon nanotubes and titanium oxide reported a lowering of the abatement efficiency compared to the system containing only nanotubes.

Keywords: adsorption, blue patent V, carbon nanotubes; titanium oxide

1. Introduction

The treatment of water contaminated by pollutants through the use of carbon nanotubes (CNTs) is a new frontier and is of particular interest to researchers working in this research area. As is known, carbon nanotubes can be represented as tubes generated from a graphene sheet rolled up into a cylindrical shape with a nanometric diameter (Popov, 2004). They are very versatile materials and can be used in different industries. Particularly interesting is their

*Selection and peer-review under responsibility of the ECOMONDO
** Corresponding author: e-mail: pierantonio.deluca@unical.it

use as adsorbent materials in the treatment of contaminated water (Apul and Karanfil, 2015; De Luca et al, 2022; De Luca et al. 2021a; Sarkar et al., 2018). The application of these materials has also been extensively studied in the treatment of water contaminated by dyes (De Benedetto et al., 2020; Upadhyayula et al., 2009).

Blue Patent V, or E131, is an organic synthetic dye, blue in color and is frequently used in the food industry. It comes as a bluish powder and is very soluble in water. In high doses it can cause harmful effects on human health. Small quantities dissolved in water can produce an intense color making its impact on the environment even more evident. In the treatment of contaminated water, in addition to the use of adsorption processes, photocatalytic processes are equally important. In the latter, thanks to the use of particular substances, called photocatalytic agents, and the combined action of light, it is possible to degrade the molecules of pollutants (Binas et al. 2019; De Luca et al, 2019). Titanium oxide is the most common photo catalytic agent.

The optimization of water treatment often involves the serial application of different processes that can act synergistically, bringing the entire purification process to high efficiencies. In particular, in this research carbon nanotubes were used for the treatment of water contaminated by the organic dye Blue Patent V. In addition, to optimize the adsorption process, the simultaneous use of titanium oxide and carbon nanotubes was experimented, followed by programmed times of exposure to sunlight.

The aim was to verify whether titanium oxide, in a first phase, could photodegrade the dye molecules into smaller fragments, which could subsequently be more easily adsorbed by carbon nanotubes.

2. Materials and methods

An initial solution of the Blue Patent V dye was prepared with a concentration of 0.1 g / L. The solution is blue in color. Blue Patent V reagent is a commercial product (Merck). The titanium oxide used is a commercial product (Anatase - 99.6% Alfa Aeser).

Carbon nanotubes have previously been synthesized through catalytic chemical vapor deposition (CCVD). They have been extensively studied in previous papers (De Luca et al., 2020; De Luca et al., 2021b) Briefly, they are multi-walled and have a very high purity of 95%. For this reason, they have been used in experimentation as is, without proceeding with purification processes. Previous investigations have shown an average pore width of 103.70 Angstrom and a specific BET area of 108.70 m^2/g.

Several systems containing predetermined amounts of the dye solution, titanium oxide and carbon nanotubes were prepared. In particular, the following Table 1 reports the different systems studied.

Table 1. Composition of the systems

System	***Composition***
A	15 mL $_{\text{Blu Patent V solution}}$ + 0.02 g_{CNTs}
B	15 mL $_{\text{Blu Patent V solution}}$ + 0.1 g_{TiO2}+ 0.02 g_{CNTs}
C	15 mL $_{\text{Blu Patent V solution}}$ + 0.1 g_{TiO2}
0	15 mL $_{\text{Blu Patent V solution}}$

Each system was exposed to sunlight for different times, such as: 0; 0.75; 1.5; 24, and 48 hours and subjected to constant magnetic stirring. After the exposure time, each system was filtered. The solution obtained was recovered and analyzed by UV spectrophotometry (UV-3100PC Shimadzu), to determine the residual concentrations of dye after the treatment phase.

3. Results and discussion

Figure 1 shows the concentration of dye present in the solution after treatment with carbon nanotubes (system A), as the treatment times vary.

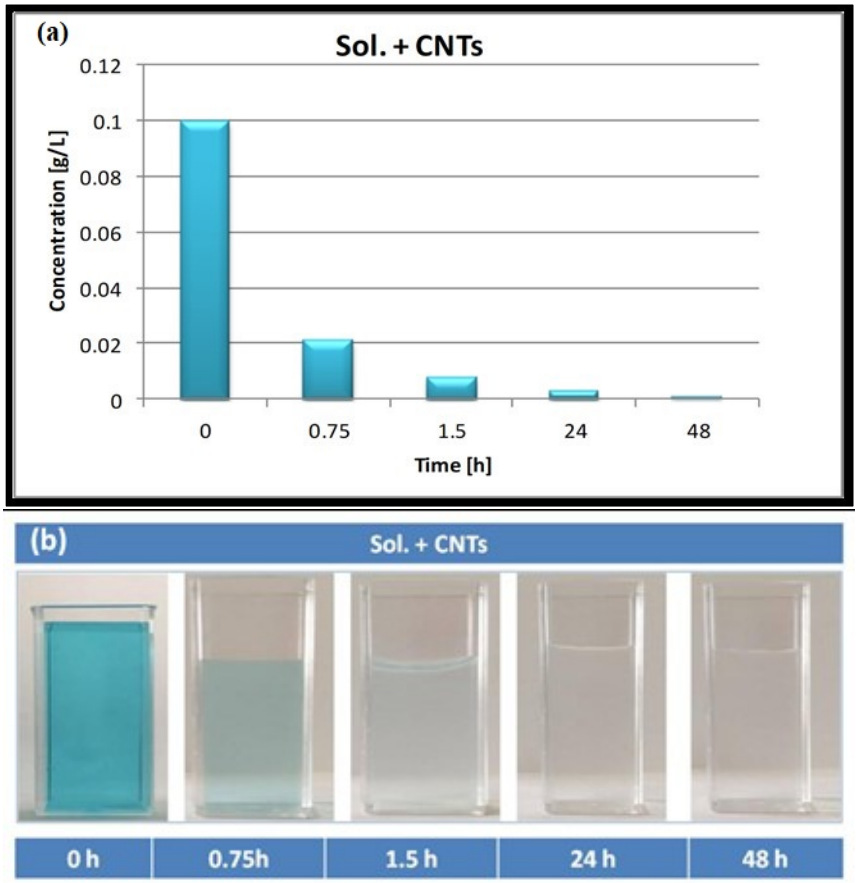

Fig. 1. (a) Concentration values and (b) images, of system A after different treatment times

The results obtained show a high efficiency of the carbon nanotubes. In fact, after only 45 min of treatment, the concentration of the dye is reduced by a fifth compared to the initial one. After 90 minutes, a reduction of close to 92% is reached. The reduction in the concentration of dye basically occurs in the interval within the first two hours. The reduction of the dye concentration is easily visible by observing the color of the solution with naked eyes after the treatments. Figure 1b show a discoloration of the solution which becomes almost complete when 24 hours are reached. At 24 hours the residual concentration of dye is very low so that the solution is completely colorless.

Subsequently, in order to optimize the adsorption process, in addition to the carbon nanotubes, small quantities of titanium oxide were added (system B). The system was placed under magnetic stirring and also left exposed to sunlight for the entire treatment time, in order to activate any reactions of photodegradation of the dye by titanium oxide. The following Fig. 2 shows the residual concentrations of the dye, after different treatment times.

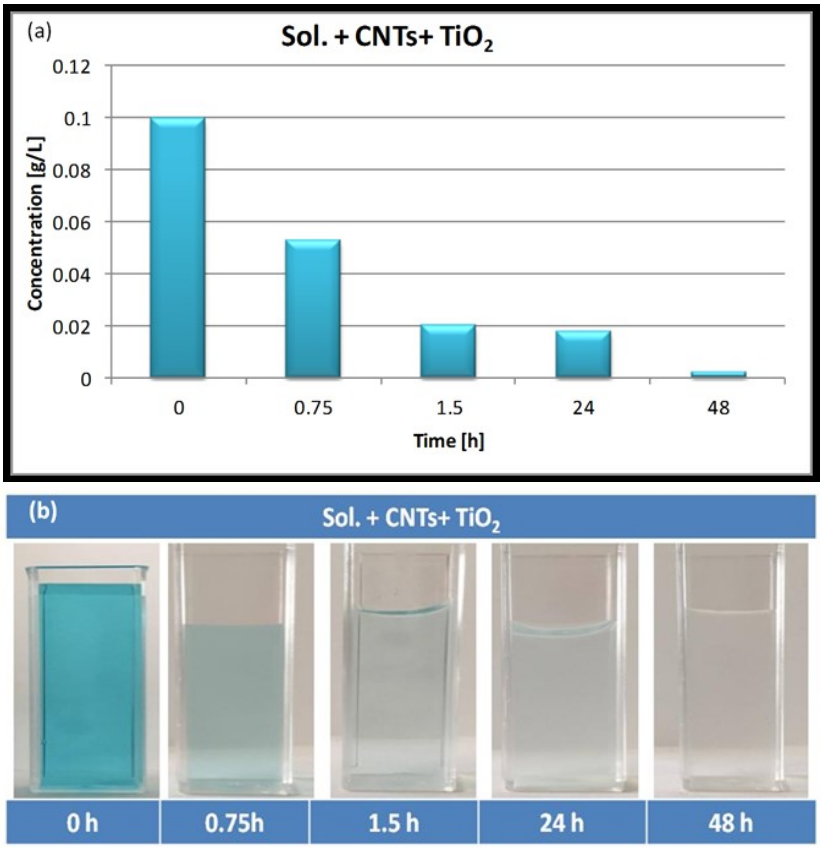

Fig. 2. (a) Concentration values and (b) images of the solutions of system B, after different treatment times with exposure to sunlight

The reported results show that the system continues to have a high efficiency in removing the dye. It should be noted, however, that in system B, there is no improvement in adsorption as hoped for. The adsorbing capacity of the carbon nanotubes is, in this case, slightly decreased compared to the previous system containing only carbon nanotubes. It is possible to hypothesize that in system B, there are two processes: the adsorption of carbon nanotubes and the photodegradative action of titanium oxide. These two processes, however, occur at different speeds.

In this system and for the operating conditions used, the adsorbing process of carbon nanotubes predominates. Titanium oxide does not have the time necessary to achieve an efficient photodegradation of the dye. The lowering of adsorption efficiency, which is recorded in system B, is attributable to a partial adsorption of titanium oxide by the carbon nanotubes, which leads to the establishment of competitive adsorbent processes between dye and titanium oxide molecules. However, system B reaches, more or less, the same efficiency as system A at 48 hours.

Figure 3, compares the percentage reduction, as a function of the treatment times with exposure to sunlight, of systems A, B, C and 0. This also allowed to verify the photostability of system 0 (solution only) and system C (solution and titanium oxide only).

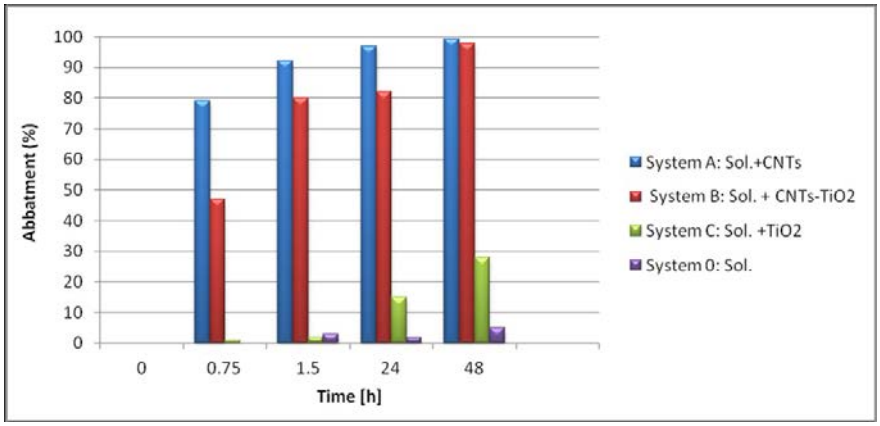

Fig. 3. Comparison of the abatement percentages, as a function of the treatment time with exposure to sunlight, for the different systems

The results obtained show that systems 0 and C exhibit a low photodegradation rate. In fact, after 48 hours, these latter systems show a reduction of 5% and 28% respectively. The results obtained in addition to highlighting a low tendency to photodegradation of the dye solution alone (system 0), highlight that the photodegradative activity induced by the mere presence of titanium oxide (system C) is less important than the adsorption process of the nanotubes of carbon which occurs as in the case of system A.

These results confirm the hypotheses previously set out, namely that the photodegradative activity by titanium oxide is much slower than the adsorption process of carbon nanotubes. In fact, considering 90 min of treatment, the system containing only carbon nanotubes (A) and the system containing only titanium oxide (C), have a reduction of 92% and 2% respectively. Therefore, in system B, where carbon nanotubes and titanium oxide are present, the adsorption process prevails over the photodegradative process so that the presence of titanium oxide does not lead to any improvement in the treatment process, on the contrary it leads to a partial inhibition of the adsorption action of carbon nanotubes.

4. Concluding remarks

The carbon nanotubes proved to be very efficient in removing the dye, in fact after only 90 minutes of treatment there was a reduction in the concentration of the dye equal to 92% accompanied by an evident discoloration of the solution.

In systems containing carbon nanotubes and titanium oxide at the same time, a slight decrease in the adsorption efficiency of carbon nanotubes was recorded due to competitive processes between the dye molecules and titanium oxide molecules.

It has been shown that the photodegradation phenomena of the dye, due to the presence of titanium oxide, in the adopted operating conditions, are much slower than the adsorbing action of carbon nanotubes, which is very high. This leads to not having an evident improvement of the adsorption phenomena in systems that simultaneously contain carbon nanotubes and titanium oxide.

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COLD ASPHALT CONTAINING 100% RECLAIMED ASPHALT: A SUSTAINABLE TECHNOLOGY FOR CYCLE PATHS AND MAINTENANCE INTERVENTIONS *

Paola Di Mascio[1], Nicola Fiore[1], Antonio D'Andrea[1], Carlo Polidori[2], Loretta Venturini[3]**

[1]Sapienza University of Rome, Piazzale Aldo Moro, 5, 00185 Rome, Italy
[2]AIPSS – Italian Association of Road Safety Professionals, Via Bergamo, 3, 00198, Rome, Italy
[3]Iterchimica S.p.A., Via Guglielmo Marconi 21, 24040, Suisio, Bergamo, Italy

Abstract

Both the National Recovery and Resilience Plan (Next Generation EU Program) and the development strategies for Smart Cities focus on cycle and pedestrian paths. Their pavements must be safe, durable and sustainable and considering the need to preserve the resources that Planet Earth offers to humans, it is essential to opt for innovative construction technologies that allow recycling methods without necessarily involving the addition of first-use materials.
In the field of road infrastructure, the recovery of material deriving from the demolition of old pavements (RA - Reclaimed Asphalt) is only possible thanks to the use of specific products. A state-of-the-art rejuvenator is currently being used for the construction of cycling paths with 100% cold-mixed RA.
This product is currently being studied for the INFRAROB project: "Maintaining integrity, performance and safety of the road infrastructure through autonomous robotized solutions and modularization" (Horizon 2020) with particular reference to "potholes patching" materials. Some technical data of the experiences developed to date are shown below.

Keywords: circular economy, cycle path, Green Deal, recycle

*Selection and peer-review under responsibility of the ECOMONDO
** Corresponding author: e-mail: loretta.venturini@iterchimica.it

1. Green Deal and cycle paths

The European Green Deal aims to achieve zero emissions by 2050, also through the development of policies for a circular economy. With the Paris Agreement, the EU made a commitment to reduce greenhouse gas emissions by at least 40% by 2030, compared to 1990 levels, but in 2021 it raised the target to at least 55%. The package of reference is "Fit for 55%", which includes the revision of the existing legislation on emission reduction and energy, ensuring a fair and socially just transition, strengthening innovation and industry competitiveness, and supporting the EU's leading position in the global fight against climate change (Chamber of Deputies, 2011).

It is acknowledged, among other things, that "circular economy" means the reintroduction of waste products at the end of their service life into new production cycles, in order to minimise, and if possible, eliminate negative effects on the environment. Such actions make it possible both to avoid the accumulation of waste in landfills and to exploit resources, especially non-renewable ones. It should also be pointed out that there is a close correlation between energy efficiency and circular economy (CSCP, 2006).

Recently, in July 2022, the European Commission highlighted the fundamental contribution of cycle paths to achieve sustainability, supporting a strategy that aims to encourage cycling to reduce dependence on fossil fuels and to mitigate emissions into the environment, leading to improved air quality in urban areas. By 2025, the proposal for new rules for investments in the transport network includes the requirement for a plan to make urban mobility "clean, sustainable and emission-free", with particular reference to cities with more than 100,000 inhabitants (Baccini, 2022, hiips://www eunews it/2022/07/07/commissione-ue-strategia-mobilita-ciclabile-europa-verde/). It is obvious that stimulating the use of cycle-pedestrian paths necessarily leads to an implementation of the infrastructural system. In fact, the number of cycle paths is planned to double by 2030.

The right importance of bicycle lanes within the urban mobility system is unfortunately not so taken for granted, even though the bicycle is extremely versatile: it does not produce noise and environmental pollution, for the same mobility it means less parking and less deterioration of the road network, it implies less congestion and a relative decrease in wasted time, excellent daily exercise (not to be underestimated from a social point of view), etc. (Gaballo, 2021). Some new recent studies show that the main needs that influence the choice of bicycle use are enjoyment of bicycling, safety, and comfort (Thigpen et al., 2015).

Contextualising the abovementioned to the asphalt pavement sector, also for cycle paths, there are innovative technological solutions that fit perfectly within the tools to achieve the Green Deal. Certainly, along with increased performance and reduced maintenance, the recycling of pavements at the end of their service life is an essential component in reducing the carbon footprint. The material resulting from the demolition of pavements is known in Italy as "granulate of bituminous mix or, in jargon, milled material" and internationally as RAP - Reclaimed Asphalt Pavement.

2. Asphalt pavements for cycle paths

In Title I, Art. 3, the Italian Highway Code defines the concept of "bicycle lane" as the longitudinal part of the carriageway, normally on the right, delimited by a white strip, continuous or discontinuous, intended for the circulation on the roads of velocipedes in the same direction of travel as other vehicles and marked by the velocipede symbol (Legislative

Decree, 1992). The type of route depends substantially on the areas where the pavement is laid and can be, for example, shared with car traffic, on country roads or roads with low traffic density, precluded to car traffic, etc.

In the context of a circular economy, it is essential to limit the construction of infrastructure as much as possible, either by rehabilitating abandoned infrastructure or by using secondary road networks such as disused roads, service roads, embankments, country roads, sidewalks, embankments, service roads, etc. In any case, the asphalt pavement must not only be safe, but also durable and easily recognizable to users. Therefore, the two main obstacles to overcome are the environmental impact and the small allocated spending budgets (Lombardy Region, 2022).

The structural solutions mainly used are: 1 – asphalt concrete pavement, which is the most widely used solution in all contexts because it gives a safer and more durable wheel-rolling surface; 2 - granular pavement (possibly treated with protective treatments or emulsifiers), which is especially suitable in suburban areas in the countryside, hills, mountains, etc, and in general where it is desired to reduce the architectural impact at a very low cost; 3 – special pavements, used in exceptional situations as they are expensive and not very comfortable for cyclists (block paving, cobblestones, interlocking paving, etc.).

Focusing on AC flexible pavement, the wearing course of the bituminous mix is the top layer, and its function is not only to provide a safe and durable surfacing, but it must be smooth, skid resistant, dust-free, waterproof, long-lasting and protective of the underlying courses (DITSA, 2015).

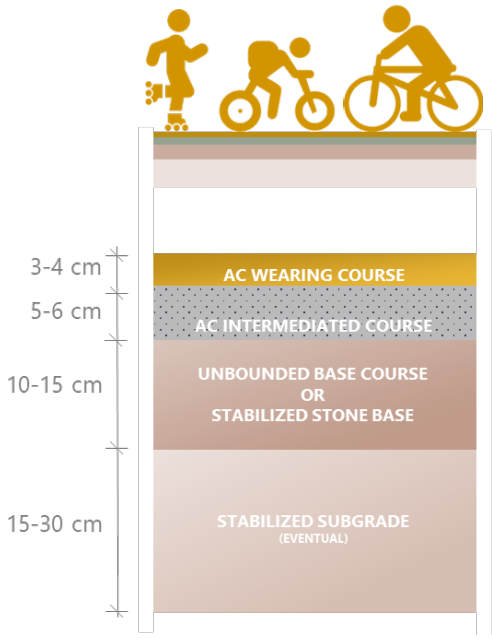


Fig. 1. Typical section of a cycle path

As with all road infrastructures with one or multiple layers, the section of a cycle track is usually made up of a series of asphalt layers, laid on a sub-base, according to typical construction techniques (Fig. 1). For example, the typical cross-section for newly constructed cycle paths consists of a stabilized subgrade (or existing soil) of approx. 20-40 cm, a 10-20 cm

thick bituminous bonded or unbounded base course, an AC (Asphalt Concrete) intermediate course of 5-6 cm and an AC wearing course of approx. 3-4 cm. Please note that for cycle paths built using existing asphalt pavements it is often only necessary to resurface the wearing course by approx. 3-4 cm. The determination of thicknesses is always an engineering choice that depends substantially on loads and environmental conditions. It must be considered that the asphalt pavement is sometimes used by more or less light and/or more or less fast traffic, especially for cleaning and maintenance of the cycle path. Without forgetting that, in the case of surmountable signage, the track is often mistakenly used by cars for short stops and overtaking manoeuvres (Fig. 2).

Fig. 2. Cars parked on the cycle path

3. Innovative and sustainable asphalt concrete for cycle paths

3.1. 100% Cold rejuvenated RAP

Asphalt mixes are mixtures of bitumen (waste from oil processing) and aggregates (they can be of different kinds), which also contain RAP in different percentages depending on the design choices and the relevant technical standards. Recycled RAP is almost always returned into the new asphalt concrete pavement in different forms: sometimes used as an aggregate in base or subbase construction, but generally it is incorporated in the new asphalt concrete (AC) using hot recycling technique, exploiting the full potential of the bitumen contained. In terms of sustainability, the use of RAP for the production of the new mixtures implies a reduction in the amount of material to be landfilled, a substantial decrease in soil consumption and new raw or first-use materials.

Speaking about traditional AC and bike trails, the main performances to be met/checked are cracking and rutting resistance, and durability. When using RAP, even for cycle paths, it is clear that it is necessary to proceed with the rejuvenation of the aged bitumen. The RAP should meet the specifications identified by local laws. Furthermore, we should not forget that the pavement of the cycle paths must be designed like any other pavement (Simpson et al., 2012). When properly crushed and screened, RAP consists of high-quality, well-graded aggregates coated by asphalt cement (bitumen) (FHWA, 2016). By using a milling machine or a rhino horn on a bulldozer and/or pneumatic pavement (full-depth removal), the broken material must be treated and processed, including crushing, screening, conveying, and stacking. This procedure is very important because the properties of RAP depend on the original constituent materials and the type of asphalt concrete mix from which they derive (wearing course, binder course, etc.). For example, the wearing course aggregates normally have higher

quality than the aggregates in binder course applications, where polishing resistance is not of concern.

In addition to the proper treatment of RAP, especially for the recovery in HMA mixtures, a further "problem" to be managed is the ageing of the bitumen. Due to its organic nature (a residue of oil distillation), the bituminous binder undergoes a chemical-physical transformation over time (Phase 1 - production and storage of bitumen; Phase 2 - production, storage and laying of asphalt; Phase 3 - service life of the pavement) that leads to its deterioration through the evaporation of the volatile components and the oxidation process, resulting in a decrease in mechanical performance, loss of adhesiveness, increase in stiffness values and consequently increasingly fragile behaviour. For the processing of RAP, it is essential to highlight the difference between "rejuvenate" and "reuse". The two main categories of recycling products are: softening agents (softeners) and rejuvenating agents (rejuvenators). A softening agent action is the reduction of viscosity and softening point, and the increase of penetration of the final binder. However, the permanence of the effect is not guaranteed since the modification is limited to physical and rheological properties. This category includes flux oils from different origins (organic or inorganic). A rejuvenating agent has instead partially or totally the capacity to restore the lost chemical features of the RAP and the properties of its aged bitumen as well as recovering the physical and rheological features. The level of successful recycling is highly dependent on the correct choice of the type and quantity of the recycling agent. Recycling agents play a key role also in the recycled mixture's performance and durability of new HMA, but nowadays it's possible to distinguish between rejuvenator and flux oil, using laboratory tests (Loise et al., 2020).

During the last decade and as a result of several years of research, a new method of recycling of 100% reclaimed asphalt at ambient temperature (CMRA with 100% RAP - cold mix recycled asphalt with 100% reclaimed asphalt pavement) was developed, rejuvenating the aged bitumen with a new, specially formulated rejuvenator. In this manner, the saving in terms of energy and economic aspects is evident (zero emissions, material recovery and no energy consumption). In the rejuvenation process, the innovative rejuvenator allows to return the chemical ratio back in balance, restoring the bitumen composition to its original state or as close to it as possible. In particular, despite being initially designed for the production of bituminous mixtures for pothole patching, road maintenance and rehabilitation works, thanks to the high performances achieved, the CMRA with 100% RAP could be used as an alternative to HMA for cycling paths and light-traffic roads.

The innovative rejuvenating agent is a liquid additive free of aromatic substances with hydrocarbon binder enriched with rejuvenators, plasticizers, vegetal flux oils, anti-oxidative chemicals and moisturizer diluent (Table 1). This material is otherwise compatible with different kinds of colouring pigments.

Table 1. Some of the given physical properties of rejuvenating/binder

Characteristic	***Value/Description***
Aspect	Fluid substance
Colour	Brown
Density at 20˚C	0,94 ± 0,02 g/cm3
Viscosity	400 - 500 cP
Flash point	> 150°C

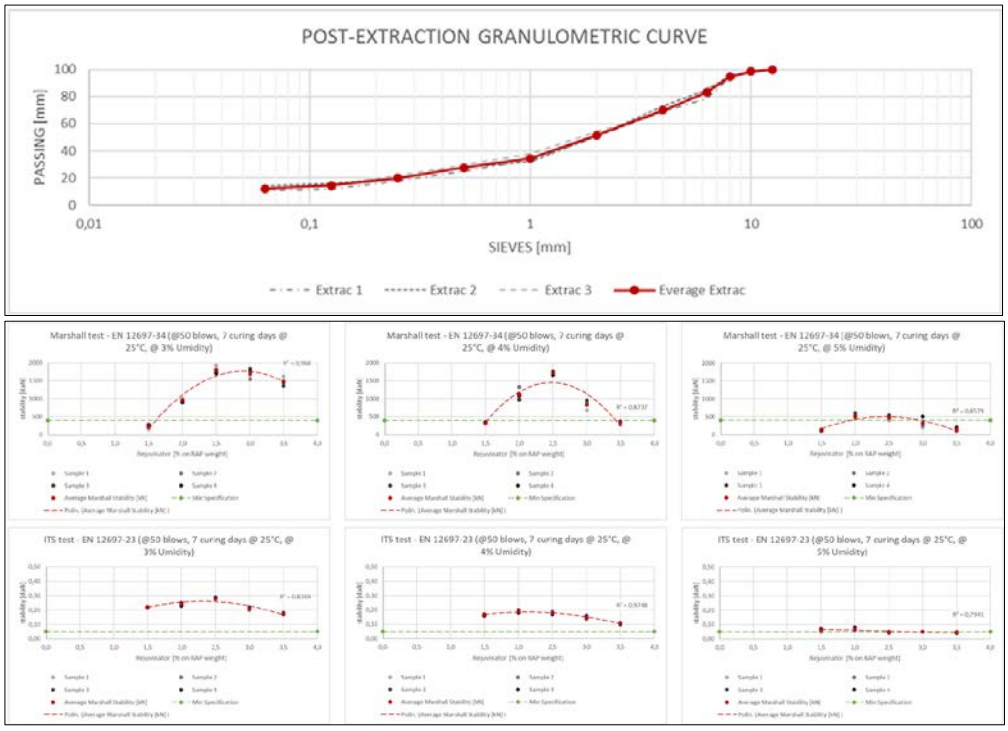
Considering also the area of application, the special bituminous mixtures produced with this technology evidently require a dedicated verification method that cannot be the same as HMA (Hot Mix Asphalt) and WMA (Warm Mix Asphalt). The technical standards of the

Municipality of Milan and the Lombardy Region report a verification process that highlights the advantages of this technology compared to traditional CMA. The required performances are shown in Table 2 (Lombardy Region & Municipality of Milan, 2021).

Table 2. Procedure for the performance testing of CMRA with 100% RAP

Test	***Test method***	***Unit of measurement***	***Values required***
Compaction	UNI EN 12697-34	Blows per side	50
Marshall Stability after 7 days in the open at 25°C	UNI EN Test Method 12697-34	kN	> 4
Indirect Tensile Strength after 7 days in the open at 25°C	CNR n.134/91	kPa	> 50
Cantabro particle loss after 28 days of conditioning at 25°C, 300 rotations at a speed rate of 30 rotations/min, using Los Angeles machine without abrasive charge	---	%	< 10

The results of a mix design study using the abovementioned procedure are shown below (Fig. 3).



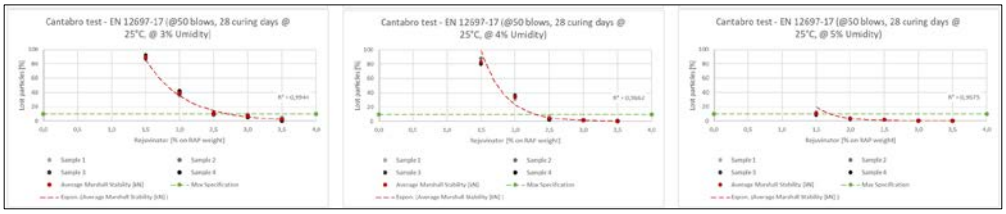


Fig. 3. Mix design of cold mix recycled asphalt with 100% RAP

3.2. European project and performance of sustainable CMRA with 100% RAP

A study on the CMA with 100% RAP and rejuvenator was performed also for the project InfraRob, a research project funded by the European Commission's research programme Horizon 2020 aiming at maintaining integrity, performance, and safety of the road infrastructure through autonomous robotized solutions and modularization. A specific task of the project is focused on the development of a system able to extrude a specific mixture for filling in small cracks and potholes. Grading, Marshall Stability, void content, indirect tensile strength, and particle loss have been studied ranging the additive content from 1.5% to 3.5% and the water content from 3.1% to 5%. The maximum size of the aggregate was limited to 8 mm, due to the size of the potholes to be treated in the project. The mixing and compaction process of the specimens were performed at room temperature. The specimens' compaction was carried out with 50 strokes of Marshall's hammer, considering the reduced compaction ability of the material in a restricted area. The Marshall Stability and the indirect tensile strength were carried out at 25 ° C after a period of curing of 7 days at the same temperature in a ventilated oven. The particle loss has been studied with the Cantabro test according to EN 12697-17 after a curing period of 28 days at 25°C. Eight totally different mixes were tested and the results are listed in Table 3.

Table 3. Mixtures laboratory test results

Cold mix	***Reference standard***	***Recycling agent for 100% RAP (CMA)***							
Mixture		A	B	C	D	E	F	G	H
Recycling agent [%]		1.5%	2.0%	2.5%	3.0%	3.0%	3.0%	3.5%	3.5%
Water content [%]		3.1%	3.1%	3.1%	3.1%	4.0%	5.0%	4.0%	5.0%
Bulk density [g/cm³]	EN 12697-6	1.97	2.05	2.08	2.13	2.11	2.12	2.1	2.11
Maximum density [g/cm³]	EN 12697-5	2.47	2.47	2.47	2.47	2.47	2.47	2.47	2.47
Air voids [%]	EN 12697-8	20.3	17.3	15.8	13.8	14.6	14.4	14.8	14.8
Indirect tensile strength 7dd [N/mm²]	EN 12697-23	0.18	0.19	0.19	0.23	0.12	0.12	0.04	0.09
Marshall Stability 7dd [daN]	EN 12697-34	908	1043	1055	1285	612	603	246	403
Particle loss 7dd [%]	EN 12697-17					84	76	84	83
Particle loss 28dd [%]	EN 12697-17	95	46	20	13	3	5	0	3

Since the Cantabro test does not respond exactly to the damage produced by the traffic, the material has been laid down in some potholes and it was monitored under traffic. Four potholes 10 cm deep and 10 cm as diameter were dug in the parking lot annexed to the school of Engineering of Sapienza-University of Rome.

The potholes were filled with mixtures E and F listed in Table 3. The four potholes' repairs were loaded with a road vehicle (FIAT Doblò), immediately after laying and they were monitored after 50 and 100 passages of the vehicle. The surveys were carried out visually to verify that there are no losses of material, even immediately after laying, when the material is not cured and just self-compacted. The in-situ mix tests show a good thickening and absence of disintegration of the material or loss of cohesion, even immediately after laying. The passages were repeated thirty days later and the material was found stable and without distresses. So far, after two months under traffic, the filling material is in place and no detachment or raveling is revealed.

3.3. CMRA with 100% RAP for cycle paths

The Grande Raccordo Anulare delle Biciclette (Bicycle Ring Road), also known as GRAB, is the first cycle route in the City of Rome, consisting of a ring of approximately 50 km that ideally has its km 0 at the Colosseum - San Gregorio Street. The project was preliminarily approved in April 2018, with funding from the Ministry of Infrastructure and Transport. Today, the project is part of the sustainable development plan for the city, allowing for a review of the mobility from the point of view of everyday travel (e.g. home-work and home-school) and for tourist approaches in an area full of history and natural resources. Today, the project is in its final phase with the collaboration of the Sapienza - University of Rome.

The cycle path is articulated in 6 Lots with different characteristics: it has a separated 3.5 m wide carriageway (where there is the need to reconfigure the spaces intended for vehicle traffic or to extend the existing cycle paths); in certain parts it is a recognizable path, but separate from the pedestrian path; it is an integral and main part of the road for example near the archeological sites along the Via Appia Antica (Mobility of Rome, 2022). With particular reference to the sections being newly resurfaced and built, in February 2022 a trial section was carried out using CMRA with 100% RAP. It consisted of a 140-metre long by 2-metre wide (with a thickness of 3 cm) section in Via del Campo Boario and a 84-metre long by 3-metre wide (with a thickness of 3 cm) second section in Via Nicola Zabaglia. The work phases included the demolition of the old pavement, the in-plant production of the innovative mix and the laying using a paver and a rolling machine.

The laboratory analysis for the verification of the mixture was carried out by the Road Laboratory of Sapienza-University of Rome.

4. Conclusions

The reuse of waste products and the promotion of cycle and pedestrian paths both urban and rural environment are two interventions that Europe is focusing on to protect the environment. A lucky marriage of the two was presented in this article. The use of a cold asphalt mixture composed of 100% RAP and an innovative bitumen rejuvenator has been proposed.

The material was studied at the Road Materials Laboratory of Sapienza - University of Rome as part of the European Infrarob project for the robotic repair of the road potholes. Laboratory and on-site tests have revealed a good behavior of the material which is resistant and long-lasting. The material has already been applied for the construction of cycle paths in various Italian cities, demonstrating a good flexibility of application.

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BATTERY STORAGE TECHNOLOGICAL INNOVATIONS. CASE STUDY: BAXENERGY LTD*

Marco Di Mauro[1], Salvatore Gulina[1], Antonio Zerbo[1], Concetta Patania[2], Simone Massaro[2]**

[1]Department Economics and Business- University Of Catania-Corso, Italia 55 - 95129 Catania, Italy
[2]Baxenergy Italia S.R.L. - Via Sclafani 40 - 95024 Acireale, Italy

Abstract

Innovative developments concerning battery technology are deeply changing our lives, from transportation to stationary applications used to store energy.
Batteries are composed of materials whose production may cause adverse environmental impacts. In case the demand for these materials outpaces supply, scarcity may become a relevant problem and impact the price and feasibility of large-scale adoption of battery-powered vehicles.
This paper presents the technological innovations applied to battery storage management systems. We analyzed BaxEnergy, a proactive company which aims to deliver innovative solutions to renewable energy stakeholders for complete data analysis and optimization of their power plants. BaxEnergy links multiple plants together to form a larger and interlinked system, called power-grid.
BaxEnergy continuously look for new clients in order to undertake new project and becoming an even more important business reality. The current potential clients operate across a large part of the world and perform a portfolio of renewable energy and battery storage project.

Keywords: battery storage, electric vehicles, energy renewable resources, environmental impacts, technological innovations

1. Introduction

Mobility is the opportunity that is given to people to move freely throughout the territory by promoting aggregation, free time and work, while recognizing, at the same time,

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** Corresponding author: e-mail: dimaurom110@gmail.com

safety and comfort. Unfortunately, private vehicles continue to be preferred over public transport, with obvious economic and environmental repercussions. This is the reason why, there is great interest in solutions that make it possible to encourage citizens towards sustainable mobility (Chan et al., 2004).

The term "sustainable mobility" highlights two important declinations, the environmental and the social one. On the one hand mobility can be sustainable from an environmental point of view when it reduces impacting effects such as traffic congestion in the city and consequently atmospheric and noise pollution caused by emissions from both public and private vehicle (Bielaczyc et al., 2001). On the other hand, it can be sustainable from a social point of view if it facilitates the choice and use of means of transport by citizens, improving the value of their free time, the speed of service as well as reliability. New technologies offer further efficiencies, as a matter of fact they offer the promise of higher productivity, increased efficiency and decreased pollution. Not only do electrically driven vehicles have many advantages but also electricity is more efficient than the combustion process. Electricity can be generated through renewable sources, such as hydroelectric, wind, solar and biomass. Electric vehicles (EVs) will allow to overcome the transport-pollution binomial (Mi and Masrur, 2017). EU emissions regulations require a change: less diesel and petrol, more battery. The electric motor converts electric energy into mechanical energy to propel the vehicle; because energy and power densities of storage batteries are smaller than that of fuel for ICE (internal combustion engine), a larger number of batteries must be used to assure a certain level of power performance. However, more batteries on a vehicle reduce interior and luggage space, the resulting increase in vehicle weight sacrifices acceleration and other performances and the cost of the vehicle also rises. The structure provides an electric motor powered by one or more accumulator batteries. EVs are at the brink of entering the commercial market. To succeed in a competitive market, attention should be paid to finding the optimal cost customers are willing to pay. It is important that the power consumption of the air conditioning systems used in EVs is minimized, to minimize penalties to vehicle driving distance and performance.

In the latest EVs the concept of weight-saving design that turns into energy-saving ought to be adopted. Innovative ideas propose the vehicle sale separated from the battery, which is instead rented through a third company. This mechanism allows people to reduce the car price, paying a monthly fee for the battery (ICSU, 2017). Moreover, in case the performance of the battery decreases, the renting company is required to replace it with a new or regenerated one, to guarantee at least 75% of the original autonomy. Sustainable development underlines the limits imposed in the use of environmental resources, it is aimed at climate change on a regional, national and international scale (Smith et al., 2012). Scientists underline urgent but complex problems: CO_2 and CFC emissions, contribute to stratospheric ozone depletion and global warming. Environmental degradation, first seen as a problem of the rich nations and a side effect of industrial wealth, has become a survival issue for developing nations.

There is no doubt about the direct emissions reduction associated with the spread of electric cars. As a matter of fact, absence of combustion means that electric vehicles do not emit nitrogen oxides (NOx), carbon monoxide (CO), particulate matter (PM10 and PM2.5), unburnt hydrocarbons and volatile organic compounds. Consequently, the EVs spread is certainly advantageous for the air quality in the inhabited center (ICSU, 2017). Concerning greenhouse gas emissions on a global scale (often evaluated in terms of carbon dioxide CO_2 equivalent), the advantages offered by electric cars are not certain as they depend on the emissions associated with the electricity production needed to recharge the batteries. Development cannot subsist upon a deteriorating environmental resource base; changes are required in all countries as part of a package of measures to maintain the stock of ecological capital (Ehsani et al., 2018). The urgency with which risk mitigation needs to be solved is high,

people cannot afford the luxury of producing theory for its own sake in the hope that someday it might somehow be useful.

The objective of this paper is to outline an analysis prospectus which may highlight the huge impacts induced by the vehicle sector and in particular analyze the even more developed industry of battery storage. For this purpose, the case study has been accomplished in BaxEnergy, one of the most proactive companies of the Sicilian territory. It is located in Acireale (CT) and develops solutions adopted worldwide to monitor and control infrastructures in the sectors of energy, telecommunication, healthcare and industrial.

2. Materials and methods

A battery cell consists of three primary elements: two electrodes (positive and negative) immersed into an electrolyte (Fig. 1). The lead-acid battery has been a successful commercial product for over a century and is still widely used as electrical energy storage in the automotive field and other applications. The advantages concern low cost, mature technology, and relative high- power capability (Ehsani et al., 2018). Lead-acid batteries also have several disadvantages; among these, the low energy density should be highlighted, as a consequence of the high molecular weight of lead. Fuel cells can be used as alternative power sources for electric and hybrid vehicle sys- tems. Normally, even a pure EV using a fuel cell will need a battery to initiate the fuel cell activation process. In a fuel cell electric vehicle, it is possible to eliminate the alternator as a power generating source (ISO 6469-1, 2019). In place of a battery, it is possible to have an ultracapacitor and even though the ultracapacitor could be eliminated; it is recommended to retain it under normal circumstances.

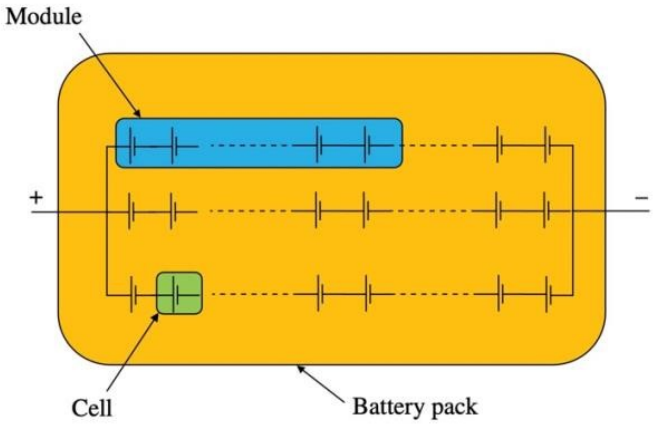

Fig. 1. Battery cell

Hybridization of energy storage is one of the leading recent technologies, it consists on combining two or more energy storages together so that the advantages of each one can be used and disadvantages compensated (ISO 15118-3, 2015). Batteries are composed of materials whose production may cause adverse environmental impacts and consume large amounts of energy. Moreover, if demand for these materials (especially lithium or cobalt) for batteries outpaces supply, scarcity may become a relevant problem and impact the price and feasibility of large-scale adoption of battery-powered vehicles. When an EV battery reaches the end of its useful first life, manufacturers have three options: they can dispose of it, recycle

the valuable metals, or reuse it. Disposal most frequently occurs whether packs are damaged or if they are in regions in which there is not the appropriate market structure. Recycling can make sense if the battery electrodes contain highly valued metals such as cobalt and nickel (CEI EN 61960, 2014). Reuse can provide the most value in markets where there is demand for batteries for stationary energy storage applications that require less-frequent battery cycling. Nowadays, battery recycling procedures are realized in large part thermochemically, through pyrolysis, producing significant quantities of toxic emissions (Reddy et al., 2020). The cost of recycling a ton of lithium batteries is on average between 4 thousand and 6 thousand euros, it is therefore an expensive process considering that the value associated with recoverable raw materials does not exceed one thousand euros. Second life batteries management represents an effective way for accumulators (conserve energy and distribute it in the form of electricity) to enter the circular economy (Bai et al., 2020). Accumulators do not necessarily have to meet the standards required for batteries, they can be reused for applications associated with less binding specifications from the performance point of view.

Waste from electrical and electronic equipment is increasing at a growth rate of 3-5% per year. They include any electrical product with a plug or battery that people want to discard (Zhang et al., 2017). The treatment takes place in special centers adequately equipped; the recycling processes make it possible to recover up to 90% of the entire product. Second-life batteries may be 30 to 70 percent less expensive than new ones in these applications until 2025, requiring significantly less capital per cycle (Engel et al., 2019). Renewable power sources are typically intermittent. On the contrary, batteries overcome this limitation warehousing energy when the sun shines or the wind blows, and releasing it overnight, or when the wind drops. In so doing storage ensures uninterrupted power to consumers. Through accumulating additional energy and releasing it when necessary, storage systems can optimize energy consumption and ensure that business activities can effectively combine cost savings, efficiency and resilience.

3. Case study: BaxEnergy

BaxEnergy, at the beginning operated only in the wind power industry but going through its timeline is possible to discover how the company broke into the whole sustainable global energy market. In 2012, projects spread in Portugal and Austria reaching 10 GW energy handled. In 2013 it was present even in South America and only a year later in Africa. In 2019, 100 GW were treated by BaxEnergy but the company never stopped going forward, even considering the difficulties the world pandemic has brought, until the actual result of more than 110 GW. Even if BaxEnergy has its main operations center in Italy, has commercial offices in Germany, South Africa, Portugal and Chile, as well as representatives in India, Austria, Ireland and and UEA. BaxEnergy provides an all-inclusive strategy which offers on-site hardware and software solutions with 24/7 ICT (Information and Communication Technologies) infrastructure monitoring and cyber defense services. The customers are: Multi-Giga Utilities, TSO (Trasmission System Operators), Operation and Maintenance, Independent Power Producer and Investment and Pension Found (D'Arienzo, 2017).

The company's products also integrate smart modules for power and price prediction, energy trading and support for industrial-grade battery storage management. The monitoring platform extends even beyond the renewable energy field to cover monitoring of electric vehicle charging stations and other critical segments of the national infrastructure such as transportation and telecommunications. With over 110 GW of renewable energy power plants connected, BaxEnegy is leading the green ecological transition. Several analysts making part of the BaxEnergy's team deal with the large amount of GW treated, their role is to provide technical support from the control rooms situated in the office to clients all over the world. It is possible to affirm that the company's goal is to make renewable energy more efficient, affordable, and safe. BaxEnergy provides the most innovative technologies available in the

market, such as the IoT and AI. IoT (Internet of Things) uses a precise computing technology to acquire information from industrial devices in the power plant and performs intelligent and complete data. It also refers to the interconnection of electronic devices each other to gather, monitor, control, and transfer information over the network (Esposito and Massaro, 2017).

The main purpose is to collect the entire amount of data generated by those devices in a unique scenario, then extracting and leveraging information to promote useful and innovative applications and services. BaxEnergy invests in renewable energy sources and tries to make the initial approach to the green energy field easier for the other companies. The aim of company is to guarantee a constant inflow of energy that could both face the demand and prevent the excess and shortage of energy. In order to make the system more efficient and able to contrast potential drawbacks.

In line with the innovative approaches to green energies, BaxEnergy goes further with the sustainable process. The next step concerns the transition from renewables to green hydrogen.

4. Results and discussion

New developments in battery technology are deeply changing our lives, from transportation to stationary applications used to store energy. Batteries are promoting the adoption of renewable energy worldwide and as a response the government policies in support of this evolution are leading to an increase in grid storage capacity (Patania et al., 2021). Thanks to continuous innovations, the energy market is changing faster. Energy transition is moving forward worldwide.

The growing interest and investments in renewables are making people aware about the energetic needs and renewable energy sources' potential (La Cagnina et al., 2020). BaxEnergy, aware that battery storage is one of the promising technological applications that might help to accelerate the energy transition and, at the same time, reducing the overall costs of this process, helped Enel Green Power realizing the first large battery storage project in Italy. The project "Catania 1" represents a crucial step for the green energy market. EGP is using BaxEnergy's integrated software solution to monitor and analyze the battery storage system's data. BaxEnergy provided a data interface which integrates several services for scheduling and controlling energy production through a battery storage system. After the success of "Catania 1" project, EGP has entrusted BaxEnergy with a similar project for the 18 MW wind farm "Potenza Pietragalla" (Bottino, 2022).

The wind farm is the first in Italy to be combined with a storage system and connected to the grid. Thanks to the collaboration, BaxEnergy and EGP continue to lead innovative changes in the renewable energy market, providing new opportunities to progress and power a greener tomorrow (Li et al., 2018). If the energy produced by sun and wind can be stored, and then released at exactly the right time, that could fundamentally change the world's power dynamics.

BaxEnergy aims to deliver innovative solutions to renewable energy stakeholders for complete data analysis and optimization of their power plants.

5. Concluding remarks

Society needs to move away from fuels that are polluting the air and water and warming the entire planet. We need to make energy globally available, making the storing system easy for individuals all over the world. By storing renewable energy and delivering it when the demand requires, people may reliably and cleanly power houses, work environment and entire

buildings even when there is no wind and the sun has set. The energy management system works as an intelligent central brain able to take affective decisions on how to use energy as required. Consume energy when the price is low, sell it when the price is high, optimize energy and storage. BaxEnergy offers a comprehensive, scalable solution ranging from field-level energy data aggregation to grid-wide energy analysis at the management level. A proactive approach allows the system to plan appropriate actions timely, thus preventing problems before they occur. An effective monitoring saves both costs due to unforeseen failures and to physical replacement of all monitoring chain elements out of service or whose behavior is unexpected. Health and economic benefits are clear and cannot be ignored anymore. The more we invest in efficient energy strategies and technologies, the more we will create responsible, self-sustaining jobs and empower countries, improving our life, making the world greener. As a matter of fact, advancements and forward-thinking green actions have led to the birth of new renewable energy industries. Sustainable energy sources are now more affordable and accessible than ever.

Society and modern applications of energies need to make energy globally available, making the storing system easy for individuals all over the world.

In a competitive environment in which companies have to provide more and more effective and efficient services/products, asset management allows to achieve the company's business objective. To accomplish both the goals to ensure good operational performance and long durability of the final products/services, it is necessary to define effective business processes, to monitor their performances and to provide corrective actions when necessary. Energy storage can automatically inject power to support grid stability during contingency events. This enables operators to increase the capacity of existing transmission lines, without having to build another trellis. The goal is to create networks that never go down. Furthermore, energy storage can be used as a fast-acting load resource to ensure supply and demand are managed in lockstep. The balancing capability ensures the maintenance of a stable network throughout the whole process. Co-locating renewables with storage let capture all the energy resources generated and dispatch it when it is needed. As a result, there is no longer the necessity to use it or lose it.

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SUSTAINABILITY TOOLS APPLIED IN THE VIDEOGAME SECTOR. ISO 29110/2016 STANDARD IN CINIC GAMES*

Marco Di Mauro[1], Enrico Cocuccio[1], Chiara Tabita[1], Agata Matarazzo[1], Serena Dal Maso[2]**

[1]Department Economics and Business, University of Catania- Corso, Italia 55 - 95129 Catania, Italy
[2]Cinic Games S.R.L., Via Solferino 10 - 50123 Firenze, Italy

Abstract

The video game industry is one of the driving engines of digital development. The environmental impact from this industry is represented by the intensive mining of minerals. On top of that, it was estimated that video game development would be responsible for 0.04% of global emissions. The ISO 29110 standard was specifically designed with the aim of making the various production processes, centered in the production and management of software and hardware resources, more sustainable by targeting small businesses. The objective of this paper is the experimental application of the ISO 29110 standard to the company CINIC GAMES s.r.l., located in Florence (ITA). The norm is a useful life cycle management standard, which can be applied to smaller organizations in order to introduce the of environmental sustainability and circular economy into their production process.

Keywords: circular economy, environmental sustainability, ISO 29110, videogame sector

1. Introduction

The video gaming industry possesses remarkable peculiarities and potential of a different nature that make it one of the most profitable sectors worldwide. Towards this sector, the Italian context is characterized by a disarming slowness of the public operator in recognizing the socioeconomic value of gaming, which will have to be overcome to avoid a failure to exploit of "a new power in the process of resilience and revitalization."

* Selection and peer-review under responsibility of the ECOMONDO
** Corresponding author: e-mail: dimaurom110@gmail.com

For this reason, it is hoped that, as soon as possible, the public operator will close this cognitive gap and put in place appropriate fiscal and investment and employment support policies, in light of obvious economic and social reasons that will be discussed below (Zackariasson and Wilson, 2012). Since the 20th century, video games have become part of the media family along with other existing media such as, for example, movies and music. But the further we go into the 21st century, the more we understand how video games have become the media with which human beings interact most during the course of their lives, thus ousting the dominant role played by movies, plays and operas, or music (Kent, 2001). Such a figure turns out to be unopinionated when one considers that, unlike the other creative industries mentioned above, which have a history of more than a hundred years, the birth of the video game industry dates back only fifty years. Putting the focus on the economic point of view, the video game industry has reached a sales value of 2.4 billion euros in the Italian territory, with a performance of 10.2%; the turnover, therefore, was more than doubled compared to 2016, when sales presented a value of just over one billion euros.

The hardware retail-related portion of sales is 368.1 million euros, with a compound annual growth rate (CAGR) of 2.3%, while the software retail-related portion is 2042.8 million euros, with a CAGR of 12.6%. Some aspects related to the video game world are reflected in clear legal regulations. Relevant among these is Directive 2009/24/EC of the European Parliament and of the Council of April 23, 2009 on the legal protection of computer programs, which in Article 4 paragraph 2 states, "The first sale of the copy of a program in the Community by the right holder or with his consent shall exhaust the right of distribution of the copy within the Community, with the exception of the right to control the further rental of the program or a copy thereof." Although the gaming industry brings social and economic benefits to society, it is also worth investigating the impacts of this sector on the environment. Based on what that is known about the bio-physical limits of the planet, it seems quite likely that, sooner than expected, more severe choices will have to be faced than anticipated. Choices that, within the video game industry, take the form, for example, of a choice between focusing research and efforts on actions that might benefit a modest number of players or choices which could benefit everyone through concrete reductions in CO2 emissions. Indeed, by many researchers, the video game industry is called "a sustainability nightmare." As with environmental impact, the concept of dematerialization also needs to be analyzed within the video game industry. First, it should be pointed out that the definition of dematerialization, especially in reference to the world of video games, is overwritten by the definition of digitization (Laurent, 2017). It is identified as a process that is capable of transforming analog units into digital units and, consequently, which is capable of producing a good or service by making use of technology alone without making use of the materials that previously were used to produce the same.

The objective of this paper is to understand the possibility of implementing ISO 29110:2016, "Lifecycle profiles for Vero Small Entities," to the video gaming industry; to that end, a case study is presented of the company Cinic Games®, whose services rendered, and the benefits derived from the application of the standard.

2. Materials and methods

In the preamble to the document Transforming our world: the 2030 Agenda for Sustainable Development, the UN states, "The 17 Sustainable Development Goals and 169 targets build on the Millennium Development Goals and aim to complete what these have not succeeded in achieving. They are interconnected and indivisible and balance the three dimensions of sustainable development: the economic, social and environmental dimensions".

Istat, like the other National Statistical Institutes, is called upon by the Commission United Nations Statistics Commission to play an active role in the production of indicators for the measurement of sustainable development and the monitoring of its goals. Annually, the

institute owns the burden of an update or possible expansion of the statistical measures it through the SDGs Report.

In order to make the video game industry more sustainable, in September 2019, the "Playing for the Planet Alliance" was launched. By joining the Alliance, each member makes several commitments to environmental sustainability that can range from reducing CO_2 emissions to supporting the global environmental agenda (Maltais et al., 2018). In particular, the Playing for the Planet Alliance was established with the intent to support the industry's video games to achieve the following goals:

- Push the industry to reduce its carbon footprint and ensure that it possesses the means to measure, reduce and set goals for decarbonization;
- Promote environmental sustainability through the inclusion within the video game of activities, including interactive activities, that inspire video gamers to become increasingly green sensitive.
- Sharing what has been learned within such an initiative so that other companies in the industry can follow suit;
- Exploring new strategies for the future through new ways of video gaming and approaches, innovative approaches to storytelling.

The production of most software products fails, but not because of the fact that these do not possess a market, but because the cost of creating them far exceeds far exceeds any level of profit obtainable from the sale of them. The ISO/IEC 29110 "Lifecycle profiles for Very Small Entities" standard pursues the goal of to solve the problems identified above and to address the specific needs of enterprises in the private sector and to address the problem of low adoption of standards by small businesses. Within the standard resides the Management and Design Guide, which focuses its attention on Project Management and Software Implementation. The purpose of the project management process is to not only establish and complete in a systematically the tasks of a software implementation project, but also to meet the project objectives in terms of quality, time and cost.

The project management phase requires the generation of a project plan in order to direct the implementation of the software; Project Plan whose content, however, could change as a result of change requests that might arise during the implementation of the process. It should also be noted that the project plan mentioned above is subject to evaluation and monitoring throughout its duration, until the completion of the of Software Implementation and the closure of the project. The Software Implementation phase produces a specific software system implemented as a software product or service. This process begins with the definition of the software requirements, after which the designs are produced architectural and detailed designs. The software is built and verified using procedures for integration and testing. And finally, the final phase of the project coincides with the delivery of the product to the customer

3. Case study - Cinic Games™

Cinic Games is an independent company founded in Pisa in 2015 by Francesco Liotta with the purpose and ambition of creating strongly narrative video games with a peculiar artistic direction art for pc and consoles. The team consists of three partners and a few other multi-professional figures, with no headquarters and with an open and flexible business direction.

The company under examination has acquired a particular importance in the Italian territory mainly thanks to the videogame title produced by it: "The Wardrobe ©" masterpiece which in past years has enjoyed enviable success not only on the Italian territory but also on the foreign one. The company Cinic Games®, also, contextually to the mere realization of video game products, also offers three main services coinciding von three of the typical

functions of the Game Development process: Character Design, Story Development and Game Mechanics.

The production cycle adopted by the company has Game Development as its core activity, as it is for most video game companies in the world. The first phase consists of in the search for a concept that can be developed and, consequently, an appropriate analysis of the market having the primary objective of understanding whether the idea above turns out to be potentially profitable and successful. Accompanying the one previously described is the activity of forming a team of work, which involves the search for individuals who can cover the typical and necessary tasks for the project to come to life. Subsequently, the software house will make an estimated preliminary of the years in which the project will be carried out. As a direct consequence of the search for market indicated above, the company will work on identifying the target clientele to which the product and, consequently, the most suitable type of formula to meet the interests and demands of the target itself. Alongside the implementation of the activities just described, and particularly after successfully carrying out the reception of the physical-technical resources indicated above indicated, the company should take care to make an initial statement of the production budget required by the project.

The previously named roadmap is divided into three basic macro-phases. The first, called Pre-Production, involves the drafting of the GDD (Game Design Document). The GDD is a software design document that serves as a guideline on which the entire base the entire Game Development activity and, in particular, helps define the scope of the game and sets the overall direction of the project. Its structure consists of the following cores Thematic cores: 1. Overview; 2. Mechanics; 3. Dynamics;4. Aesthetics; 5. Experience; 6. Assumptions and Costrains (Salazar et al., 2012).

Having carried out a complete and exhaustive drafting of the GDD, the Pre-Production phase involves the creation of a "tech demo" aimed at validating not only the game mechanics, but also of the "core loop", where that term refers to that set of actions that the videogame player is asked to perform repeatedly within the video game. The next phase, called Production, focuses on the production of all the assets required for the realization of the project, their implementation and the completion of the tasks of each individual function. Also within the same phase is the realization of a "vertical slice"; the term stands for the realization of a version demo of the video game having the purpose of being shown to potential publishers as well as potential backers of the project. Finally, the last phase of the roadmap is Post-Production. In this last part of the of production efforts and energies are used to optimize and stabilize the game. In the post-production phase, the team's efforts are also directed to the realization of patch notes, DLC (Downloadable Content) or additional downloadable content (Lizardi, 2012). As already evident from the presentation of ISO/IEC 29110 made earlier, it offers a general model for Software development that promotes the best practices of the other existing process standards, which is flexible enough to be used in very small development organizations. In this sense, ISO/IEC 29110 could be an ideal model for the video game industry, as it would allow small software houses in the industry to adopt more mature approaches to software development. The following is aproposal for application of the ISO/IEC 29110 standard to the Cinic Games ® company; application which, upstream, is feasible because Cinic Games ® itself falls within the definition of VSEs (Very Small Entities) provided by ISO/IEC 29110-1:2016.

That said, it is possible to define and present a proposed model that is not only able to combine the process of Software Development as described by the standard and the iterative production process undertaken by the company under consideration, but also one that is potentially able to overcome the critical issues of the application of the standard to the video game industry that will be exposed later. The model, in particular, makes it possible to be able to merge the activities of Project Management and Software Implementation proposed by the ISO/IEC 29110 standard with the typical phases of the roadmap followed by the enterprise

(ISO/IEC 29110, 2016). In the proposed application-integrative model, the Project Planning phase coincides with and should take place in the Pre-Production phase. In particular, during Pre-Production will have to be integrated the activities, usually preceding this phase but falling within the Project Planning, which include the search for a concept that can be developed, market analysis and the identification of the target clientele; to these are also added the search for resources, physical and financial, which, as imposed by the standard analyzed here, should be meticulously measured and described or, if necessary, estimated; these measurements or estimates will have to, then, necessarily be reported in stand-alone documentation that will be part of the larger broader final documentation useful for the certification process. Putting the focus on the middle section of the proposed model, note how at the stage of the Production of the roadmap, the phases of Project Plan Execution and Project Assessment and Control. In this section, the actual software development will begin upon following the approval of the Project Plan. In addition, the company, in addition to the monitoring and quality assurance that it already implements, will have to document everything within appropriate documentations and, in particular, it is expected to prepare the progress Status record, as described above.

In addition to these activities, the company will need to follow up and document the Software Implementation phases and in particular the first 5 phases. Finally, within the Post-Production phase come both the Project Closure activity and only following a successful Review Meeting with the customer, the last phase of the Software Implementation, or Product Delivery.

4. Results and discussion

Based on the above considerations, it is possible to present the possible risks and benefits arising from the application of the integrative-modification model proposed above. In particular, one of the main issues arising from the application of the model is the possible lack of iterative development support, especially within the design phases. In addition, the application of the steps proposed by the standard to the production process, could make the latter somewhat cumbersome, especially with reference to the additional documentation that the enterprise will have to draw up (O'Connor, 2012).

The application of the model proposed above, could erode the flexibility available to the enterprise. Such complexity could lead to a significant increase in production timelines.

The integrative-application model would lead the company to reap several benefits of both an economic and environmental nature. In particular, it would greatly improve the company's efficiency from an organizational perspective; in particular, it would enable Cinic Games to improve the design phases of video game product development, avoiding thus wasting resources in terms of money and time, but more importantly it would allow the company to improve its quality assurance activities, allowing it to save costs additional costs. Regarding environmental benefits, it is known from company data that the company, despite not having a physical production site, nevertheless turns out to make use of a large amount of electricity for software development. Energy use that, protracted over the period of time required for software development, causes a not inconsiderable amount of CO_2 emitted into the atmosphere (Kasurinen et al., 2013).

The standard proposed here would help the company reduce the consumption of electrical energy. For these reasons, ISO 29110 certification would help the company to empower itself from the perspective of eco-sustainability, while also enabling it to enrich its brand equity towards its chosen target audience and towards potential investors.

5. Concluding remarks

In consideration of the preceding arguments, the ISO 29110 standard presents itself as a potential opportunity, not only for Cinic Games ® but also for other companies within the industry, net of necessary changes to be made to the standard for its full applicability to the company, chief among which are the adoption of a more flexible approach that is able to able to support reiterative processes within the larger process of making the software so that the flexibility that the company has at its disposal is not affected, to change the cards on the table and to be able to contribute, above all, to the development and awareness within the industry of environmentally sustainable issues (ISO/IEC 29110-1, 2016). For these reasons, Cinic Games ® could be the forerunner of a long path that would lead Italian companies belonging to the sector to become eco-sustainable and, for that reason, to assert even more within the market Italian the potential and importance of the industry for economic recovery following the COVID-19 pandemic.

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RifiuTIAMOci: ECO-EFFICIENT MANAGEMENT OF URBAN WASTE*

Matteo Lombardi**

Ellequadro Ingegneria srls, Via E. D'Onofrio 57, 00155 Rome, Italy

Abstract

In the concept of circular economy there is more and more talk of intervening upstream of the production of waste, intervening on the differentiated system downstream of use, but there is no fundamental step inside the homes. The step consists in reflecting on what happens inside the houses introducing a score alarm in the house.
The design idea is to intervene with the census inside the houses on the potential waste present. In every house there are various objects that are potentially waste but which remain silent until they become waste. The house, however, becomes a flow of objects that is always unbalanced towards accumulation to the detriment of its disposal. The idea was born precisely from these concepts, in which to have an application that reminds at the user if and how many objects are owned in the house with a potential value of waste present in the house, also compared with estimated production waste for inhabitant. This census is a real window into the situation of each home that can lead to careful reflection and a general and personal improvement of one's habits.

Keywords: environmental impact, LCA, recovery, special waste

1. Introduction

The growth of waste generation rates is an important issue in the whole world. For us is now important to reduce the waste. The concept of a circular economy has gained significant attention in recent years, with increasing emphasis on addressing waste generation at various stages of the product lifecycle (Ellen MacArthur Foundation, 2019). While efforts have been focused on intervening upstream of waste production and implementing effective waste management systems downstream, one crucial step has often been overlooked - the need for

*Selection and peer-review under responsibility of the ECOMONDO
** Corresponding author: e-mail: amministrazione@ellequadroingegneria.it; info@ellequadroingegneria.it

fundamental interventions within our own homes. Within the context of a circular economy, it is essential to recognize the significant role that households play in the generation and management of waste (European Commission, 2020). Despite advancements in waste management infrastructure and recycling programs, the success of these initiatives ultimately depends on individual behaviors and choices made within households. Intervening at the source, inside our homes, becomes a fundamental step toward achieving a more sustainable and circular approach to waste management (Kaza et al., 2018).

By targeting interventions within households, we have the opportunity to address the root causes of waste generation. This includes raising awareness about consumption patterns, promoting responsible purchasing decisions, and encouraging waste reduction and recycling practices at the household level. Implementing effective waste segregation systems within homes and providing access to appropriate recycling facilities can significantly contribute to reducing waste sent to landfills and maximizing resource recovery (Feitosa et al., 2016). Furthermore, education and awareness campaigns aimed at households can foster a culture of sustainability and empower individuals to take proactive steps in waste reduction. By promoting behavioral changes and providing practical guidance on waste management practices, we can create a collective impact that extends beyond individual households and contributes to a more circular economy.

We always work with refusal from the conferred, leaving out the potential refusal we have inside the house. To play a great importance beyond the communication on how to differentiate also the awareness on the reduction of the production of decline. This must be done by giving the population technological tools with the possibility of self-regulating. The data of waste produced are in various studies, but these are non-personal and aseptic data and do not arouse the right reflection that each of us should do (Gorbenko et al., 2021; Hoornweg et al., 2013).

Since the growth of waste generation rates is a pressing global concern that requires immediate attention, it is crucial for us to focus on waste reduction strategies. While we often prioritize the waste we dispose of externally, it is necessary to address the potential waste generated within households. Achieving significant progress in waste reduction entails effective communication, emphasizing the importance of waste differentiation, and raising awareness about declining waste production (Dzawanda and Moyo, 2022; Gopal Sahoo, 2021).

To effectively tackle this issue, it is imperative to equip the population with technological tools that enable self-regulation. By providing individuals with the means to monitor and manage their waste output, it is possible to empower them to actively contribute to waste reduction efforts. This approach emphasizes personal responsibility and encourages individuals to make conscious decisions regarding their consumption and disposal habits (Phuong et al., 2021; Torio et al., 2020).

While various studies provide data on waste generation, it is important to note that these figures often lack a personal connection and fail to inspire the necessary introspection within each individual. It is crucial for each of us to reflect upon our personal waste production and its implications for the environment and society. By fostering a sense of responsibility and encouraging self-reflection, we can foster a more sustainable and waste-conscious society (Stöckert and Bogner, 2021)

The objectives of this application is to make everyone aware of the impact that their behavior has on the environment and on the circular economy in general. Giving full awareness to every citizen of how he acts with good actions to safeguard the environment is an element that stimulates the reflection and my improvement in general of those who want to participate in personal improvement.

The development of this application was divided into the following phases:

- identify the bibliographic data made available;
- develop an app that contains such data;
- analyze the necessary needs of users to make this application bearer of benefits;
- analyze the results and formulate the relative conclusions.

2. Materials and methods

The application was created using the Microsoft Visual Studio Community 2019 development environment. The starting data of the single Municipalities have been uploaded from the official ISPRA data which it publishes annually (hiips://www.catasto-rifiuti.isprambiente.it/index.php?pg=comune&aa=2020&regid=12058&nomereg=Lazio&p=1). Once registered (Fig. 1), users are prompted daily to input their activities, such as purchases or disposals. By tracking these actions, the application calculates the volume of waste generated at home each day, providing users with valuable insights and assessments (Fig. 2). From these, the user registry was populated. This application, after registration (Fig. 1) ask every day the operations that people use made like if he buys something or if trash something. With this it can be counted how many liters of waste you have at home every day and this returns a good user assessment (Fig. 2). This feedback allows users to evaluate their waste production and make informed decisions to reduce it.

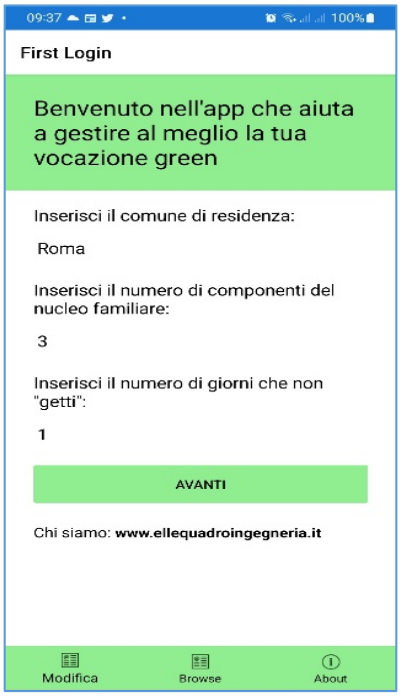

Fig. 1. Registration

Fig. 2. Score

The application was created using the Microsoft Visual Studio Community 2019 development environment. The programming language is C # and for the development of a multi-platform IOS and Android mobile app it was decided to use the popular toolkit "Xamarin.Forms ". Xamarin Forms provides the most common components of a Model-View-

ViewModel (MVVM) framework, making the link between data and user interface simple and intuitive, separating them from the rest of the application. The key elements of the MVVM pattern are:

• Models: represent the data, the business entities of an application.

• Views: represent the pages (or screens) of an application, together with all the elements that make up the appearance of what the user sees on the screen. Ideally, the View is defined exclusively with XAML, which does not contain the business logic

• Models of the View: they act as an intermediary between the View and the Model, and are responsible for managing the logic of the View. Typically, it interacts with the model by invoking methods in the classes of the Model. The View Model then provides the data from the model in a form that the View can use easily.

• Binder: The fundamental mechanism for this pattern by which the View Models and the view are constantly kept synchronized, typically through a declarative syntax within the view itself. This implies that data changes made by the user through the View will automatically be reflected in the View Templates, without this burden on the developer.

The application opens on a first login page, where the user enters residence data, number of family members and number of days of non "revenue" to initialize the app counters. Subsequently, the user indicates daily the amount of material that is introduced and what is unloaded from their home. Finally, there is a results page, where the user can view the periodic trend of waste management, and compare it with the city average.

5. Results and discussion

The extrapolation of the data clearly shows how much the percentage of waste to be differentiated can still be reduced but above all how much it can affect the initial production value. In the municipalities where the differentiated waste collection is started, the value of waste reduced by many percentage points, even reaching half of the annual waste produced. The data analyzed were those of the province of Rome. As can be seen from Fig. 3, cost ranges from 129 to 324 € / inhabitant / year as well as the estimated annual production ranging from 242 to values greater than 500 kg / inhabitant * year (Fig. 4).

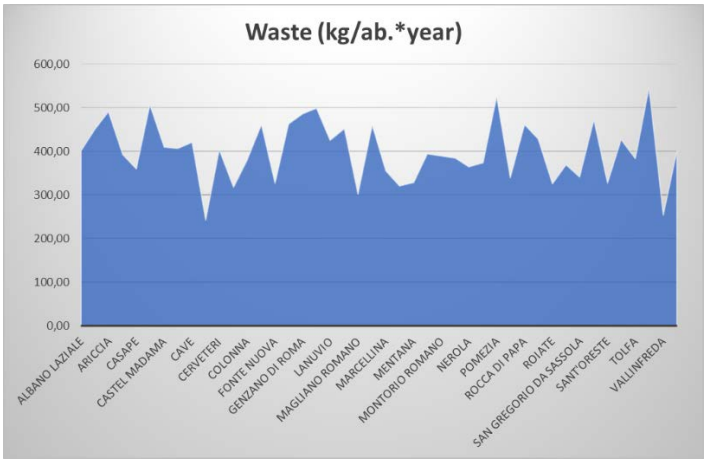

Fig. 3. Production of waste

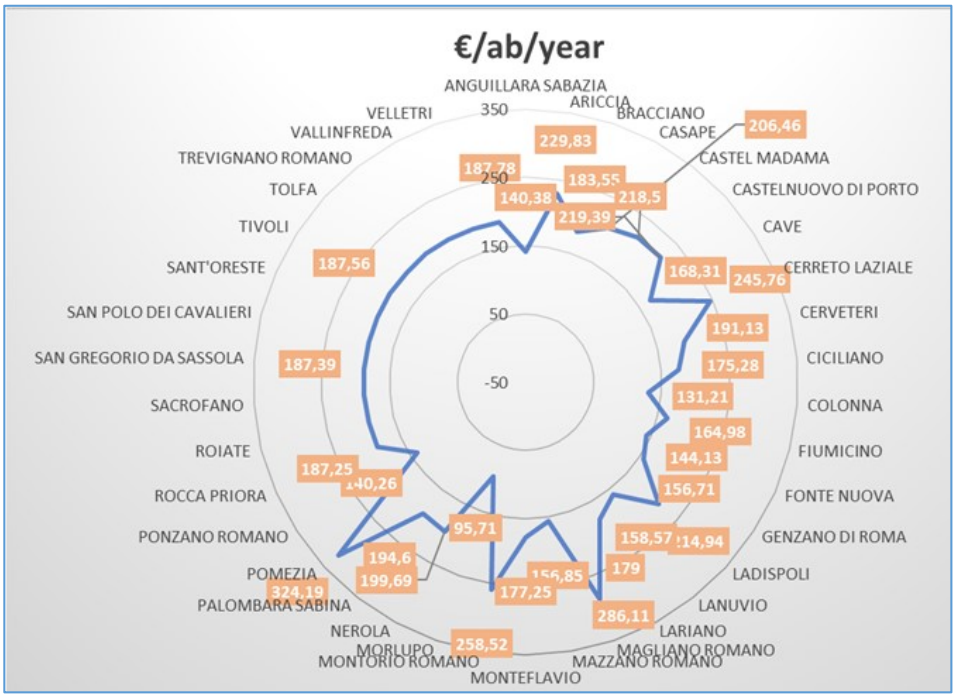

Fig. 4. Cost €/ab/year

From the production data it is clear that the quantity of annual waste produced in the Municipalities are the same annually but what varies is the different type of waste produced. Instead, what must be reversed is what is generally produced as waste by eliminating what increases its quantity.

By imposing a maximum annual production value for each citizen and inserting this parameter also on production, it would generally allow environmental savings of the order of several percentage points while generating fewer resources to be used on collection services.

6. Concluding remarks

The first data collection highlighted how there is still little awareness of what our waste generation behaviors are and what we actually introduce at home while the awareness of how to properly separate waste is higher. If combined, these data could be used by municipal administrations in terms of organizing services and avoiding collection crises in the face of enormous accumulations of waste. Generally, these are associated with festivities in a bibliographic manner while in this case an excess of production could be expected in some areas in the face of the reporting of the conferring users. We saw that only 1% for every people (about 5 kg a year) is possible to reduce more than 100.000.000 € the cost of the waste.

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ECONOMIC AND FINANCIAL ANALYSIS OF PLANTS FOR OBTAINING ENERGY FROM HYDROGEN*

Nicolò Mazzoleni, Sergio Arfò, Alberto Zufalo, Rosario Carrabino, Antonio Zerbo**

Department Economics and Business, University of Catania, Corso Italia 55, 95129, Catania, Italy

Abstract

To meet the needs of decarbonisation of the economy and the implementation of the Italian PNRR, hydrogen appears to be a current and convenient source for obtaining energy. The paper tries to evaluate some pilot projects located in the Sicily region from an economic and environmental point of view. After analyzing the Sicilian energy plan, the project carried out by a collaboration with two companies is described, of which a technical and economic analysis is carried out, highlighting the economic and environmental advantages of the pilot plant. This experimental project can allow cooperating companies to test the idea on an industrial scale, to enhance the Sicilian competitive environment and make technological innovations for the generation, storage and transport of green hydrogen in the Sicilian region, a hub for hydrogen clean consists of a regional network consisting of the production, the end use and the connection infrastructure necessary to produce and transport clean hydrogen in a functional regional market.

Keywords: circular economy, hydrogen energy, industrial area, sustainability

1. Introduction

According to the Integrated National Energy and Climate Plan ("INECP"), published in December 2019 by the Ministry of Economic Development together with the Ministry of the Environment and the Ministry of Infrastructure and Transport, one of the primary objectives that Italy aims to achieve by 2030 is the reduction of about 30% of national

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** Corresponding author: e-mail: arfosergio@gmail.com;

greenhouse gas emissions. With this in mind, hydrogen plays a key role in achieving this goal due to its unique chemical and physical characteristics (Crabtree and Dresselhaus, 2008).

The Italian legal framework governing the production, operation and connection of hydrogen is quite fragmented and this has often proved to be an obstacle to the development of new projects. For example, although the authorization process for hydrogen production and storage is set at national level, local public authorities may have different requirements regarding land use. This divergence can lead to uncertainties in terms of project funding and timing.

Another relevant aspect is the lack of a clear distinction, in terms of authorization procedures, between:

- the production of hydrogen for industrial use obtained by the reforming process;
- the production of green hydrogen obtained through the electrolysis process.

The Italian environmental authorities do not distinguish between these two processes with the result of imposing the same level of restrictions, even if electrolysis is an extremely more sustainable production process, almost zero impact, compared to steam reforming, which generates CO_2 emissions. Therefore, it is desirable to introduce different authorization regulations based on the dimensional scale of the plants and which distinguish hydrogen production processes that involve greenhouse gas emissions from those with low or zero emission levels (Barisano, 2021).

On 23 October 2018, the Ministry of the Interior, in agreement with the Ministry of Infrastructure and Transport, issued a Ministerial Decree containing "Fire prevention technical standards for the design, construction and operation of hydrogen distribution systems for motor vehicles ". The objectives of the technical regulation are to minimize the causes of fire and explosion; limiting damage to people and buildings in the event of an event and allowing rescue to be carried out safely. The “Energy efficiency, mobility, hydrogen decree” (not yet issued) for the launch of the ecological transition is being drafted. It is considered optimal to transfer all the Mise competences on renewables, decarbonisation, energy efficiency, research, sustainable mobility, hydrogen plan and sector strategies, etc to Mite (Capozza et al., 2021).

It is necessary to differentiate hydrogen based on the production process through which it is obtained:

- Gray hydrogen: it is the most polluting, as its production generates emissions of CO_2. It represents the majority of hydrogen produced today (about 95%)
- Blue hydrogen: with low CO_2 emissions. It is carried out through the steam reforming of methane, but associated with a process of capturing and storing the greenhouse gases produced through this process, or, carried out with electrolysis, but powered by low-emission electricity sources (such as nuclear power plants) or in turn associated with a capture & storage method.
- Green hydrogen: zero or close to zero emissions. It includes: o that produced by electrolysis in electrolysers powered by energy from renewable sources; o clean hydrogen from bioenergy;
- Turquoise (or circular) hydrogen: it is produced from waste, by pyrolysis and subsequent purification. Green hydrogen seems to be the only viable alternative capable of generating an important reduction in emissions of CO_2.

The objective of this PAPER is to verify the effective applicability and functionality that hydrogen can have in the process of decarbonization of the economy. To achieve this goal, the analysis of a case study was carried out concerning the project implemented, in collaboration with two companies in the sector, aimed at the creation of a hypothetical innovative Hydrogen Hub in the Catania hub.

2. Materials and methods

Hydrogen is a very important molecule with an enormous range of applications and uses. The main uses are: oil refining, ammonia production, methanol production, steel production through the direct reduction of iron ore, fertilizer production and food processing (Zhang et al., 2021). The uses of hydrogen can be roughly divided into the following categories:

- As a reagent in hydrogenation processes;
- As a CO_2 "scavenger";
- As a fuel;
- As a refrigerant in electric generators.

In most applications of hydrogen as a reagent, hydrogenation takes place to insert hydrogen in order to saturate the molecules or to split them in order to remove atoms such as sulfur or nitrogen (Popa et al., 2015). Hydrogen as a reagent is used above all in the chemical and petroleum industry: among the most frequent uses we find: Ammonia production (almost 50%), petroleum refining (37%) and methanol production (8%). A sudden increase in the use of hydrogen within oil refining is expected due to changes in environmental regulations, which have become more stringent (Ramachadran and Menon, 1998). The primary application of hydrogen as a fuel occurs in the aerospace industry. The combination of liquid hydrogen and oxygen has been used as a propellant for numerous applications for several years. A mixture of H_2 and O_2 is able to release the highest value of energy per unit weight of propellant, a property that is fundamental in aerospace applications (Aline, 2008). Hydrogen can then be used inside fuel cells, devices that convert hydrogen and oxygen into electricity, they represent a valid alternative to fossil fuels for their efficiency, versatility and environmental sustainability.

Different types, of different sizes, of fuel cells are available for various applications: small cells can power laptops or mobile phones, large cells instead can supply power to electric grids, emergency energy systems and allow to supply electricity to places not connected to a eletricity grid. Carbon Capture, Usage and Storage (CCUS) technology can be applied to both SMR and ATR hydrogen production. The use of CCUS with SMR plants can lead to a reduction in carbon emissions of up to 90%, when applied to both process and energy emission streams. There are several ways in which CO_2 capture can take place in an SMR facility. CO_2 can be separated from the high pressure synthesis gas stream, reducing emissions by up to 60%. CO_2 can also be captured by the more diluted furnace fumes. This can increase the level of overall emissions reductions by up to 90% or more, but it also increases costs. ATR is an alternative technology in which the required heat is produced in the reformer itself. This means that all CO_2 is produced inside the reactor, which allows for higher CO_2 recovery rates than those achievable with SMR. The splitting of methane offers a potential new way to produce hydrogen from natural gas. Several technologies have been developed since the 1990s. The main technology is based on three-phase AC plasma and uses methane as a raw material and electricity as an energy source.

Splitting methane requires high-temperature plasma and significant thermal losses reduce its efficiency advantage, but it uses three to five times less electricity than electrolysis for the same amount of hydrogen produced. It produces a small amount of CO_2 and creates solid carbon in the form of carbon black. It requires more natural gas than electrolysis, but could create additional revenue streams from the sale of carbon black for use in rubber, tires, printers and plastics.

Water electrolysis is an electrochemical process that divides water into hydrogen and oxygen. Today, there are three main electrolysis technologies: alkaline electrolysis, proton exchange membrane electrolysis (PEM), and solid oxide electrolysis cells (SOEC):

- Alkaline electrolysis: it is the method with greater maturity and greater commercial diffusion. The system consists of a pair of electrodes immersed in an alkaline solution, usually potassium hydroxide (KOH) at a concentration of 25 to 30% and separated by a diaphragm. In the cathode the water is split to form H2 and release hydroxide anions which pass through the diaphragm and recombine at the anode to form O_2.
- Proton Exchange Membrane Electrolysis (PEM): PEM electrolyser systems were first introduced in the 1960s by General Electric to overcome some of the operational drawbacks of alkaline electrolysers. They use pure water as an electrolyte solution, thus avoiding the recovery and recycling of the potassium hydroxide electrolyte solution needed with alkaline electrolyzers.

They are relatively small, which makes them potentially more attractive than alkaline electrolysers in dense urban areas. They are capable of producing highly compressed hydrogen for decentralized production and storage at filling stations. In the face of this, however, they need expensive catalysts for electrodes (platinum, iridium) and materials for membranes, and their lifespan is currently less than that of alkaline electrolysers. Their overall costs are currently higher than those of alkaline electrolysers and are less common. Solid oxide electrolysis cells (SOEC): they are the least developed electrolysis technology; they have not yet been commercialized.

3. Case study

Sicily can be an excellent starting area for the implementation of a transition to a hydrogen economy, in fact, this region has the following characteristics that make it an excellent starting zone:

- its good availability of renewable resources at competitive costs given the high solar radiation in the region and the potential for imports from North Africa at even lower costs;
- limited interconnection with the rest of the Italian electricity grid due to physical constraints to be connected via submarine cables;
- an existing capillary natural gas network: the area has a transmission network of 1,100 km of national pipelines and 1,500 km of regional pipelines, as well as a large network that covers all cities
- good mix of final applications on the demand side, the region has 1.6 million gas-powered residential and commercial companies, the transport sector has 80,000 medium and heavy trucks and buses, as well as 578 km of diesel railways, and Sicily also includes refineries with a current production volume of 0.7 Mbbl per day.

The Environmental Energy Plan of the Sicilian Region (Pears), is the programmatic document which, in line with the European objectives of the 'Green Deal', defines the evolution of the regional energy system up to 2030, through useful actions for the energy transition and decarbonisation (Matarazzo et al., 2022). The plan envisages two main objectives: the reduction of energy consumption in end uses, with particular reference to the civil-agricultural sector and to the transport sector (smart mobility); the increase in the share of renewable energy, with an estimated incidence of 68% by 2030 on the total regional energy production, compared to 33% in 2019. The plan also focuses on the modernization of existing photovoltaic and wind systems and on the installation of new plants in suitable areas, which are primarily disused quarries and landfills, unproductive agricultural land, industrial sites.

All the professionals involved in the hydrogen supply chain will participate in the observatory, from renewable energy producers to academic professors involved in research.

The project will be developed in collaboration with two companies in the sector and will aim to accelerate the full commercial maturity of all those technologies that make it possible to produce green hydrogen in a sustainable and competitive way. Enel manages a large part of the country's electricity distribution network and offers integrated solutions for products and services for electricity and gas. In total, the group in question has a net installed capacity of over 84 GW and distributes electricity and gas to approximately 69 million customers thanks to a network of approximately 2.2 million kilometers (Di Leo et al., 2020). The production of electricity is made from various energy sources including geothermal, wind, photovoltaic, hydroelectric, thermoelectric, nuclear, biomass and solar thermodynamic. In the year 2021, the Enel group produced a total of 232 billion kWh of electricity, distributed 510.3 billion kWh on its networks and sold 309.4 billion Kwh.

4. Results and discussion

A clean hydrogen hub is a regional network consisting of the production, end use and connection infrastructure needed to produce, transport, store and use clean hydrogen in a functional regional market. These potentially large demonstration projects aim to test and demonstrate the technologies needed to minimize the greenhouse gas (GHG) emission intensity of hydrogen production, use it in new applications to aid decarbonization and store it and transport it in new ways to meet the demands of a newly formed national hydrogen market.

The development of a Hydrogen Hub in Sicily is at the very heart of the collaboration between these two companies, which intends to activate a supply of green hydrogen produced from renewable energy from the Carlentini wind farm in eastern Sicily (Saccani et al., 2020). The more than 200 tons of estimated production capacity of the Sicilian hub are the subject of the annual supply provided for in the agreement.

Once fully operational, green hydrogen will be produced primarily by a 4 MW electrolyser, powered exclusively by renewable energy from the existing wind farm, and to a lesser extent by state-of-the-art platform-tested electrolysis systems. Launched by one of these companies in the sector in September 2021, NextHy's Hydrogen Industrial Lab is a unique example of an industrial laboratory where production is constantly accompanied by technological research. In addition to the sectors reserved for large-scale production, there are also areas dedicated to the experimentation of new electrolysers, components such as valves and compressors, and innovative liquid and solid storage systems. This is an ambitious project that focuses on a sustainable energy source that will develop at every link in the supply chain: in NextHy green hydrogen will not only be produced, stored and moved to an industrial scale, but also purchased and used by companies that have understood that green hydrogen is the solution to decarbonize their production processes.

One of the two groups, founded in 1922 and based in Monza, operates in the industrial and medical gas sectors and in home care throughout Italy and abroad in France, Germany, Slovenia, Turkey and Spain. With a turnover of over 700 million euros and 2,250 employees, it produces, develops and markets gas, innovative technologies and integrated services for the industrial sector. To carry out a satisfactory technical and economic analysis, it is appropriate to implement the 3S (Source, System, Service) analysis method. In terms of energy source (Source), a company has chosen to exploit the Carlentini wind plant, a plant built by the same company, inaugurated in December 2001. The structure consists of two wind farms: Carlentini 1, consisting of 11 wind turbines and Carlentini 2, consisting of 17 wind turbines of 850 kW.

The total power of the two parks is 21.7 MW and the expected production of approximately 38 million kilowatt hours. The exploitation of this wind farm will allow one of the two companies to make significant savings in terms of costs, as the company will be able to count on its own structure, of which, as regards the Carlentini 1 park, it has already amortized the costs of construction, which amount to approximately 6.2 million euros, over 20 years, while for Carlentini 2 it was possible to amortize the costs for approximately 14 years (Billi et al., 1986).

As for the second S (System), reference can be made to the operational arm of the Nexthy project, namely the Hydrogen Live Industrial Platform located between Carlentini and Sortino. This plant will leverage a 4 mw electrolyser with a production capacity of 245 t/year and will also act as a yardstick for the test platform, located alongside it, which will be able to test new technologies for hydrogen: electrolyzers up to three MW, innovative stacks or storage systems and components necessary for the production of hydrogen can be tested.

Finally, as regards the last S (Service), the analysis can be divided into two dimensions: o Marketing service in collaboration with one of the two companies; o Research and innovation service in collaboration with partners, stakeholders and innovative startups.

The transport of the product will be carried out through a network of hydrogen pipelines and cylinder wagons already available to the company that has set itself several goals:

- Being able to reliably and safely satisfy both production and energy efficiency industrial needs;
- Contribute to the creation of the demand for green hydrogen, collaborating with public services such as, for example, public transport;
- Building the largest green hydrogen hub in Southern Italy.

What the company is looking for are new solutions, based on both new technologies and existing technologies, but revisited to reduce costs and increase efficiency and sustainability, looking at both electrolysers and storage systems (Rubin et al., 2013). The proposals received are evaluated and selected on the basis of expected performance, maturity and sustainability.

5. Concluding remarks

The project developed by one of the two companies, in collaboration with another in the sector, can give unprecedented impetus to the economy of the Italian island, generating a significant amount of environmental benefits, allowing to avoid the emission of tot kg of CO_2 per year, giving the possibility to offer a balancing service to renewable energies, managing to accumulate the energy produced in excess, and at an economic level, leading to the development of the work chain and consequently to the formation of new jobs.

Work, attracting foreign investments, reducing the costs of the various energy-intensive industrial chains and contributing to the increase of the region's tourist attractiveness by improving its image from a green point of view. The advantages of using green hydrogen in various application fields are undoubted: using it as an energy source, in terms of environmental impact, both CO_2 and particulate emissions are drastically reduced, which would derive alternatively from the use of fossil fuels. ; as an energy carrier it allows greater efficiency in the production of renewable energy sources by allowing the storage of excess energy during peak production hours.

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INDUSTRIAL SYMBIOSIS - FASHION SECTOR: CHIENGORA STARTUP – TECHNOLOGICAL INNOVATION*

Federico Motta[1], Federico Mertoli[1], Antonio Zerbo[1], Raffaele Puleo[1], Samuele Russo[2]**

[1]Department of Economics and Business, University of Catania, Corso Italia 55, 95129, Catania, Italy
[2]Department of Economics and Business, Luiss University Guido Carli, Viale Romania 32, 00197, Roma, Italy

Abstract

The project is related to “the industrial symbiosis for the National circular economy strategy” and comes from the increasingly current need to bring the textile market closer to sustainability. The idea is based on the use of canine undercoat also called "Chiengora" to create wovens. This type of waste is generated naturally with the dogs brushing and allows the creation of knitwear and clothing fabrics. Obtaining the raw material is the project keypoint, to be able to create a network of highly relevant and branched agreements to better optimize the collection of Chiengora waste through pet shops, breeders and dog owners. The goal is to create an app that can interface with suppliers that can report the achievement of a certain quantity, and customers who can easily purchase the items and products available. The project starts from the transformation process, from the raw material to the final product, with the possibility of being able to create different finenesses, up to the 24 thousand count, obtaining different fabrics and knits.

Keywords: Chiengora, fashion sector, industrial symbiosis, start up, technological innovation

1. Introduction

The traditional production model is the one related to the so-called linear economy based on the pattern of "extract, produce, use and throw away". This model turns out to be

*Selection and peer-review under responsibility of the ECOMONDO
** Corresponding author: e-mail: federicomertoli@hotmail.it

highly detrimental to the planet. Industrial symbiosis encourages the transformation of linear supply chains into interconnected systems, where waste from one industry becomes a valuable input for another. This concept promotes the circular economy principles of reducing waste, recycling materials, and extending the lifespan of resources. By implementing industrial symbiosis, industries can minimize their environmental impact, conserve natural resources, and foster sustainable economic growth (Astarita, 2017; Brunori et al., 2016; Cutaia et al., 2015). By transforming linear supply chains into interconnected systems, industrial symbiosis allows for the circulation of materials and resources within a network of industries, mimicking the nutrient cycles in natural ecosystems. Instead of considering waste as a liability, industrial symbiosis views it as a potential resource that can be utilized by other industries, thereby reducing the need for new raw materials and minimizing environmental impacts.

In fact, the traditional economic system is being increasingly replaced every day by that of the Circular Economy. The intent of this model is to reduce the waste of natural resources belonging to all kinds of sectors by being more efficient. It revalues the quality and quantity of goods by reusing, repairing, reconditioning and recycling materials and products in the market (Mancuso and Fantin, 2017). The circular economy principles mentioned align with the goals of industrial ecology. By reducing waste, recycling materials, and extending the lifespan of resources, industrial ecology aims to create closed-loop systems where resources are continuously cycled and reused. This approach helps to minimize the extraction of new resources, decrease pollution, and improve overall environmental sustainability (Ehrenfeld, 2004).

As soon as the asset's state of dormancy is reached, such a system allows the creation of a link between different types of assets, so as to reintroduce the materials of which it is composed into the same, or different, production cycle and allow some waste to become resources in other production cycles (Scilletta et al., 2020). Doing so, the effect is to extend the products life cycle. It is important to take measurability into account, to achieve positive economic, social and environmental feedbacks.

With various tools and indicators both economic and capable of measuring the physical part, like material and energy flows, it is possible to assess the degree of circularity of any resource. Thus, the European Commission has developed, through a working group, a set of indicators to measure the circularity performance of the 27 European countries. (Villari et al., 2020). Within the territory of the European Union, in June 2018, the "Circular Economy Package," an action plan aimed at promulgating the transition to the circular economy, has been institutionalized (Razzante, 2018).

The aim was to realize the fundamental goals for the environment and economy: an average annual reduction in emissions of about 617 million tons of CO_2 and, according to European Parliament estimates, up to 7 percent more GDP growth by 2035. The paper purpose is to propose and analyze a start-up idea from the perspective of circular economy in the textile-fashion sector. The business idea named "Pom Era" intends to reduce the waste generated by pet stores, breeders, kennels and individual owners. The main goal is to be able to collect Chiengora's waste and then to create a network with suppliers to use the waste for the purpose of making textiles and garments and thus transform a waste and reinsert it within a production cycle through transformation processes that can be either artisanal or industrial.

2. Materials and methods

Italy is the third-largest textile-clothing exporting country in the world, the trend of revenue growth remains stable and the Italian Fashion brands like Luxottica, Ferragamo, Moncler and Prada have marked a relevant performance in 2016. In fact, it is quite evident how Made in Italy is attractive to the eyes of the rest of the world in the textile sector. The

changes that will be a consequence of new consumer trends will bring new supply choices from manufacturers and end sellers toward the circular economy. By the end of 2021, a record 80 billion in turnover has been reached, with an increasing importance of Italian GDP, which will exceed 1.2 percent (Benini, 2016). Textile products must comply with the provisions of general EU consumer goods legislation, such as: the General Product Safety Directive (EC Directive, 2001), which establishes general safety requirements for all products placed on the market for consumers; the REACH regulation (EC Regulation, 2006); the Biocides Regulation (EU Regulation No. 528/2012 concerning the making available on the market and use of biocidal products); and EU Regulation No. 850/2004 on persistent organic pollutants. New provisions on the use of the terms "leather" and "fur" and those derived from them or their synonyms and the related sanctioning discipline (Law 68, 2020), the provision imposes the obligation to label the composition of products that invoke the terms "leather," "skin," and "furs," sanctioning operators who fail to provide the information to consumers. This is a measure that updates the rule dating back to the 1960s with reference to new materials on the market and is a tool to counter unfair competition and counterfeiting, widespread in the leather and fur industry.

Globally, the textile industry is worth about $1.3 billion involving about 300 million people in the entire supply chain, the production of clothes has doubled, driven by a growth in purchasing by the middle class of the world's population; therefore, there has been a noticeable increase in collections from year to year and this phenomenon has been called "fast fashion" (hiips://ellenmacarthurfoundation.org/a-new-textiles-economy).

At the G7 in Biarritz in 2019, the 32 most important brands signed the "Fashion Pact" a document that aims to align the fashion industry with the UN Sustainable Development Goals (SDGs), the 17 goals set by the United Nations Organization focused on three major themes "climate," "biodiversity," and "oceans". This document was also created thanks to the goals previously drafted by the Science-Based Targets (SBT) Initiative (Rinaldi, 2019). This organization wants to stimulate businesses by providing useful information and tools in each work sector to improve environmental performance. All the questionnaires and surveys conducted around the world contain important information that makes it clear how consumers are slowly changing their purchasing choices and how demand is therefore changing, businesses that won't adapt to this change will see their turnovers drop by heading for bankruptcy in the long run (hiips://www.euromonitor.com/podcast/fashion-friday-sustainability-in-beauty-and-fashion).

The Global Organic Textile standard certification is among the most important in the textile industry with regard to sustainability, it is recognized and promoted by the leading organizations in organic agriculture, to try to ensure responsible development in the perspective of Circular economy. It is an international recognition that allows the company that are able to obtain it a competitive advantage to target environmentally conscious customers throughout the global market (Segre Reinach, 2015).

GOTS involves the issuance of a third-party verified environmental declaration that attests to: the organic natural fiber content of both intermediate and finished products; the maintenance of traceability throughout the entire production process; restrictions in the use of chemicals; and compliance with environmental and social criteria at all stages of the production chain, from field harvesting of natural fibers to the subsequent manufacturing stages, and the labeling of the finished product. Textiles, manufacturing operations and textile chemicals can be certified under GOTS.

The Global Organic Textile Standard guarantees: Products containing at least 70 percent natural fibers from organic agriculture, such as (but not limited to): fibers, yarns, fabrics, clothing, textile accessories, textile toys, household linens, mattresses and bedding, and personal care products. Manufacturing activities, such as dyeing or printing, carried out on behalf of third parties, which are provided by operators who have themselves adopted

management models and procedures that comply with the required requirements; Chemical products used in the processing of the textile industry that comply with the required requirements, through appropriate assessment, based mainly on the verification of toxicological characteristics. Fast fashion has a sharp increase in the amount of garments produced, used and then discarded. In February 2021, the European Parliament voted for the new Circular Economy Action Plan, calling for additional measures to achieve a zero-carbon, toxic-free and fully circular economy by 2050. Also included are tougher recycling standards and binding 2030 targets on material use and carbon footprint. Among the proposals, MEPs also called for new measures against the release of microfibers into the environment and stricter standards for water consumption. According to the European Environment Agency, textile purchases in the EU in 2017 generated about 654 kg of CO_2 emissions per person. The way people dispose of clothing they no longer want to keep at home has also changed: many garments are thrown away rather than donated. Since 1996, the amount of clothing purchased in the EU per person has increased by 40 percent as a result of a sudden drop in prices. This has led to a reduction in the life cycle of textile products: Europeans consume nearly 26 kg of textiles each year and they dispose about 11 kg of it. Used clothing may be exported outside the EU, but mostly it is incinerated or taken to landfill (87%). Globally, less than 1 percent of clothing is recycled as clothing, partly due to inadequate technologies. (European Environment Agency, 2020). According to the waste directive approved by the European Parliament in 2018, EU countries will be obliged to provide separate collection of textiles by 2025. The new strategy also includes measures to support circular materials and production processes, to counter the presence of hazardous chemicals, and help consumers choose sustainable textile products.

The Italian Ministry of Economic Development's plan "Impresa 4.0" sets policy and strategic goals to achieve the "Fourth Industrial Revolution" by which digitization and important technologies enable to change the way products, services and processes are made and implemented. The policies were based on four pillars: The support of digital investment; improvement of workers' skills; digital infrastructure, including 5G; and digital services through mechanisms of competence centers and digital hubs. In 2019, the Minister of Economic Development opened the door to funding for specific new technologies such as artificial intelligence (AI) and blockchain to have a more economically efficient fashion industry by minimizing human errors in the production process.

3. Case study

Currently, thousands of kilograms of Chiengora waste from all over the world are thrown away never to be reused again and ending up a very large part in landfills.

"Pom Era," wants to create an efficient and effective supply chain so that much of the waste can be sourced and turned into fabric, effectively achieving waste reduction and plastic free production. The startup plans to obtain funding through Invitalia, Private Equity, Crowdfunding, business angels, in order to gradually integrate the machinery of the production process and analyze and patent the best ways to obtain less impacting clothes. The very first action necessary to be carried out in order to eliminate any allergic substances, odors and clean the raw material is definitely the washing phase, the material has to be washed, in a manual way. Nowadays many machineries are able to wash also the Chiengora such as the Tumbler which is used to eliminate all the contaminations from the fibers and can be used both before. After this phase, a second washing is carried out through a machinery called Wash System where the fiber can be selected through 8 different types of washing including a soap with 3 different categories according to the degree of purity of the material.

Through another machinery called Pucker the fibers are placed and rotated inside after compacting the fibers an oil is introduced which serves to eliminate static electricity

and keeps the fiber elastic during the processes. The fiber separator is designed to selectively remove coarse guard hairs and other forms of contamination. The finer fibers are placed in the belt mold, in a collection box for further processing.

The next step involves the Carder which processes the material to stretch it and make it homogeneous, from this it can be made felt, knitted or woven because here the fibers are separated and aligned longitudinally and homogeneously. The Rug Yarn Maker creates a wound yarn core in combination with the carder, this is a great way to use coarser fibers. It can be crocheted or felted into a variety of products. The Spinder Spinner is a machine that is able to vary the thickness of the yarn to the manufacturer's liking based on the need and the requested quality. The Cone Winder is a winder that is used to prepare the yarn for artisans, skilled in crochet work but also for industries with textile machinery, it is therefore used to prepare the yarn for the realization of the final product in relation to the Cone Winder the Steamer should also be applied in order to be able to dry and ensure greater quality to the material.

The Dye Vat is a machine that washes the processed product to clean it permanently, then it must be dried to be ready for garment making. The word Chiengora comes from two separate words "chien" which means dog in French and "angora" which is known for angora wool. This is a waste in all parts of the world and is generated in the shedding period of dogs, when they are washed in pet stores or privately and finally when they are brushed to keep their coats healthy. Chiengora after several analyses has found comparable characteristics to cashmere, in addition to this it is possible to obtain both knitwear at the moment produced by different artisans around the world.

4. Results and discussion

The main innovation of the start-up is the procurement mode, i.e., the supply chain system rooted in the territory, first regional and then national in order to optimize Chiengora waste collection from pet stores, breeders, kennels and individual owners. It will require a mobile app and website that interfaces with the supplier and the customer. The supplier will be able to report the quantity collected in kilograms that can be shipped with in return an economic incentive that "Pom Era" will guarantee, while the customer will be able to purchase the garment directly if they are an end customer or fabric if they are a brand. In addition, an explanation will be provided on how to facilitate the collection phase to suppliers through the most suitable practice in hair brushing. In the production process, finishing and machine loom are useful that will allow to obtain a fabric with 100% Chiengora, also Chiengora can be mixed with other natural fibers such as for example Broom, Bamboo, Hemp, Eucalyptus, Cyprus and Viscose allowing to vary the type of fabric with more elastic and lighter characteristics. Through the use of the latest frontiers of digital technology (virtual reality), it will be possible to build customer loyalty by showing them sensory experiences related to the company's history. In addition, blockchain and Iot sensors allow Pom Era to be able to be higher performing in the production process and more efficient regarding transparency. IoT sensors make it possible to digitally connect all the physical devices therefore also the machinery, once the connection is done, it will be possible to measure speed, errors and other important production factors that allow working on errors to improve production performance.

The blockchain which is a set of technologies, where the ledger is structured as a blockchain containing transactions and the consensus is distributed across all nodes in the network. All nodes can participate in the process of validating transactions to be included in the ledger. This system will provide transparency in the complete supply chain that can clarify the path taken to produce finished product so that environmental impact can be measured. From this comes sustainable utility from both environmental and economic

perspectives.

5. Conclusions

The future Start-up Pom Era offers relevant environmental benefits regarding the material used for the creation of the fabric, because it is a waste that is generated globally in industrial quantities, only in Sicily regarding pet stores it is estimated that the potential amount is 500 kg, between Chiengora and sheared fur useful for the realization of the felt, then at the national level the amount can reach even 5000 kg, without considering the individual owners and breeders whose potential monthly amount can exceed 10000 kg, a considerable amount given that currently all these kilos are thrown in the undifferentiated waste.

Thus, it is clear that the environmental benefit manifests itself on two levels: on the reduction of waste from future suppliers and the use of plastic free raw material with the possibility of mixing Chiengora fibers with other natural fibers while keeping the product sustainable. Technological and digital strategies will help the start-up to improve indirect pollution from the production stage and transportation. The economic benefits are clear deriving from a clear profit margin. B2B is the most immediate strategy by Pom Era, because it will take care of producing the fabric by bearing the costs of sourcing and production and selling the fabric to high-fashion Brands guaranteeing a high profit margin such as the signatories of the Fashion Pact and the Life Program. B2C represents the second stage of the business that is definitely more profitable as Pom Era will be able to create its own collection of clothes and sell them directly to customers via the mobile app or site by also creating an avatar with the customer's measurements in order to try on the clothes with the measurements matching the real ones directly from their smartphone or pc. A lot of brand creation and communication will be made in order to expand the customer base and loyalty.

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DESIGN FOR RECYCLING OF A SKI: FROM A COMPREHENSIVE RECYCLABILITY STUDY TO THE DESIGN OF A COMMERCIAL PRODUCT*

Esthel Ossó[1], Guilhem Grimaud[1]*, Jacky Christoud[2], Virgile Aymard[3]

MTB GROUP, Saint-Chef, F-38890, France
[2]ROSSIGNOL, Saint-Jean de Moirans, F-38430, France
[3]AIR Coop, Annecy, F-74000, France

Abstract

This study aimed to assess the recycling potential of the current ski design. Multiple shredding and sorting campaigns were realized in industrial conditions to compare the recyclability rate (theoretical) versus the recycling rate (experimental) of these complex products. Based on the field results, a list of design for recycling recommendations was set to create a more recyclable ski. Prototypes of redesigned skis were tested in the same conditions to evaluate their recyclability. The Product Environmental Footprint (PEF) method was used to compare the environmental impacts of two end-of-life scenarios of the new ski design: complete recycling and household waste (incineration and landfill).
One of the key achievements in this regard is the significant improvement in the recyclability rate of skis. In the past, the recyclability rate of skis was around 55%, meaning that only a portion of the materials used in their production could be effectively recycled. However, through careful redesign and the implementation of advanced recycling techniques, this rate has now been boosted to an impressive 95%. Additionally, the recycling rate of skis has also seen a substantial improvement. Previously, only about 8% of skis were recycled, while the majority ended up in landfills or incineration facilities. However, thanks to the introduction of new recycling methods and increased awareness, the recycling rate has been raised to 71%. Moreover, a comprehensive study evaluating the environmental impact of the redesigned ski design has revealed an impressive result. In a complete recycling scenario, where the redesigned skis are efficiently recycled at the end of their lifecycle, a remarkable 19% reduction in greenhouse gas (GHG) emissions can be achieved compared to the alternative of disposing of skis as household waste. This finding highlights the importance of implementing sustainable practices in the ski industry and the significant contribution that recycling can make in mitigating climate change.

* Selection and peer-review under responsibility of the ECOMONDO

** Corresponding author: email: Guilhem.GRIMAUD@ensam.eu

The study on skis recycling has not only yielded positive environmental outcomes but has also allowed for the development of an industrial scheme for the recycling process. By establishing a clear framework and guidelines for the collection, sorting, and processing of discarded skis, the industry can effectively integrate recycling practices into their operations. This industrial scheme ensures that the recycling process is streamlined and efficient, maximizing the recovery of valuable materials and minimizing environmental impact.

Keywords: eco-design, design for recycling, LCA, PEF, recyclability, ski

1. Introduction

The scarcity of natural resources and the increase of waste volumes is pushing customers and manufacturers to change their mindset about the end-of-life of products. In Europe, 5 tons of waste were produced per inhabitant in 2020 and only 39% of this waste were recycled (Eurostat, 2020*)*. To tackle this issue, the European Union created the 2008/98/EC Waste Framework Directive which objectives are to improve waste management, stimulate innovation in recycling and limit landfilling. Many companies are committing to more sustainable production patterns. The Rossignol Group stated its pledge with their program "Respect". The company's ambitions are set into three objectives: reduce their carbon footprint by 30% by 2030 and aim for carbon neutrality by 2050, reduce waste by 40% by 2025 and "act for the good life together" (hiip://www.respectprogram.org/).

Skis are Rossignol's most emblematic product. Within the frame of the "Respect" program, the company undertook the redesign of this currently non-recyclable product. The purposes of the new design are to facilitate the end-of-life treatment of a ski, the recovery of the materials and the reduction of the environmental impact of the product. In this context, Rossignol asked the MTB Recycling to support them in their eco-design approach.

The first objective of this study was to evaluate the recyclability of a conventional ski in a representative industrial environment. Capitalizing on the experimental results, the second objective was to set a list of recommendations to assess Rossignol in the design of a more recyclable ski. The third objective was to verify whether the new design was indeed more recyclable than the conventional ski. Finally, a life cycle analysis (LCA) of each ski design allowed to compare their environmental hot points. The analysis of the LCA results will feed the research towards a fully eco-designed ski.

This work is divided in 4 main parts:

- Conventional ski recycling results and issues for material recovery
- Design for recycling recommendations for a more recyclable ski
- Recycling of the new design of ski and results
- Comparative LCA of the two ski designs

2. Materials and methods

2.1. Product nomenclature: the structure of a ski

A conventional ski is made of several layers glued together. Up to 10 layers can be used, integrating a large variety of materials. Figure 1 illustrates the structure of a ski (Puget, 2011).

The most used materials for each layer of a ski are:

- Topsheet: engineered plastics and inks
- Sidewall: ABS
- Core: glued laminated wood or injected polyurethane rigid foam

- Composite layers: epoxy reinforced glass-fibers, aluminum sheets can also be used
- Base: extruded or sintered polyethylene
- Edges: steel

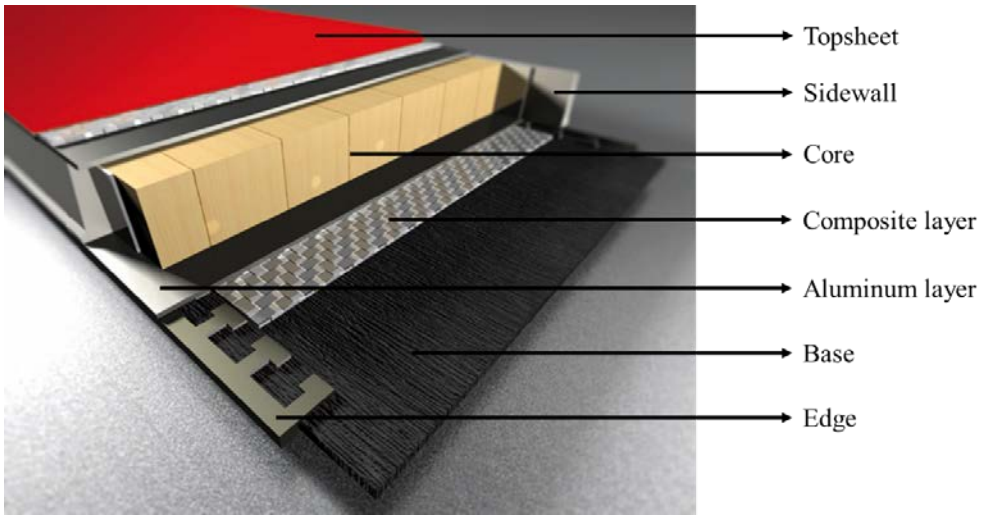

Fig. 1. Schematic view of the structure of a conventional ski

2.2. Recycling definitions and performance indicators

2.2.1. Definitions

Recycling: "Recycling means any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations" (EC, 2008)

Waste management: "waste management' means the collection, transport, recovery and disposal of waste, including the supervision of such operations and the aftercare of disposal sites, and including actions taken as a dealer or broker" (EC, 2008)

2.2.2. Performance indicators

The scope of the calculation in Table 1 is a product design approach. It is calculated by dividing the mass of the materials that can be theoretically recycled in the product (m_{th}) by the total mass of the product ($m_{product}$).

Table 1. Recyclability rate (IEC, 2012)

Indicator r_{th}	***Recyclability rate (theoretical)***
Equation	$r = \frac{1}{m_{product}} \sum_{i=1}^{n} m_{th,i}$
$m_{th,i}$	Mass of theoretically recyclable materials, without considering the existence of a specific waste management process
$m_{product}$	Mass of the product

The scope of the calculation in Table 2 is a product design approach. It is calculated by dividing the mass of the materials that can be recycled in the product (m_{exp}) by the total mass of the product ($m_{product}$).

Table 2. Recycling rate (Grimaud, 2019)

Indicator r_{exp}	***Recycling rate (experimental)***
Equation	$r = \frac{1}{m_{product}} \sum_{i=1}^{n} m_{exp,i}$
$m_{exp,i}$	Mass of materials that are recycled thanks to an existing waste management (collection, processing, and manufacturing).
$m_{product}$	Mass of the product

Table 3. Material purity rate (Grimaud, 2019)

Indicator p	***Material purity rate***
Equation	$p_{A,Oi} = \frac{A_{Oi}}{I_{Oi} + A_{Oi}}$
A_{Oi}	Mass of target material A in a sample from the output i
I_{Oi}	Mass of other materials present in a sample from the output i

The material purity rate (Table 3) expresses the ability of a sorting technology to concentrate a targeted material (AOi) in an output composed of a mix of other materials (I_{Oi}). This quantity is expressed by the ratio between the quantity of targeted material present in the output flow and the total quantity of matter constituting the outgoing fraction (A_{Oi} + I_{Oi}).

Table 4. Mass balance

Indicator m_b	***Mass balance***
Equation	$m_b = \frac{m_i}{m_{input}}$
m_i	Mass of the output i
m_{input}	Mass of the process input

The scope of the calculation in Table 4 is a process approach. The mass balance expresses the distribution of the input flow into the different sorted flows.

2.3. Materials for the study

Wooden-cored skis were tested during this project. According to their structure, the following machines were used to shred and sort the materials: a knife shredder, a magnetic pulley, an air density table separator.

The following methods were used to study the recyclability of the skis:

- Mass balance: weighing of the input and of the output fractions of the process to obtain the material recovery rate.

- Manual counting: for each output of the process, a sample of around 100 g was collected. To study the composition of an output, the materials of the sample were manually separated and weighted to obtain the material purity rate.

2.4. Design for recycling and process optimization

The experimentations conducted in this study allowed to understand the technologic locks to recycle a ski. An analysis of causes and consequences was realized to submit a list of recommendations to design a more recyclable ski.

3. Results and discussion

3.1. Recyclability of a conventional ski

The mass balance chart on Fig. 2 displays the proportion of the different outputs obtained by the sorting steps.

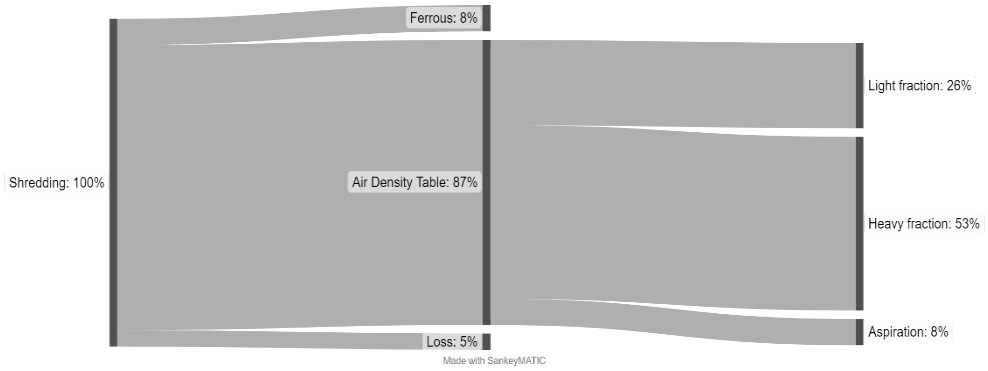

Fig. 2. Mass balance of the tested recycling process of a conventional ski

During the trials, 969 kg of wooden-core skis were used. The recycling indicators obtained after the sorting process of the skis are presented in Table 5. The shredding and sorting of the skis in industrial conditions revealed the gap between the recyclability rate (55%) and the recycling rate (8%). Theoretically, 3 kinds of materials were recyclable: steel, wood, and thermoplastics. Depending on the definition of "recyclable material", wood can be considered as not recyclable (when shredded, wood can no longer be re-used with the same functionalities). In this case, the recyclability rate would decrease to 37%.

Due to its magnetic properties, steel is easy to recover, at a high purity level (100%). However, the mix of shredded wood, plastics and composites was not separable because of several reasons. The structure of a ski and its mechanical performances lie on the cohesion of the different layers of materials. Epoxy reinforced glass-fiber is a widely used composite to fit these two purposes. Once shredded, epoxy reinforced glass-fiber turns into needles that have a similar morphology to shredded wood. When shredded materials have close densities and morphologies (bulk density), the air density table is not able to separate them.

This explains the results obtained during the sorting trials.

- The light output of the air density table (26% of the mass of the input) was a mix of thin particles of wood (8%), glass-fiber needles and plastic foils.

- The heavy output of the air density table (53% of the mass of the input) was a mix of bigger particles of wood (3%), plastic granulates but also glass-fiber needles.

Table 5. Results of the tested recycling process on conventional skis

Indicator	***Methods and hypothesis***	***Calculation and result***
Recyclability rate (theoretical)	Recyclable materials: steel, wood, and thermoplastics	$r_{th} = \frac{confidential}{100} = 55\%$
The materials of interest to recover are steel and wood		
Material purity rate		
Steel	Manual counting of steel in a sample of the ferrous output	$p_{steel,ferrous\ fraction} = \frac{50\ g}{50\ g} = 100\%$
Wood	Manual counting of wood in a sample of the light output	$p_{wood,ligh\ fraction} = \frac{3{,}4\ g}{44\ g} = 8\%$
	Manual counting of wood in a sample of the heavy output	$p_{wood,heavy\ fraction} = \frac{1{,}8\ g}{57\ g} = 3\%$
Mass balance		
Steel	Mass balance of the ferrous output	$c_{ferrous} = \frac{76\ kg}{969\ kg} = 8\%$
Wood	Mass balance of the light output	$c_{ligh\ fraction} = \frac{250\ kg}{969\ kg} = 26\%$
	Mass balance of the heavy output	$c_{ligh\ fraction} = \frac{514\ kg}{969\ kg} = 53\%$
Recycling rate (experimental)	Recycled materials: because the wood couldn't be separated from the plastics and composites mix, the recycled material is only steel.	$r_{exp} = \frac{8}{100} = 8\%$

A sieving experiment was conducted on the light output of the air density table to separate wood from glass-fibers, but the results were not satisfactory.

Another reason why the separation of wood, epoxy and plastics was not effective is the presence of laminated particles. Laminated particles are particles that are composed of two materials glued together. In this case, the bulk density of the particle is higher that the isolated materials, so this causes sorting errors. Also, the glue prevents the materials from being separated and sorted.

3.2. Design for recycling recommendations and new ski design

Based on the results of the recyclability study, the following recommendations of design for recycling were given to Rossignol.

3.3. Recyclability of the new ski design

The purpose of this experiment was to verify whether the new design of the ski was indeed more recyclable than the conventional ski. The methods used for studying the recyclability of the new ski were the same as previously presented. However, the process was adapted to better recover the materials of interest (steel, aluminum, and wood). An additional sorting machine was added to sort out the light output of the air density Table.

Table 6. Summary of the recommendations of design for recycling for a new ski design

Technical issues for recycling	***Recommendation***	***Rossignol response***
Large diversity of materials	Decrease the material diversity by redefining the target uses of the new ski: match between the technicity of the product and the user experience	From about 12 materials to 7 materials (decreasing by ≈ 40%)
Large number of layers	Decrease the number of layers by thickening them or choosing other materials, preferably non composite and/or recyclable materials	From more than 8 layers to 5 layers
Similar bulk density of the materials Plastic mix	Choose materials with the most different physico-chemical properties possible: magnetism, inductive response, density, chemical structure Avoid black plastics. Avoid plastic mixing. If plastics are necessary, choose plastics with the most different chemical structure possible.	Increase of the amount of wood and aluminum Drastic reduction of plastics (no plastic mix used in the global structure)
Composite materials	Avoid composite materials If composite materials are necessary, choose composites that are designed to be more recyclable (thermoplastic matrix)	Banning of composite materials
Glued materials	Look for a glue that could melt during the shredding (melt temperature to be determined by further experiments)	Reducing the number of layers reduced the using of glue

The mass balance chart on Fig. 3 displays the proportion of the different outputs obtained by the sorting steps. During the trials, 41 kg of new-design ski prototypes were used. The recycling indicators obtained after the sorting process of the skis are presented in Table 7.

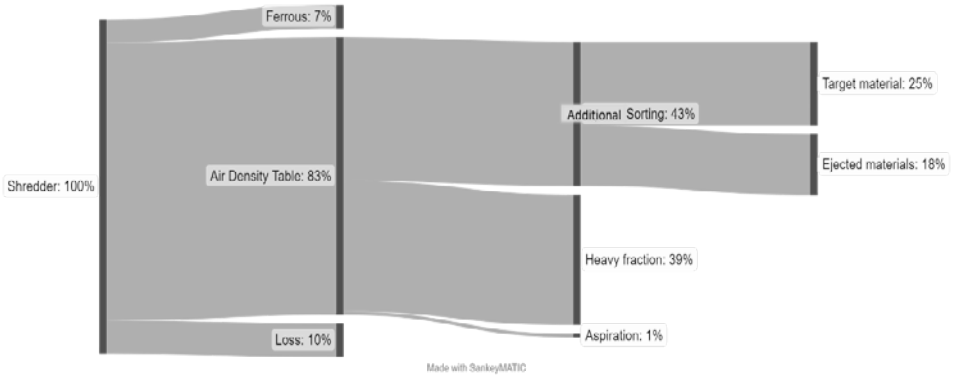

Fig. 3. Mass balance of the tested recycling process of the new ski design

Table 7. Results of the tested recycling process on the new ski design

Indicator	***Methods and hypothesis***	***Calculation and result***
Recyclability rate (theoretical)	Recyclable materials: steel, aluminum, wood, polyethylene	$r_{th} = \frac{confidential}{100} = 95\%$
The materials of interest to recover are steel, aluminum, wood, and polyethylene		
Material purity rate		
Steel	Manual counting of steel in a sample of the ferrous output	$p_{steel,ferrous\ fraction} = \frac{22\ g}{23\ g} = 96\%$
Aluminum	Manual counting of steel in a sample of the nonferrous output	$p_{Al,nonferrous\ fraction} = \frac{42\ g}{53\ g} = 80\%$
Wood	Manual counting of wood in a sample of the target material output	$p_{wood,target\ fraction} = \frac{16\ g}{16\ g} = 100\%$
Polyethylene	Manual counting of polyethylene in a sample of the ejected materials output	$p_{PE,eject\ fraction} = \frac{3\ g}{13\ g} = 23\%$
Material recovery rate		
Steel	Mass balance of the ferrous output	$c_{ferrous} = \frac{3\ kg}{41\ kg} = 7\%$
Aluminum	Mass balance of the nonferrous output	$c_{nonferrous} = \frac{16\ kg}{41\ kg} = 39\%$
Wood	Mass balance of the target material (wood) output	$c_{wood} = \frac{10\ kg}{41\ kg} = 25\%$
Polyethylene	Mass balance of the ejected materials (thermoplastics) output	$c_{polyethylene} = \frac{7\ kg}{41\ kg} = 18\%$
Recycling rate (experimental)	Considering the low purity rate of the polyethylene output, this material can't be recycled. The recycled materials of the product are steel, aluminum, wood, and polyethylene	$r_{exp} = \frac{7+39+25}{100} = 71\%$

In comparison to the results obtained with the conventional skis, the new ski design revealed a smaller gap between the recyclability rate (95%) and the recycling rate (71%). This is mostly due to the simplification of the composition: less layers and less materials.

When it comes to recycling, the less materials, the better the sorting. In parallel, a better sorting enhances the purity level of the recovered materials.

- The magnetic pulley allowed to totally recover the steel, at a purity rate of 96% (the 4% of pollution comes mostly from the wood and glass fiber dust and minorly from sorting errors of aluminum).
- The heavy output of the air density table (39% of the mass of the input) was composed at 80% of pure aluminum. The 20% left are laminated aluminum/wood particles.
- The target material output from the optical sorting machine (25% of the mass of the input) allowed to recover wood particles with a purity of 100%.
- The ejected materials output from the optical sorting machine (18% of the mass of the input) was a mix of polyethylene granulates and wood particles. The settings of the machine were intentionally harsh on the ejection parameters to obtain the purest "target material" output.

3.4. Comparative impacts of two end-of-life scenarios for skis

A life cycle analysis methodology (LCA), an internationally standardized methodology (ISO 14040 and 14044, 2006), has been used to compare the environmental hot points of two end-of-life scenarios for skis. More specifically the European recommendations for the Product Environmental Footprint (PEF) (EC, 2021) were applied for the calculation of the impacts of recycled or to be recycled materials using the Circular Footprint Formula (CFF) presented in Fig. 4.

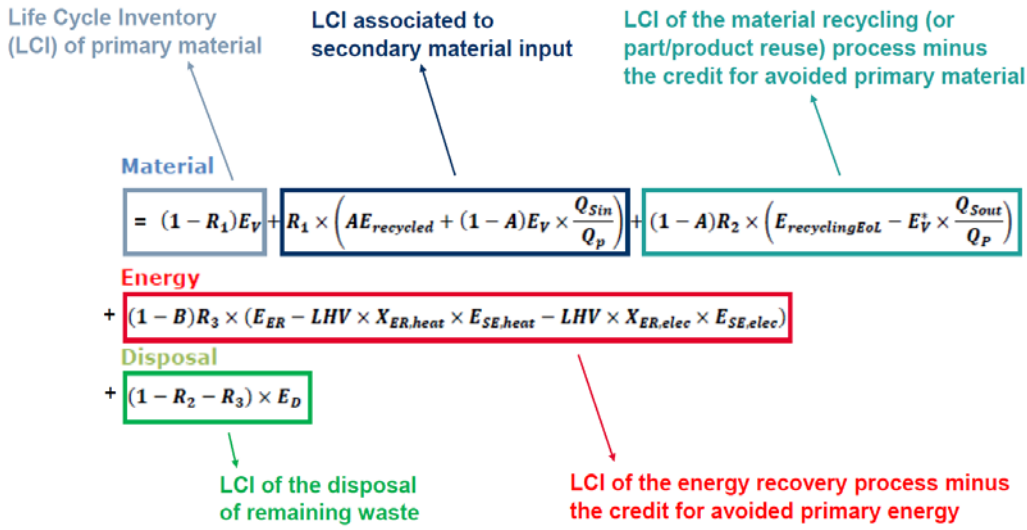

Fig. 4. Circular Footprint Formula (CFF) as defined in Annex C of PEF method (Zampori and Pant, 2019)

The study was conducted on six impact categories among the sixteen selected by the PEF: Climate Change, total, Acidification, Eutrophication, freshwater, Resource use, Fossils, Resource use, Mineral and metals, Particulate matter. Table 8 shows the environmental gain of recycling a ski compared to its treatment with household waste (incineration and landfill). Compared to a treatment with household waste, the recycling of a ski allows a reduction of:

- -18.7% for global warming
- -15.1% for the Eutrophication of fresh water
- -22.7% for Acidification

On the other hand, 56% increase in fine particle emissions due to the shredding operation. These figures consider the allocation factors according to the CFF formula. It is important to note that according to the principle of allocation of expenses and benefits defined in the CFF formula, the recycling of ski materials will also provide credits to the product incorporating these recycled materials. These credits have not been considered in this study, which focuses on the "ski" system.

These figures do not show the comparison of a conventional ski versus a ski designed to be recycled. They are there to compare two end-of-life scenarios on the same model and demonstrate the environmental interest of recycling a ski designed to be recycled.

Table 8. Environmental gain of recycling a ski compared to its treatment with household waste

						
Impacts for 1 pair of skies	EF 3.0. Climate Change [kg CO_2 eq.]	EF 3.0. Acidification [Mole of H+ eq.]	EF 3.0. Eutrophication, freshwater [kg P eq.]	EF 3.0. Resource use, fossils [MJ]	EF 3.0. Resource use, mineral and metals [kg Sb eq.]	EF 3.0. Particulate matter [Disease incidences.]
Gain in ski recycling versus incineration/landfill (CFF formula with burden and credit allocation) (%)	-18.7	-22.7	-15.1	-10.5	-4.7	56.2

This LCA validated the following:

- The recycling of metal elements (aluminum and steel) brings the most interesting gains (compared to wood and plastics).
- The recycling of wood and plastic elements will bring a small gain compared to their incineration with energy recovery.
- The LCA of an alpine ski designed to be more easily recyclable has validated the environmental benefit of recycling materials. Nevertheless, improvements can still be made to reduce the impact of components:
  - Reduce the production scraps of metal elements and wood cores to reduce the consumption of materials (potential gains: impact of raw materials, manufacturing of components and production waste)
  - Use low-carbon energy for the manufacture of skis and their components.
  - Reintegrate recycled materials into new skis (closed loop recycling) to benefit from 100% of the credits.
  - Use more efficient filters when shredding skis at the end of their life.

4. Concluding remarks

The conclusions drawn from the study on ski recycling are as follows:

Shredding and sorting tests conducted under industrial conditions provided valuable insights into the actual recycling potential of conventional skis. The results of these tests revealed a recycling rate of 8%. This finding emphasizes the limited recyclability of traditional ski designs and the need for improvement.

Based on the on-field observations and the data gathered from the shredding and sorting tests, design recommendations were formulated to create a more recyclable ski prototype. These recommendations aimed to address the shortcomings of the conventional design and enhance the recyclability of the ski.

Subsequent recycling studies were conducted on the new ski design in the same industrial conditions. The results were highly encouraging, demonstrating a significant improvement in the recycling rate, which reached 71%. This indicates that the efforts made to develop a more recyclable ski design were successful in achieving a substantial increase in recyclability.

It is important to highlight that while a more recyclable ski design is beneficial for waste management and resource recovery, it does not automatically guarantee a reduction in the overall environmental footprint. To evaluate the environmental impact comprehensively, a life

cycle analysis (LCA) calculation was performed. This analysis compared the environmental impacts of two end-of-life scenarios for the new ski design. The results of the LCA calculation revealed that the environmental footprint of the new ski design is reduced only when the ski is recycled. This underscores the importance of implementing effective recycling practices to maximize the environmental benefits of a more recyclable design. It emphasizes the need to divert skis from the waste stream and ensure their proper recycling to achieve the desired sustainability outcomes.

The concept of eco-design, as demonstrated through this study, is an iterative process of experimentation and refinement. The findings and insights gained from the study will guide future efforts to further improve ski design and reduce the global environmental impact. For Rossignol, the next step would be to capitalize on these results and continue developing a fully eco-designed ski that encompasses not only enhanced recyclability but also a comprehensive reduction in its overall environmental impact throughout its lifecycle.

The study's findings highlight the significance of improving the recyclability of skis, the importance of effective recycling practices, and the need for ongoing eco-design efforts to achieve a more sustainable ski industry. By incorporating these conclusions into future design and manufacturing processes, the ski industry can make substantial strides towards minimizing its environmental footprint and embracing a more circular and eco-friendly approach.

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BIOCONVERSION MEDIATED BY BLACK SOLDIER FLY (*Hermetia illucens*): THE HERMES PROJECT*

Enrico Santangelo[1], Silvia Arnone[2], Claudio Beni[1], Massimiliano De Mei[2], Monica Carnevale[1], Francesco Gallucci[1], Francesca Lecce[2], Francesco Petrazzuolo[2], Eleonora De Santis[1], Alberto de Iudicibus[1], Alberto Assirelli[1]**

[1]CREA, Research Centre for Engineering and Agro-Food Processing, Via della Pascolare, 16, 00015 Monterotondo, Italy
[2]ENEA, Energy Technologies and Renewable Sources Department, Via Anguillarese 301, 00123 Santa Maria di Galeria, Italy

Abstract

The treatment of organic residues with the black soldier fly (*Hermetia illucens, Diptera, Stratiomyidae, Hermetiinae*) belongs to the so-called CORS (Conversion of Organic Refuse by Saprophages) process. The bioconversion carried out by the larvae of black soldier fly (BSF) can allow for the recovering and exploiting of organic residues. The process will produce a larval biomass as source of biomolecules or feed for animals, and a residual substrate, potentially available for agricultural use.
The HERMES project was funded within POR FESR Lazio 2014-2020 to develop a biorefinery model based on CORS at regional level. The general objective of the project is the setting-up of a sustainable technology for the bioconversion of residual biomasses through the saprophagous activity of the BSF. In a circular economy perspective, the project aims to draw a "closed" cycle downstream the production processes recovering biomolecules from the larval biomass beside the use of the bioconverted substrate as soil amendment. A key issue of the project is the design of a prototype for the automation of the process on a laboratory scale, but with characteristics suitable for the scaling-up. The work will present the structure and objectives of the project as well as some results of the first year of activity on the mass rearing of BSF and the characterization of the residual substrate after bioconversion.

Keywords: circular economy, CORS, *Hermetia illucens*, leftovers, waste

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** Corresponding author: email: enrico.santangelo@crea.gov.it

1. Introduction

The Circular Economy is a model of production and consumption based on sharing, lending, reuse, repair, reconditioning and recycling of existing resources and products for as long as possible (Bourguignon, 2016). The basic idea is to move from the paradigm of the "linear" economy (production – consumption - disposal) to a new paradigm based on the reuse and the conversion of waste products in products that still find a destination within the economy, until the complete exhaustion of the intrinsic energy/value contained in them. In the described context, increasing are the efforts of world scientific community addressed to identify ways for the reduction and conversion of organic wastes (Barbi et al., 2020; Diener et al., 2011).

The activity of the black soldier fly larvae (BSFL) *Hermetia illucens* (L.) allows for a worthy rescue of organic matrices having different origin (Arnone et al., 2022). The application of the BSFL approach belongs to the Conversion of Organic Refuse by Saprophages (CORS) involving the transformation of residual organic biomass and waste to produce "secondary raw materials" including molecules of interest for green chemistry. The regional project HERMES funded within POR FESR Lazio 2014-2020 (Reg. Det. n. G09493 140721, 22/07/2021) aimed at developing a biorefinery model based on the activity of larvae of *H. illucens* for the conversion of organic wastes from Lazio agri-food supply chain and foresees the collaboration of the researcher groups of CREA and ENEA. The present work describes the project and presents the preliminary results of the activity.

2. The “Hermes” project

The bioconversion mediated by the BSFL offers the chance to recover and exploit waste or by-products through the production of a larval biomass as source of biomolecules or feed for animals, and of a residual substrate, potentially available for agricultural use.

HERMES is a project funded within POR FESR Lazio 2014-2020 born to develop a biorefinery model based on CORS (hiips://hermes.crea.gov.it/). The general objective of the project is the setting-up of a sustainable technology for the bioconversion of residual biomasses (by-products of the agro-industry, and agro-food leftovers,) through the saprophagous activity of the BSF. In detail, the Hermes project intends to define the conditions for the standardization of a mass rearing of the insect to produce the inoculum (insect biofactory) and for the subsequent bioconversion activity (insect biorefinery) of different types of leftovers on a pre-prototype scale (Fig. 1).

A pivotal aim of project is the design and development of a prototype at laboratory scale that in a continuous and automated manner can carry out the larval growth by the initiation of the process with larvae at youth stage. Downstream the process, mature larvae will be separated from converted substrate using a system of sieves to find a destination in chemical and pharmaceutical sectors. After a composting phase, the residual substrates will be used as soil amendment for both potted plants and field crops. The last two WP’s will be committed to favor the involvement of stakeholders and companies interested in results research and to foster the dissemination of the results (Fig. 1).

3. Materials and methods

In the present study we report some preliminary results about the growth of larvae and the composition of substrate after the bioconversion. In the first year, the *Hermetia*-mediated bioconversion has been focused on the use of agri-food leftovers provided by a local large-scale retail with which a supply agreement was finalized. The newborn larvae from eggs laid

by a colony of *H. illucens* were fed for the first six days on the moistened Gainesville diet (Hogsette, 1992; Sheppard et al., 2002). After six days, larvae were weighted and used for the experimental trials. Plastic box vessels (59 × 39 × h 17 cm) covered with perforated lids, were filled with 10 kg of a mixture of agri-food and bakery leftovers (80:20 ratio) and the initiation of bioconversion was carried out with about 5,000 six-days-old larvae.

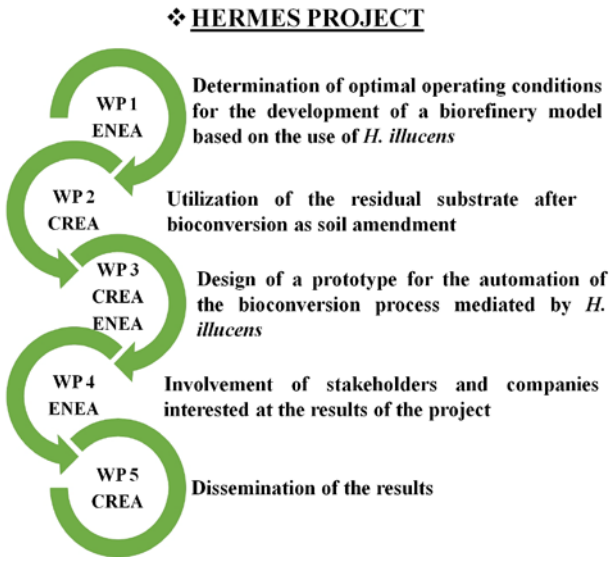

Fig. 1. Main objectives of the Work Packages of the HERMES project

To monitor the growth of the larvae during the experiment a Falcon® test tube of 40 ml was filled with larvae taken at 13, 17, 20 and 24 days after eggs hatching. For each date, we considered three replicates. Larvae in each test tube were counted and the mean weight (g) of a single larva was obtained as ratio between total larval weight (g) of the larvae, and the number of larvae contained in the test tube. Finally, the larval weight (g) was also referred to 1 L of volume.

The final substrate was analyzed for the content of the main elements and heavy metals. Before the characterization, 50 g of each substrate were dried for 24 h at 105 ± 2°C (Memmert UFP800 drying oven) to determine the moisture content following the standard UNI EN ISO 18134-1:2015. The dried biomass was treated with a Retsch SM 100 kneading mill and then with a centrifugal mill (Retsch ZM 200) to shred and homogenize the matrix. To determine the content of carbon (C), and nitrogen (N), about 5 mg of each sample was analyzed by Costech ECS 4010 CHNS-O elemental analyzer according to UNI EN ISO 16948:2015. The quantification limit (LOQ) for each sample was 0.05% w/w. For the macro- and trace element content, 0.5 g of the dehydrated sample were homogenized and solubilized with 6±0.1 ml of HNO_3 65% and 3±0.1 ml of H_2O_2 30%.

The solution was digested in a microwave oven at 180 °C, 650 W for 8 min and then for a further 15 min. At the end of digestion, the samples were filtered and diluted with MilliQ water. Two replicates and a blank were made for each sample. The calibration line was made in nitric acid on five points at increasing concentrations of internal standard. Element analysis was performed using ICP-MS (Agilent 7700).

All results were subjected to One-way ANOVA and, in presence of significant differences, Tukey-Kramer (HSD) test at P<0.05 was used for mean separation. All statistical analysis were performed using JMP 14.0 software (SAS Institute, Cary, NC).

4. Results and discussion

The larval weight was still risen from 13th to 17th day when the mean weight reached the peak of 0.328 g (Fig. 2). The end of larval stages occurs when the maximum larval weight is reached because after that the mature larvae undertake the prepupal period with a non–feeding phase, lose weight and darken the body color (Arnone et al., 2022). As observed also in the cited study, our data confirmed the decrease of larval weight since 17th day from eggs hatching to 24th (0,233 g), day of the end of trial. The volume employed by larvae followed the same trend decreasing from 7.75 to 5.84 g/L with a statistic difference at 24th day (Fig. 2).

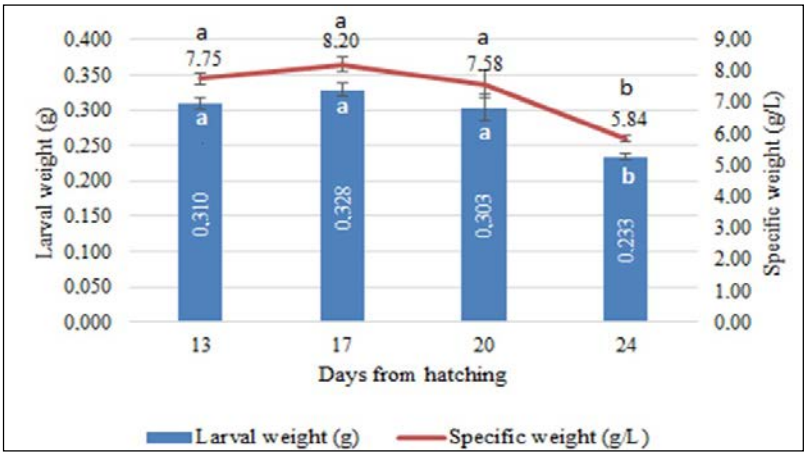

Fig. 2. Larval weight (g) and specific weight (g/l) of larvae at 13, 17, 20 and 24 days from eggs hatching. Bars indicate standard deviation. Different letters indicate significative differences for Tukey-Kramer (HSD) test at p<0.05

Table 1. Mean (±SD) of moisture (%), pH, carbon (%) nitrogen (%) and C/N ratio in substrate before and after bioconversion. The asterisk indicates a significant difference for P<0.05; ns, not significant

Parameter	***Before bionconversion***	***After bioconversion***	***Significance***
Moisture content (%)	75.13 ± 1.58	77.22 ±0.21	*
pH	4.82 ± 0.05	6.15 ± 0.16	*
C (%)	31.12 ± 1.64	30.90 ± 1.07	ns
N (%)	2.25 ± 0.10	2.97 ± 0.14	*
C/N	13.93 ± 1.34	10.44 ± 0.73	*

Such indications have a great importance for the design of the prototype addressed to the automation of the process. Among the variables to consider for its implementation, a key role is played by both the growth cycle and the size of the larvae. The correct definition of

these variables will allow for determining the sizing of the containers and the choice of system for handling and separating the larvae from the bioconverted substrate.

The bioconversion mediated by *H. illucens* caused significant changes in the main components of the organic raw material (Table 1). Moisture level resulted significantly higher after the larvae bioconversion (from 75.13 to 77.22%). The pH of final residue risen from 4.82 to 6.15. The percentage of carbon was the only variable comparable in organic leftovers before and after the bionconversion. Levels of nitrogen resulted slightly augmented (from 2.25 to 2.97%) and, consequently, the C/N ratio after the conversion (10.44 ± 0.73) was significantly lower than the starting biomass (13.93 ± 1.34).

This is another important information for using the residue as soil amendment. In fact, a C/N ratio close to 10, as in the soil condition, could suggest the possibility of direct use of the bioconverted substrate for fertilization. But, importantly, the organic matter of which it is composed is still fermentable, therefore unstable. To stabilize the organic matter and the nutrients content, composting process is needed. For a good composting process, the raw material C/N ratio is 30, and the compost is considered to be mature if the C/N ratio drops to less than 20 (Golueke, 1977). To balance C/N ratio the WP2 of the Hermes project foresees the addition of wheat straw and a period of compost maturation for at least three months.

The levels of the main elements were strongly affected by the bioconversion (Table 2). Magnesium, potassium, manganese, and iron were significantly higher after the action of *H. illucens*. The content of sodium (Na) in substrate after the larval bionconversion resulted higher than the measurements range of the instrument. The content in heavy metals too (Table 2) increased after the bioconversion. Although this may seem a negative factor, it should be kept in mind that the contents in heavy metals resulted below the limits set by law (UE Regulation, 2019) for the destination as soil amendment.

Table 2. Mean (±SD) of main elements and heavy metals in organic substrate before and after bioconversion. The asterisk indicates a significant difference for P<0.05. OR, off range; LOQ, limits of quantification

Element	***Before bionconversion***	***After bioconversion***	***Significance***
Na (g/kg)	0.24 ± 0.01	OR	
Mg (g/kg)	0.86 ± 0.04	2.08 ± 0.04	*
K (g/kg)	12.13 ± 0.66	46.41 ± 1.12	*
Mn (mg/kg)	11.83 ± 0.71	14.90 ± 0.26	*
Fe (mg/kg)	55.58 ± 3.30	141.84 ± 2.82	*
Ca (mg/kg)	393.32 ± 20.72	252.17 ± 8.68	*
Cr (mg/kg)	0.69 ± 0.15	1.30 ± 0.03	*
Co (mg/kg)	<LOQ	0.05 ± 0.004	
Ni (mg/kg)	0.83 ± 0.05	1.42 ± 0.02	*
As (mg/kg)	0.11 ± 0.013	0.19 ± 0.01	*
Cd (mg/kg)	0.01 ± 0.01	0.06 ± 0.003	*
Pb (mg/kg)	0.104 ± 0.01	0.230 ± 0.004	*

Such behavior is very interesting and call in cause the action of the larvae and their capacity in metabolizing biodegradable wastes and some elements contained in them, concentrating the elements in the residual substrate, and increasing the nutritional value of it. The reader should be aware that during the process the larvae undergo a huge increase of the weight and that in this phase the separation of larvae was not accomplished completely. Moreover, the larvae release in the residue their feces which are a further source of some metals. Hence, the final composition of the residue must consider the contribution of a small portion of the larval biomass.

5. Concluding remarks

The results highlight the possibility to produce and recover a larval biomass useful for the extraction of biomolecules (lipids, proteins, and chitin). The residue of the bioconversion of fruit and vegetable leftovers showed a composition compatible with a use as soil amendment, respecting limits of law in terms of content of heavy metals. Studies about rearing substrates optimization and crops response to soil fertilization with the residues are the objectives of the current work.

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ANAEROBIC CODIGESTION OF TOMATO POMACE AND BUFFALO SLURRY*

Enrico Santangelo[1], Massimo Calì[2], Emanuela Rossi[2], Roberto Scalella[2], Maria Chiara La Mantia[2], Antonella Chiariotti[2]**

[1]CREA, Research Centre for Engineering and Agro-Food Processing, 16 Via della Pascolare, 00015 Monterotondo, Italy
[2]CREA, Research Center for Animal Production and Aquaculture, 31 via Salaria, 00015 Monterotondo, Italy

Abstract

The buffalo farming and tomato processing produce considerable amounts of residues whose disposal has critical profiles in terms of environmental and economic impact. Peels and seeds (pomace) produced during the processing of tomatoes can be a raw material available in quantities for reuse in anaerobic digestion. The amount of buffalo slurry is also huge, but, although there are some lines of research on bio-hydrogen production, its reuse has not received due attention. The work investigated the anaerobic codigestion of buffalo slurry and tomato pomace for biogas production under mesophilic (39°C) and thermophilic (50°C) conditions. The study was conducted in a batch experiment using the Automatic Methane Potential Test System. Four inoculum/substrate ratios (ISR) based on volatile solids content were compared: 3.6, 2, 1, 0.5. The buffalo slurry was used as inoculum and control. In the thermophilic conditions, the cumulative curves reached the plateau after about two weeks showing a shorter hydraulic retention time than in mesophilic digestion, where the plateau was reached at 20 days. The data obtained confirmed the higher biomethane yield determined by thermophilic conditions. The highest value was obtained for the 0.5 ISR where the highest amount of tomato pomace was present. This would indicate that a greater amount of waste can be digested in thermophilic conditions in the unit of time with the same digester size, or that the same amount of feedstock can be digested in a smaller plant, reducing the cost of the plant. The right trade-off between higher TP recovery and increased process energy costs should be considered.

Keywords: agricultural waste, biogas, tomato pomace

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** Corresponding author: e-mail: antonella.chiariotti@crea.gov.it

1. Introduction

The biowastes produced by several food chains have considerable potential for chemicals and bio-energy production and could meet 2% of the EU renewable energy target (Boccia et al., 2019). The cultivation of tomatoes for food processing and buffalo farming are typical Italian productions widespread in southern regions of the peninsula. The global tomato processing market reached a volume of 43.4 Mil Tons in 2021 (hiips://www imarcgroup com/tomato-processing-plant). Italy is the first producer in Europe and the second largest producer in the world. Tomato pomace (peels, seeds, and pulp-TP) is the main waste separated before and during processing.

The buffalo supply chain also produces by-products whose management have an economic and environmental issues. According to European Directive 91/676/EEC, concerning water pollution caused by nitrates from agricultural sources, manure can be a problem for disposal, especially on intensive livestock farms. So, both feedstocks, renewable and abundant, may find useful exploitation in suitable conversion technologies opening new routes for their recovery and reducing environmental and economic burden for farmers and entrepreneurs.

The Anaerobic codigestion (AD) of agro-food wastes with cattle slurry has been analyzed (Caruso et al., 2019), the use of buffalo slurry for the same purposes is less studied (Chiariotti and Crisà, 2018; Manfredini et al., 2021). AD exploits the synergies established between bacterial population from different origins during the digestion, as well as the supply of missing nutrients from the co-substrates, which confer a greater buffer capacity and reduces the mass and volume of feedstocks. Several parameters, like pH, maintained between 7.0 and 8.5 for the optimal growth of archaea methanogens main responsible for methane production, as well as the substrates ratio, may improve microbial activity and the kinetics of degradation (Carotenuto et al., 2016; Raposo et al., 2012).

Process temperature is another important AD parameter. In fact, compared to mesophilic conditions the performances under thermophilic conditions are improved due to higher activity of enzymes and co-enzymes, higher biogas production, higher methane yield and higher pathogen destruction rates (Carotenuto et al., 2016; Deepanraj et al., 2015; Zhang et al., 2014). Moreover, studies found that the ammonia toxicity was alleviated at thermophilic condition (Wang et al., 2016).

There are limited papers on the use of buffalo sludge (BS) codigested with agro-industrial waste to produce biogas, and no studies on buffalo sludge and TP under thermophilic conditions (50 °C) have been conducted, at the best of our knowledge. This work analyzed various parameters during anaerobic codigestion of buffalo slurry and tomato pomace for biogas production both in mesophilic and thermophilic conditions. The optimum Inoculum Substrate Ratio (ISR) of BS and TP, based on volatile solid (VS) content was evaluated in batch experiments.

2. Materials and methods

2.1. Starting materials

Full ripened fruits of a commercial variety of tomatoes (San Marzano type) were carefully washed in tap water. Then, TP were separated from the pulp by an electric tomato squeezer (Bialetti, Italy) and stored at − 20 °C until use.

Buffalo slurry, a mixture of manure and urine, was taken in CREA experimental field station in Monterotondo, Rome (Tor Mancina, 42° 05′ 26.0″ N 12° 36′ 44.7″ E), where an

experimental buffalo herd is located. The BS was strained (two layers of cheesecloth) and maintained for 3 weeks at room temperature before use.

2.2. Batch experiments

TP were codigested with BS to measure the biogas production during two consecutive batch experiments in an Automatic Methane Potential Test System (AMPTS, Bioprocess Control, Sweden).

AMPTS glass reactors (0.5 L) were filled with 0.4 L of substrate according to four Inoculum/Substrate (BS/TP) ratios: 3.6, 2, 1, 0.5, based on VS content in three replicates each (Table 1). BS alone was used as control. At the beginning of the trial, the batches were flushed with di-nitrogen gas (N_2) to gain anaerobiosis and maintained at mesophilic condition (39°C – trial 1) and thermophilic conditions (50°C - trial 2) until the gas production in all reactors was less than 10 mL. AMPTS measures cumulated biogas production in NL (normal liter, 0°C, 1 atm) CH_4 day^{-1}. The trial 1 lasted 55 days, the trial 2 lasted 25 days.

Samples were collected at the beginning and at the end of trials for the following chemical analysis: pH, total solids (TS), VS and ammonia nitrogen ($N\text{-}NH_3$) according to APAT - CNR - IRSA standard methods (IRSA 2060, IRSA 2090A, IRSA 2090D, IRSA 4030A2 respectively), fiber content according to Martillotti et al. (1987) and Van Soest et al. (1991). All the determinations were performed in triplicate.

The amount of total volatile fatty acids (VFA) was analyzed in HPLC (Shimadzu, Japan) with Aminex 85 HPX-87H column, on isotherm condition at 40 °C, on isocratic 0.008 N H_2SO_4 with flow rate of 0.6 mL/min. UV detector at 220 nm was used.

Biogas composition was analyzed in gas-chromatography (MicroGC, GCX MPX, Pollution) with two channels: a) Molsieve column and b) PLOTQ column working at isotherm condition at 50 °C. The instrument used a thermal conductivity detector.

2.3. Statistical analysis

The data concerning the AD parameters of mesophilic and thermophilic conditions were analyzed with the PAST software version 3.22 (2018, Øyvind Hammer, University of Oslo, Norway, hiips://www.nhm.uio.no/english/research/resources/past). Once checked for normality, data were subjected to analysis of variance (two-way) and the significantly different means were separated by Tuckey's HSD test.

3. Results and discussion

3.1. Feedstocks characterization

The composition of the two substrates, reported in Table 1, was different in term of fiber composition: NDF, ADF and hemicellulose were higher in TP compared to BS.

The cellular components of a substrate undergoing the AD influence the process. In the case of plant tissue, the structure of the cells includes the outer cell wall where lignin and cellulose are essential components present in variable but significant amounts. In a comparison of different organic substrate, Triolo et al. (2011) observed a negative correlation between the lignin content and the Biochemical Methane Potential (BMP). Such correlation was less negative for cellulose and, when considering the animal manure and the residues of energy crops, the correlation value was higher for the manure. Animal cells, being devoid of a cell wall, are already partially broken-down during gut digestion and thus exposed to the action of

bacterial populations. Tomato peels is rich in NDF (the component comprising hemicellulose, cellulose, and lignin) and depending on cultivation methods and conditions, variety and processing procedures may vary greatly in its components (Del Valle et al., 2006; Scoma et al., 2016).

The SV reduction observed in trial 1 and 2, which mirrored the increase of TP content in the corresponding ISR, was proportional to the methane production or as in the case ISR 0.5 in mesophilic condition, to VFA accumulation (Fig. 1b) which also led to a significant pH reduction (Table 2).

Table 1. Physical-chemical characterization (Mean ± SD) of BS and TP

	Thermophilic		***Mesophilic***	
	BS	***TP***	***BS***	***TP***
TS[a]	35.80 g L^{-1}	175 g kg^{-1}	39.76 g L^{-1}	151.6 g kg^{-1}
VS	26.16 g L^{-1}	166 g kg^{-1}	29.12 g L^{-1}	143.5 g kg^{-1}
N-NH_3 (mg L^{-1})	35.80 g L^{-1}	175 g kg^{-1}	39.76 g L^{-1}	151.6 g kg^{-1}
pH	7.2	4.4	6.85	4.5
Fiber content (% DM):				
Raw fiber	18.5 ± 1.0	32.9 ± 0.3	ND	28.6 ± 1.0
NDF with ashes	46.6 ± 1.4	54.8 ± 1.3	40.9 ± 0.6	46.3 ± 0.1
NDF pure	38.1 ± 1.3	54.4 ± 1.4	35.7 ± 0.5	44.9 ± 0.4
ADF	37.4 ± 0.5	41.8 ± 1.0	29.7 ± 0.2	37.0 ± 0. 4
Hemicellulose	0.5 ± 0.8	12.6 ± 1.5	5.9 ± 0.2	7.8 ± 0.4
ADL	14.4 ± 0.8	24.3 ± 0.3	14.4 ± 0.4	11.5 ± 0.3
Cellulose	11.8 ± 1.7	17.2 ± 1.8	8.7 ± 0.5	25.3 ± 0.5

[a] TS=Total Solid; VS= Volatile Solid; DM =Dry Matter; NDF = Neutral Detergent Fiber; ADF= Acid Detergent Fiber; ADL = Acid Detergent Lignin; ND= Not Determined

Table 2. Values of the interaction "Con x ISR" for the variables observed during the anaerobic digestion. For each parameter, values followed by the different letter are statistically different at the level of P≤0.05 according to Tukey's test

Parameter	***Condition****	***ISR****				
		BS*	***3.6***	***2***	***1***	***0.5***
SV Reduction (%)	T	36.8 d	44.1 c	46.7 bc	50.2 b	57.6 a
	M	33.9 d	33.4 d	50.8 b	56.8 a	58.3 a
pH (end of trial)	T	7.49 c	7.46 c	7.50 c	7.52 c	7.56 c
	M	7.97 ab	7.98 ab	8.05 ab	7.87 b	5.34 d
PC (NL CH_4 L^{-1} substrate)	T	4.38 ef	2.86 fg	5.70 df	11.86 ab	14.24 a
	M	5.84 df	7.47 ce	9.06 bd	10.74 bc	0.54 g
PC (L CH_4 g SV^{-1})	T	167.29 bc	85.66 d	145.33 c	226.59 ab	181.45 ac
	M	200.62 ac	239.92 ac	207.76 ab	184.86 ac	6.15 e
Methane Peak (%)	T	72.9	84.6	83.4	77.7	67.7
	M	69.1	75.1	76.4	70.8	32.8
N-NH_3 final (g L^{-1})	T	0.868 f	0.955 e	1.042 d	1.290 b	1.388 a
	M	1.202 c	1.168 c	1.173 c	1.322 ab	1.181 c

T=thermophilic condition, M=mesophilic condition; **ISR – inoculum/substrate ratio; * BS – buffalo slurry; PC: cumulated production*

As observed by Saghouri et al. (2018) during a first phase of the anaerobic digestion of tomato processing wastes a decrement of pH is expected due to the production of the volatile fatty acids (VFA). The rapid accumulation of volatile fatty acids (VFA) hinders the organic matter degradation by the microorganisms (Almeida et al., 2021). In a second step, VFA are converted in CO_2 and CH_4 by methane-forming bacteria and archaea and the pH increases to higher values, up to 8. The sub-acidic pH is detrimental for the growth and development of methanogenic bacteria and archaea (Yang et al., 2015; Zhang et al., 2014), confirmed by the scarce methane production observed in mesophilic condition in ISR 0.5 reactors (Table 2).

The $N\text{-}NH_3$ values in thermophilia were significantly higher in ISR 0,5 and ISR 1 compared to the other samples and BS showed the lowest value; in mesophilia the content of $N\text{-}NH_3$ in ISR1 was significantly higher than the others ISRs (Table 2). Nevertheless, all the values were in the safe range level reported in literature (Holliger et al., 2016). Moreover, the $N\text{-}NH_3$ increase was proportional to gas production when TP was added.

The cumulated production (PC) of methane (NL CH_4 L^{-1} substrate) confirmed the range reported by other authors (Almeida et al., 2021; Calabrò et al., 2015). In thermophilia, ISR 0.5 showed the highest production of 14.24 NL CH_4 L^{-1} but not statistically different from ISR 1. The lowest production was observed for ISR 3.6 (2.86 NL CH_4 L^{-1} substrate), but it gave the highest concentration of methane in biogas (84.6%) (Table 2).

The lowest methane peak (32.8%) was obtained in ISR 0.5 in mesophilia due to the fermentation blockage by the VFA concentration which inhibited archaea growth. In all others ISRs in thermophilia and mesophilia the VFA production mirrored the biogas production (Fig. 1a, b). The codigestion of TP and BS increased the cumulated methane production (7.47 to 10.74 ISR 3.6 and ISR 1 respectively) in mesophilic conditions compared to BS alone.

The addition of TP in thermophilia decreased methane yield in ISR 3.6 which gave lower yield compared to BS alone (86.66 and 167.29 PCL g SV^{-1} respectively) (Table 2). The methane yield was not statistically different between ISR 1 and ISR 0.5 in thermophilia and all the ISRs in mesophilia (Table 2).

The cumulated production curves reported in Fig. 2a showed that in mesophilia ISR 3.6 and 2 and BS reached a plateau after three weeks. In ISR 1 the fermentation was delayed of about three weeks and reached the plateau at 50 days (Fig. 2a).

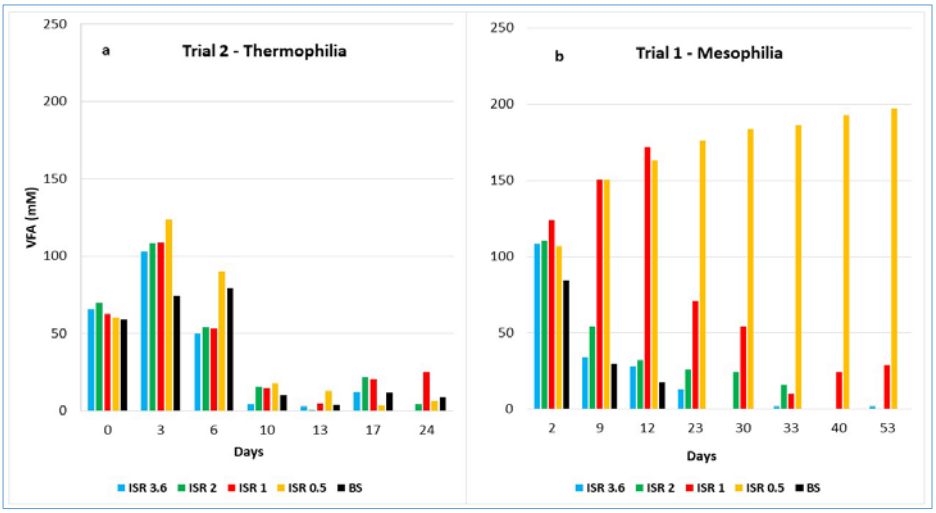

Fig. 1. VFA concentration in trial 1 and 2

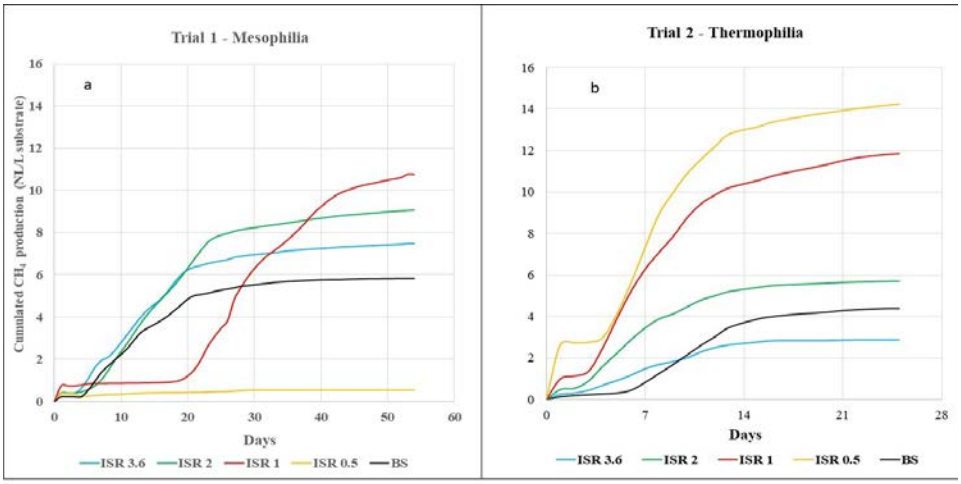

Fig. 2. Cumulated methane production curves in trial 1 (Fig.2 a) and trial 2 (Fig.2 b)

In thermophilic conditions the fermentation kinetic is different and faster, in fact the plateau was reached after two weeks in all the ISRs (Fig. 2b). This results in a shorter hydraulic retention time (HRT) of the thermophilic digestion compared to the mesophilic one. Therefore, more substrate is digested in the time unit for the same size of the digester, or the same amount of feedstock is digested in a smaller plant size reducing plant costs (energy excluded).

6. Concluding remarks

TP may have a great potential to be recycled in codigestion with BS. Parameters as an optimal substrate inoculum ratio, are important for the process: ISR 1 seem capable to assure the highest methane production and yield in both conditions. pH also plays an essential role in the fermentation inhibiting methanogenesis when dropping below 6.

The higher methane yield of ISR 0.5 suggests that the application of thermophilia may allow to recycle higher quantity of tomato waste. The temperature probably activates different microbial populations resulting in a more efficient methane production. However, the right trade-off between high recovery of TPs and increased energy cost of the process should be taken into consideration.

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REMEDIATION OF THE POLLUTED REGALBUTO SITE: CASE STUDY METASERVICE S.R.L.*

Alberto Spadaro[1], Ottavio Spadaro[1], Rosario Carrabino[1], Antonio Zerbo[1], Sarah Musumeci[2], Giulia Bellomo[1]**

[1]Department of Economics and Business, University of Catania, Italy
[2]MetaService S.r.l, Italy

Abstract

The reclamation of polluted sites is subject of numerous innovations and incentives by the state. The paper presents the case of the reclamation of the site in Brucasottana street in the municipality of Regalbuto (EN), affected by the spillage of dielectric mineral oil from a MT/BTAPALO transformer. After presenting the technological innovations in the sector, the main sites of national interest in the region of Sicily are described.
The site of interest is located at an elevation of approximately 414m above sea level and the morphology of the area is regulated by watercourse action. In the presented case study, the reclamation and hazardous waste transport activities are described. The stages of removal of the monitoring tape, the export of tampered equipment, the removal of polluted matrices, and the temporary backfilling of the excavation are also analyzed. Also quantified are the economic and technical evaluations provided by the company to better assess the investments made with a view to protecting the territory.
The technical and economic analyses of the project are presented in order to make a careful assessment of both the reclamation of the site and the recovery of the aquifers involved.
This study shows an example of polluted area remediation activities proactively managed for environmental and health protection. These actions aim to return brownfield sites to the community, respecting the relevant regulations and procedures.

Keywords: economic and financial evaluation indicators, environmental protection, hazardous waste management, remediation of polluted sites

*Selection and peer-review under responsibility of the ECOMONDO
** Corresponding author: e-mail: rosariocarrabino2@gmail.com

1. Introduction

The term 'contaminated site' refers to all those areas in which, as a result of past or ongoing human activities, an alteration of the qualitative characteristics of the environmental matrices of soil, subsoil and groundwater has been ascertained that represents a risk to human health.Pursuant to current legislation (Legislative Decree 152/2006 and subsequent amendments and additions), an area where concentrations in surface soil, subsoil or groundwater samples are found to be higher than the maximum concentrations laid down by law - CSC - (even for a single pollutant), is defined as a 'potentially contaminated site'. When, following specific investigations, it is ascertained that there is a risk to human health, deriving from pollution, the area in question is defined as a 'contaminated site' (Unnisa and Bhupatthi Rev, 2013).

The legislation on the remediation of polluted sites, Title V - "Remediation of contaminated sites" of Part Four of Legislative Decree 152/06, which replaced Ministerial Decree 471/99 - "Regulation laying down criteria, procedures and methods for the safety, remediation and environmental restoration of polluted sites", sets out in detail the provisions concerning the determination of health risks, the criteria for remediation interventions and the identification of the best intervention techniques and the penalty system (Sadhan, 2020).

The legislation on the remediation of polluted sites, introduced by Article 17 of Legislative Decree No 22, 5 February 1997 (Ronchi Decree), subsequently completed and implemented by Ministerial Decree No 471 of 25 October 1999, was amended by Legislative Decree 152/2006, which repealed Article 17 of the Rocchi Decree.

- the limits of acceptability of soil and groundwater contamination in relation to the intended use of the soil (public green/industrial use)
- the reference procedures for taking and analysing samples
- the general criteria for the safety, remediation and environmental restoration of polluted sites, as well as for drawing up the relevant projects.

The first intervention on environmental damage carried out during the 17th legislature is represented by Article 25 of the 2013 European Law (Law No. 97 of 6 August 2013).

The main consequence of soil pollution concerns the loss of its fertility and its incompatibility with animal, plant and human life. Contaminated soils usually remain sterile and empty for as long as it takes nature to clean up the toxic substances or break them down into other harmless elements, a recovery that can take a very variable amount of time. Polluted soils can see their capacity to absorb water altered, causing flash floods, or, conversely, rotten soils with unsustainable pH (very acidic or very basic) that in the presence of water give rise to toxic and deadly substances.

In addition to the obvious environmental problems, we can also see the enormous damage that all this entails on our own health. Polluted soil means polluted food, food that we ingest on a daily basis, stocking our bodies with toxic substances, the cause of numerous pathologies to which we often fail to respond. One example is the increase in diseases such as celiac disease, intolerances and sudden allergies.

The objective of this paper is to analyse technological innovations in the field of the reclamation of polluted sites resulting from the incorrect disposal of special waste. To this end, the case study concerning the company Metaservice located in Sicily, whose core business is the use of experimental technologies for the reclamation of Sicilian sites, was taken into consideration.

2. Research methodology

The remediation of large polluted sites of national interest is lagging behind, but the growing awareness of citizens and institutions is leading to an increase in the remediation and regeneration of contaminated soil and water and the search for new technological solutions.

3. Bio-assisted phytoremediation

Phytoremediation or Phytoremediation technologies can be included in this group, which we can define as a natural soil remediation technology that uses certain plants that are able to phytoextract heavy metals and/or induce the degradation of organic compounds (Centemero and Zanardi, 2008). In the context of phytoremediation strategies, bio-assisted phytoremediation is a technique, developed by the CNR, to reduce the concentration of certain chlorine-organic soil contaminants below legal limits by exploiting the interactions established between plants and microorganisms in the rhizosphere. Tree plants, carefully selected and used in high-density, short-rotation agro-forestry systems, favors a high and homogeneous production of roots in the soil that tend to entangle and melt, forming an enormous adsorbing surface and an extensive rhizosphere (Pazos et al., 2010). Within the latter, thanks to the presence of root exudates, a microhabitat is created that is favourable to the microbial community and the biodegradation of the organic contaminants present. Plants, in addition to developing an extensive root system, can produce woody biomass of a quality suitable for thermo-conversion or thermal and electrical cogeneration produced by various processes (Waite, 1995).

At a polluted site before any operation is carried out an analysis on the type of intervention to be implemented, Annex 3 of Part IV, Title V of Legislative Decree 152/06, defines the general criteria for the choice and implementation of the various types of intervention in relation to the state of contamination and use of the site and in particular provides the following measures (Brandon, 2013)

- Emergency safety measures;
- Operational securing;
- Permanent securing.

Once the type of intervention is known, we move on to the decision of the remediation technique to be used, the intervention systems on contaminated soil and water can be classified in-situ and ex-situ (Leone, 2013). The former involve treating the contaminated matrix without removing it, the latter are based on a preliminary excavation (soil) or extraction (groundwater), followed by a treatment phase aimed at their decontamination, which can take place on-site, i.e. near the site, or off-site, in a different place from the site of origin (Polprasert, 2007).

A further distinction that is sliced across remediation techniques is the nature of the processes used or the mechanism envisaged:

- Biological: Biological remediation technologies refer to those treatments aimed at the decomposition of organic molecules through the metabolic activity of indigenous microorganisms present in the subsoil, or introduced into it.
- Chemical-Physical: Chemical-physical methods, on the other hand, exploit the chemical and physical properties of the contaminant, or contaminated matrix, to decrease the concentration of contaminants and/or contain contamination (Brugnoli et al., 2014).

4. Case study

In a constantly developing sector such as waste disposal and reclamation, the Meta Service company has carved out a particular reputation in Sicily. It was founded in Sicily in

1988 by a few professionals in the special waste transport sector. Founded by Luigi Musumeci, as an oil recovery company on behalf of Agip, it became a family-run business that today is an ultra-modern reality operating in the field of industrial waste management and collection and environmental reclamation with an eye to the regulations governing the environmental sector. Equipped with state-of-the-art equipment and a highly professional staff that is continuously updated on technical and legal aspects.

The company is certified ISO 9001 - ISO 14001, ISO 45001, ISCC-EU, and has adopted a Code of Ethics and an Organisation, Management and Control Model in compliance with the provisions of Italian Legislative Decree no. 231/2001. It is registered in the National Register of Environmental Managers in categories 1/2/3/4/5/8/9/10 and also holds authorisation from the Region of Sicily for the storage of hazardous waste. The following treatise will describe the company, the market in which it operates and the services it offers, especially special waste processing with documentation of work carried out by the company

Meta Service is able to present its customers with a range of quite specific services on a request by request basis.

The services offered can be grouped into four macro-areas:

- **Remediation and Reclamation**: interventions in polluted areas, especially in contact with medical waste and contaminated groundwater, up to asbestos treatment. Meta Service operates in compliance with D. Lgs. 152/06. The decontamination of polluted sites such as disused production sites, construction sites, and unauthorized micro-dumps is carried out firstly through surveys and sampling to analyse pollutants. Subsequently, a paperwork service is activated for compliance with the relevant bodies, and then the hazardous elements are removed using qualified procedures and authorized equipment.
- **Waste Storage**: Meta Service has an authorized warehouse for the storage of solid, liquid and recoverable waste. The waste storage service on behalf of the customer for the entire duration of the storage period is guaranteed by correct ecological treatment according to the type of waste.
- **Special Waste Management**: all-round management of industrial waste. The company is a licensee of Conou and Conoe, the two most important national consortia for the collection of used mineral and used vegetable oils. The legislation on used oils, being classified as hazardous waste, is very precise and requires a certain professional rigor in its implementation. The identification of the waste, which is attested by a standardised document, is the first step in the procedure. Exhausted oil collection is then carried out using suitable containers (tanks or drums) that are transported to a temporary storage depot, to be subsequently delivered to authorized centers for final disposal.
- **Intermediation**: The consultancy is based on finding the optimal solution for both those who need to deliver waste and place it on the market. Meta Service, through direct knowledge of a number of contacts in the target market, offers a very competitive commercial brokerage service. The consultancy is based on the search for the optimal solution both for those who need to deliver waste and place it on the market, and for those who need to find new suppliers of recoverable waste and materials from recovery processes. As a leading company at regional level, Meta Service can boast a vast and ramified organization chart.

5. Results and discussions

In order to best describe the production cycle implemented by Meta Service, I have taken a look at a recent job involving the company in question: work carried out on a site

affected by the spillage of dielectric oil from a MV/LV pole-mounted transformer owned by 'e-distribuzione S.p.A'.

5.1. Event description

Emergency safety measures and environmental restoration works were carried out on the site near C.da Bruca Sottana, in the municipality of Regalbuto (EN), affected by the spillage of dielectric mineral oil from a MV/LV pole-mounted transformer (matr. no. D810-2-229924, named "Bruca") owned by e-distribuzione S.p.A. Infrastrutture e Reti Italia - Area Regionale Sicilia - Territorial Unit Caltanissetta Enna. Following the aforementioned event, e-distribuzione S.p.A. proceeded to send a notice to the interested Bodies (using Model A of the Regional Guidelines on the Remediation of Polluted Sites), on 15/04/2022, pursuant to Article 242 of the aforementioned Legislative Decree. 152/2006, as the interested party responsible for the potential contamination, in which the activation for the removal of the primary and secondary sources of contamination was made known, in order to be able to proceed with the verification of any exceeding of the contamination threshold concentrations (CSC), as well as the consequent and possible reclamation of the site.

On 15 April 2022 (at 1.30 p.m.), at a piece of land owned by third parties, located in C.da Bruca Sottana, in the municipality of Regalbuto (EN), it was found that following the theft, by unknown malefactors, of the MV/LV transformer owned by e-distribuzione S.p.A, placed on a pole (transformer pole no. D810-2-229924 named "Bruca") at a height of approximately 5 m, there was a partial leakage of dielectric mineral oil, containing PCBs with a concentration value <25 ppm, pursuant to Legislative Decree 209/99, contained in the electrical equipment, with the spillage over an area of no more than 20 m2, consisting of the ground below the pole, located adjacent to a dirt road, near the SS121.

The environmental component most affected by the spillage was the soil, which can be classified as agricultural land (uncultivated), to a maximum depth of approximately 1 m.

In the case of small sites, as in the case in question, where the extension of the area does not exceed 20 m^2, it falls within the scope of Article 249 of Legislative Decree 152/2006 and Annex 4 to Title V of the Fourth Part of the same decree, which regulates the application of the simplified procedure for small areas (< 1000 m^2).

5.2. Site description and type of contamination

The site of interest, covering no more than 20m^2, lies in C.da Bruca Sottana, adjacent to a dirt road that runs off the SS 121, about 15m to the north. The site under examination is located at an altitude of approximately 414 m a.s.l. Cartographically speaking, it is included in C.T.R. no. 624090, while cadastically it falls within P.lla 23 of Sheet 64. The area surrounding the site is currently cultivated mainly with arable crops. In the immediate vicinity there are no residential buildings, while it is in the vicinity (approximately 10 m to the east) of a secondary runoff ditch, which flows, approximately 600 m further north, into a secondary tributary of the Salso River.

The area of interest is located to the NE of the built-up area of Regalbuto, from which it is about 6.6 km away as the crow flies, on a slope slightly inclined to the North, set between gentle hills that slope towards the Salso River bed. The morphology of the area is, therefore, governed by the action of the surrounding watercourses that characterise valleys with gently sloping walls that slope down to join the valley floor where the main receptor, the Salso River, a tributary of the Simeto River, flows.

For the description of the geological, geomorphological and hydrogeological characteristics, reference was made to information gathered during direct surveys carried out in the area, specific publications and thematic maps, such as the 'Geological Map of Central-Eastern Sicily' produced by the Earth Sciences Institute of the University of Catania (1990).

The local morphology is characterized by the fluvial plain, with the presence of an alluvial mattress of a certain thickness, embedded in a hilly type context, conditioned by the variability of the erodibility characteristics of the outcropping lithologies: in correspondence with the few stone rock masses, rather rugged morphologies develop, with sub-vertical escarpments and very steep slopes; whereas, where the clayey and clayey-marly terms outcrop, the morphologies become much milder and particularly incised by the hydrographic network (Arfò et al., 2019).

5.3. Interventions implemented

The company META SERVICE S.r.l. of Catania, specialised in the sector and in possession of the following authorizations, was appointed to carry out the emergency safety and environmental restoration operations:

- **Remediation activities**: Registered at the Catania Chamber of Commerce and at the National Register of Environmental Managers (eg.National Register of Companies carrying out waste management) Sicily Regional Section, in Category 9.
- **Waste transport activities**: Registration with the National Register of Environmental Managers (eg. National Register of Companies carrying out waste management) - Sicily Regional Section - No. PA 000334 of 22/04/2016.

The same company was also commissioned to carry out chemical-physical analyses on the soil samples taken by the same company, through a suitable laboratory, to verify compliance with the CSC limits set forth in Annex 5 to Title V of Part IV of Legislative Decree 152/2006. The analyses were carried out by Studio Chimico Ambientale S.r.l. with headquarters at VIII Strada n. 8, Zona Industriale, 95121 Catania, with quality certification.

Therefore, in order to:

- definitively remove polluting sources
- prevent their contact
- contain the spread of contamination
- implement prevention, environmental protection and public health protection measures.

Following the analyses carried out, the following actions were set in motion:

1) **Removal of the monitoring tape and warning signs**: the cover sheet was removed and the monitoring tape and warning signs placed by e-distribution during the first intervention were removed.

2) **Removal of tampered equipment:** in order to avoid further oil spills, the polluting source represented by the transformer and the various fragments of electrical equipment was removed, paying particular attention to the recovery of the equipment, which was placed in a sealed container. A total of 400 kg of discarded equipment was removed.

3) **Removal of polluted matrices and placement in big bags**: using hand tools and a mechanical excavator, the soil was removed from the potentially contaminated area, excavating to a depth of approximately 15 cm for an extension of approximately 20 m2, within which the excavation was deepened by approximately 1 m, in correspondence with the area most impacted by the potential contamination, for an extension of approximately 6 m2. The material removed, for a total of 6660 kg, was placed, at the same time as removal, inside 6 big

bags, which were then placed in a sealed, approved and appropriately labelled roll-off container in accordance with the law.

4) **Provisional backfilling of the excavation pending acceptance of the work**: Given the small size of the area, following the excavation works and removal of the contaminated matrices, also in order not to leave the excavation open in an unguarded area and, therefore, in order to prevent risks to third parties in compliance with current safety regulations, the area was temporarily restored by recultivating the excavation, following the placement of a natural fibre bio-mat (straw and coconut), with no chemical additives and 100% biodegradable, on the excavation surface and the subsequent backfilling with soil of certified origin, laid by means of compaction with mechanical equipment. The bio-mat was placed for the purpose of identifying the excavation depth in the event of verifications by control bodies. In the event that the testing verifications, on the return to the CSC limits of the soils in place, give a positive result, the restoration carried out becomes definitive.

The entire area (approximately 20m^2) from which the potentially contaminated matrices were removed, was subjected to verification through testing of the implemented interventions. In particular, samples were taken according to the following criteria:

- a punctual sample of the bottom of the excavation performed at the point of greatest contamination (called "CONTAMINATED POINT");
- a composite sample (from no. 4 increments) at the walls of the excavation performed at the point of greatest contamination (called "WALL")
- a composite sample in the entire area of intervention (scarification plus excavation), resulting from the collection of 12 increments, at the same number of points located according to a regular grid (called "EXCAVATION BOTTOM").

The laboratory analyses performed on the three soil samples taken showed values of the pollutants investigated (Total Hydrocarbons C10-C40 and PCB) in concentrations (mg/Kg) lower than the relative CSC values indicated in column A of Table 1 of Annex 5 to Title V of the Fourth Part of Legislative Decree 152/2006. The waste was destined for the storage plant for hazardous and non-hazardous waste, owned by META SERVICE S.r.l., located in Aci S. Antonio (CT), Via G.Galilei no. 49, with authorization obtained with D.D.S. no. 15 of 09/01/2019; the destination operation was recovery in R13 (waste storage to undergo one of the operations indicated in points R1 to R12 of Annex B to Part Three of Legislative Decree 152/2006). It is established that the site in C.da Bruca Sottana, in correspondence with the MV/LV transformer pole serial no. D810-2-229924 named "Bruca", falling within the municipal district of Regalbuto (EN), following the emergency safety and environmental restoration works carried out, is free from residual contamination and that such works can be considered adequate to achieve the objectives of eliminating the sources of pollution (primary and secondary).

6. Conclusions

This study was carried out to analyse processing techniques on remediation in Sicily, where Meta service has carved out a dominant position in the market, mainly by processing asbestos, which is considered a very hazardous waste.

The company, which has by now consolidated its strategic position, does not want to set limits for itself. This is demonstrated by the numerous jobs carried out beyond Sicily, mainly in Calabria, which represent the company's desire to grow in more Italian regions.

Meta Service is very attached to environmental issues, as it is a promoter in areas of environmental education, carrying out its work with an ethical and responsible approach to industrial management, adopting behaviors that guarantee the quality of the work and the

lowest possible impact. This is demonstrated by the benefits of the interventions described above, which involved recovering and safeguarding a building made of eternit from highly polluting spills. The goal the company wants to achieve is to be able to contribute as much as possible to an increasingly eco-sustainable world. Companies must realize the importance of the ecosystem by implementing controls on their environmental values, so as to form sustainable companies and allow for continuous development. If all companies implemented these controls, whether they relate to energy efficiency, emissions or many other factors, the environmental results would be manifold, even if this may entail sacrifices.

Pollution of industrial sites is a major problem in many regions of both Europe and the world, not only because of the environmental risk involved but also because of the high clean-up costs involved. This leads to a potential conflict between the increasing pressure on site owners and the actual difficulties of engineering intervention. The high costs and technical unfeasibility of various engineered remediation measures, i.e. using both in-situ and ex-situ plant technologies, have led to an increasing acceptance of decision-making based on risk analysis in order to identify the most suitable and economical remediation technique for each site. Undoubtedly, however, are the importance on waste management and reclamation processes, both industrial and non-industrial, relating to the great and even necessary advantages that can be brought about by certain processes.

The ultimate aim of these management and reclamation processes is above all to safeguard and restore the health of certain areas so that living beings located in the areas cannot be harmed. In Italy, we are still lagging behind in terms of intervention and technical plans, which is also demonstrated by the high number of people suffering from diseases related to contact with hazardous materials. Fundamental, especially in Sicily, would be the implementation of information plans that can raise people's awareness and provide more information on the importance of sustainable issues and the circular economy.

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INDUSTRIAL SYMBIOSIS IN THE PRODUCTION OF SUSTAINABLE TEXTILES: ORANGE FIBER S.R.L.*

Carla Torrisi[1], Rosario Carrabino[1], Adriana Santonocito[2], Agata Matarazzo[1], Federico Mertoli[1]**

[1]Università degli Studi di Catania, Department of Economics, Corso Italia n 55, 95129, Catania, Italy
[2]Orange Fiber s.r.l,Via Monserrato n 110, 95128, Catania, Italy

Abstract
One of the sectors with the greatest impact on the environment is the fashion industry, due to mismanagement of resources. This paper aims to describe the Orange Fiber case study, a Sicilian firm that uses cellulose extracted from 'Pastazzo', the citrus by-product, to obtain sustainable luxury fabrics. In addition to describing the stages of the production process and the technological innovation in the company, it was proposed the certification of environmental management systems according to international ISO 14001 standards within the company. In particular, the phases of environmental policy, and the application of the Deming cycle to the innovative start-up were explored. From the point of view of industrial symbiosis, the paper therefore proposes the idea of transforming a waste from the agro-food industry into a raw material in an environmentally impactful sector; this could represent an innovative idea in the application of circular economy principles.

Keywords: fashion, industrial symbiosis, pastazzo, startup, technological innovation

1. Introduction

According to the Ellen MacArthur Foundation, circular economy is “a generic term to define an economy designed to regenerate itself" (Dallocchio et al., 2021).

This system is based on three fundamental pillars:

- eliminate waste and pollution;
- circulate products and materials at their highest value;

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** Corresponding author: e-mail: rosariocarrabino2@gmail.com

- regenerate nature (hiips://ellenmacarthurfoundation.org/topics/circular-economy-introduction/overview).

These principles refer to a metamorphosis of the current economic system. It is necessary, in fact, a transition from the linear model to a circular one. The first system is called "take-make-waste" and involves large amounts of resources and energy, while the second one is based on the use of secondary raw materials. These secondary raw materials derive from waste materials and after recycling, they can be introduced as new raw materials into the production process. So we respond to the needs of the economic system in a sustainable way in compliance with eco-design, one of the main themes of the circular economy.

Eco-design refers to a new way of producing, with future projections about the end of life of the product in order to recycle materials, connecting technologies and business to the right use of natural resources.

Thanks to the circular economy there is no waste and the intrinsic value of the material is preserved. In fact, the materials are reintroduced into the production process through two alternative cycles: the technical cycle and the biological cycle. In the first one we try to recover and recycle the materials; in the second one the biodegradable elements are decomposed through processes, such as composting or anaerobic digestion.

This model is called circular because it replicates the trophic chain, that regulates creatures' life, and it can be assimilated to a production system. In fact, the concept of waste is purely artificial. Investing in renewables means preserving natural resources and minimizing their exploitation, in order to limit energy dependence on fossil fuels. Today in cities 75% of natural resources are consumed, 50% of waste is produced and between 60% and 80% of greenhouse gases are emitted. It is estimated that more than 70% of the world's population will live in cities by 2050, so it is necessary a transition to circular economy (hiips://ellenmacarthurfoundation.org/topics/circular-economy-introduction/overview). The circular city is defined by the Ellen MacArthur Foundation as a regenerative system that aims to eliminate the concept of waste. The circular city is not limited to put together all the circular economy projects of the same territory, but it has the primary purpose of avoiding the waste of resources (water, energy, materials) considering both physical space and urban morphology (Innella, 2019).

2. Materials and methods

The transition to a more sustainable business model is fundamental to reduce the impact caused by the fashion industry. Also, it is important for companies to implement alternative solutions that involve the supply chain entirely. In particular, the transformation must involve all stages, from supplying of raw materials to the end of life of the garments. Sustainable fibers have been growing in the last decade. It is estimated that 50% of cotton will come from sustainable sources by 2025. With the term sustainable cotton, we mean the one produced with low water consumption. Recycled cotton is not yet widespread and it is an emerging market. For synthetic fibers it is estimated a rapid growth in the use of recycled polyester as well, thanks to new technologies. This comes mainly from PET plastic bottles, ocean plastic waste or other polyester clothes.

Certifications are the only way to ensure obligation of brands in the use of new recycled materials that reduce pollution. The STANDARD 100 of OEKO-TEX® is one of the best-known examples. In fact, a minimum presence of recycled materials is required in each product to achieve the certification, as well as a careful assessment of any toxic substances in the fabrics.

Life cycle assessment (LCA) is the most accurate tool for measuring the environmental impact of a product during its entire life cycle, from cradle to grave. At the same time, it is an index of circularity and sustainability of the product itself. This technique has evolved over

time, after analyzing other factors such as the cost and social impact of the product. The Life cycle thinking (LCT) can be defined as a method that considers the complexity of the product and related factors. This tool is considered the basis of the environmental policies adopted by the European Union, because it evaluates the presence of any boomerang effects or transversal actions of citizen in an integrated approach (Camana et al., 2021).

Models, such as the circular one, search for an innovative way for the management of the end of life of garments. This consists in putting textile waste back into circulation and obtaining secondary raw materials. The circular economy aims to overcome the current linear production model. This means ensuring a system in which the resource is valued for as long as possible.

The circular economy responds positively to the 17 Sustainable Development Goals, in particular, the sixth goal, related to the availability of water resources, and the seventh, related to energy optimization. Circular economy is also connected to the twelfth for sustainable consumption and production (Gazzola et al., 2020).

If not supported by a regulatory structure, sustainable fashion, responsible fashion and ethical fashion remain only words that can generate greenwashing and can confuse consumers at the time of purchase. It is important to establish a set of rules that is transparent and communicates the real environmental impact of a product to the public.

The textile sector is governed by EU Regulation No. 1007/2011. It establishes the principles regarding labeling, denomination of textile fibers, fibrous composition of textile products. Labeling is a fundamental instrument of transparency to show the choices made by the company in the production process. There is an obligation to inform consumers clearly and truthfully. In this context, the European Union has approved a sustainable and circular textile strategy on 31st March 2022. This strategy aims to make the textile sector greener by 2030 in compliance with the European Green Deal and the New Circular Economy Action Plan. To achieve these objectives, the European Commission is going to set minimum design requirements for textile products that facilitate repair and reuse.

If companies want to change and participate actively, they will have to adapt their structure to the international standards of ISO 14001: 2015. This certification establishes the principles for implementing an environmental management system in companies.

3. Case study - Orange Fiber

Orange Fiber S.r.l. is an innovative company that produces high quality sustainable fabrics from the citrus by-product. It has its roots in Catania and it is a female story. In fact, the creative idea was developed by Enrica Arena and Adriana Santonocito in 2012 and aims to add value to Sicily through the creation of a new material for fashion. The value proposition consists in the recovery of “pastazzo” in the perspective of the circular economy. The “pastazzo” derives from the pressing process and contains seeds, skins and everything that is not useful for food. In fact, 60%, of an orange squeezed, compared to the original weight, represents a by-product to be disposed of. In Italy it is estimated between 700000 and one million tons of by-product to be managed, which imply significant environmental and economic costs.

The process of extracting cellulose from the pastazzo was started thanks to the collaboration with the Materials Chemistry laboratory of the Politecnico di Milano in 2012, which tested the cellulose and verified that it was compatible for textile purposes.

The Orange Fiber production process has been patented, first in Italy and then extended in the main citrus juice producing countries. The process starts from citrus juice leftovers.

In this way the waste becomes a resource, and the cellulose is extracted from the by-product. The manufacturing process requires the action of additives that transform the cellulose into powder. These phases take place in the Orange Fiber pilot plant in Sicily. Then a Spanish partner turns cellulose into yarn. The cellulose yarn is silky and can be combined with other yarns or it can be used pure. In this last case it is a fabric 100% citrusy, soft, opaque or shiny depending on the creation needs of the stylists. In the end the yarn returns to Italy for the last phase of the process: weaving. The final product is sold to fashion brands so they can print or refine it according to their creative needs, preserving at the same time natural resources.

The first collaborations were made in twill, poplin and jersey fabric obtained from continuous filament citrus. Then Orange Fiber and the Lenzing Group collaborate for the creation of a new lyocell fiber: the TENCEL™ Limited Edition with Orange Fiber, composed of cellulose obtain from orange and wood. The goal is to develop alternative solutions to give new life to waste and promote greater transparency in the textile and fashion industry (hiips://orangefiber.it/impact/).

Orange Fiber guarantees a safe and high-quality product to its consumers and communicates it through the OEKO-TEX Standard certification. Controls vary, depending on the type of product and its function. The more a product is in contact with the skin and the more sensitive the skin is, the stricter the requirements are.

The company does not have the ISO 14001 standard, the subject of this paper is an application of the certification to the company. The ISO 14001 standard is a voluntary and international certification that applies to all types of companies. The Accredia, a private entity, verifies the requirements of the environmental management system within the company and issues the certification.

The latest version of the standard is ISO 14001:2015 and consists in 10 points for a High Level Structure:

1. Scope of the Environmental Management System
2. Relevant legislation
3. Terms and Definitions
4. Context of the organization
5. Leadership
6. Planning
7. Support
8. Operation
9. Performance evaluation
10. Improvement

The last points of the standard (Planning, Support, Operation, Performance evaluation) can be expressed through the Deming cycle. This model consists of four phases that repeat cyclically to achieve continuous improvement of company performance.

Orange Fiber has set strategic sustainability objectives. One of them is make management of water, energy and resources in the production process completely circular by 2030; another one is connected to safeguarding forests through its production and to avoiding the fall of 5,000 trees per year by 2026. The two objectives set for 2022 instead are: an assessment to plan the reduction of emissions and a greater transparency of the supply chain guaranteed by supplier certifications. A sustainable supply chain is ensured by an integrated approach that involves continuous collaboration between weavers and fashion houses.

This will be possible through some process implementations: a new machinery will allow significant savings in water consumption and facilitate its disposal at the end of the process, while the transition from the kiln drying to that in the greenhouse will allow a reduction in the electricity consumed.

Orange Fiber will supervise the achievement of the objectives monthly in meetings of the Board of Directors and monitor the consumption of water, energy and the main raw

materials used. It will also use the LCA (Life Cycle Assessment) analysis method to measure the environmental impact resulting from the process.

4. Results and discussion

Orange Fiber is an excellent example of how the circular economy can be applied to the fashion industry. The manufacturing process starts with the citrus juice leftovers. There are many alternative uses for this waste, from fertilizer to use it as an energy source, especially with the production of biogas. Until now no one had used its properties to obtain a fabric. The Orange Fiber process complies with a fundamental principle of circular economy: upcycling. It is a business model based on reuse and improvement of waste materials.

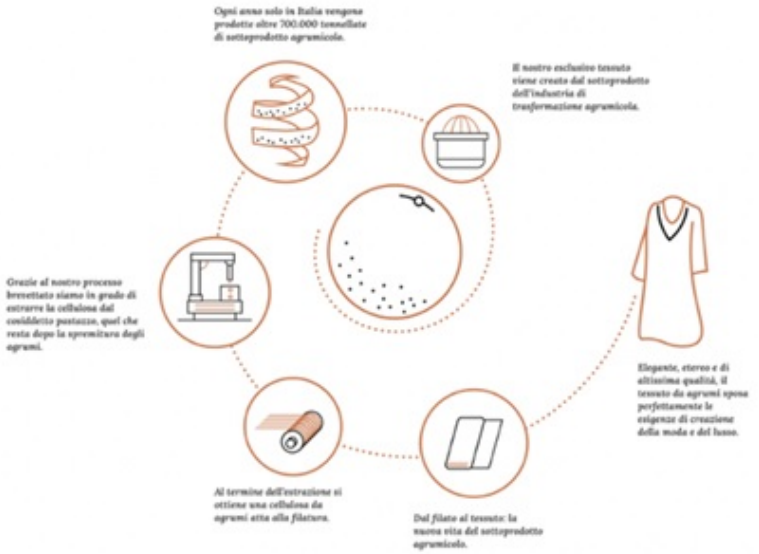

Fig. 1. Creation of orange fiber tissue

It is important to use the garments until the end of their useful life and then try to recycle them or resell them on second-hand platforms. Orange Fiber produces a biodegradable fabric that can be turned in the form of compost without any environmental impact. The dyes used are completely natural, in this way they do not pollute either during production or during decomposition. Orange Fiber undertakes every day to carry out innovative projects for the transition from a linear economy model to a circular model. In 2017 the company collaborate for its first collection with the fashion house Salvatore Ferragamo. In 2019 citrus fabrics were chosen for the Conscious Exclusive Collection of H&M and then Orange Fiber created the capsule collection of luxury neckties designed by the Neapolitan tailoring brand E.Marinella.

The Orange Fiber product can be defined multifunctional because it is capable not only of creating something unique and sustainable for fashion, but also of combining other creative universes such as design, technology and culinary art. Orange Fiber in 2020 took part in an exhibition dedicated to the different meanings of food related to the risks of environmental pollution (Villari et al., 2020).

5. Conclusions

The subject of this chapter is the application of the ISO 14001 certification to the Orange Fiber company, evaluating the environmental and economic benefits that can derive from it. From this analysis emerges that the company is implementing improvement techniques with a view to the circular economy and the environmental policy. The company also has internal monitoring systems for corrective actions. The organization could improve the efficiency control of the production process through LCA analysis. Other opportunities for improvement could derive from relations with universities. So, they could contribute to the dissemination of a good brand image and they could realize thesis or workshops.

However, we must consider that the measurement standards of environmental performance are parameterized on industrial processes, while Orange Fiber is a company characterized by development and research constantly. It is difficult to have terms of comparison valid nowadays because these are based on a continuous production scale.

For organizations that decide to implement an environmental management system there are a lot of environmental and economic advantages. In fact, the improvement of environmental performance generates a reduction in costs associated with the use of energy and raw materials. The system optimizes the management of resources considering the company problems in the different geographical areas.

The ISO 14001 certification guarantees compliance with legislative obligations regarding environment and consequently reduces the risk of sanctions related to environmental crimes.

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SPACE DEBRIS MITIGATION AND RISK ANALYSIS: A THEORETICAL MODEL*

Francesco Ventura[1], J.R. James[2], Daniela Barba[3]**

[1]CROWN Research Scarl, Rome, Italy
[2]CROWN GROUP, INC., USA, U.S. Air & Space Forces Association
[3]QBM S.r.l., Salerno, Italy

Abstract

The management of space debris or so called space junk is starting to be a widely debated topic, both in academia and in industry, because of their potential dangerousness for future space operations. In view of the fact that there is no real regulation of the subject at international level other than voluntary guidelines and standards, this work has a twofold purpose. First of all, it analyzes the regulations of space debris in the light of the most recent works that the academic literature proposes. Secondly, it proposes a risk analysis model applicable within the international standard ISO 24113:2019, useful to mitigate the risks associated with the presence of space debris already in the planning phase of the mission.

Keywords: environmental protection, debris mitigation, risk analysis, space debris, space law, sustainability

1. Introduction

The sustainable development of economic activities, understood in the common sense born in 1980 and contained in the Brundtland Report, requires "the rational and prudent use of natural resources". Such rational use is a key concept in the regulations issued by the States and must guide the latter whenever they are faced with new issues at the technical and economic level (Sanna, 2021). The technological development that has taken place in recent decades has in fact had several consequences, not always positive, on the natural environment. Just think, for example, that the process of improving the efficiency of telecommunications

*Selection and peer-review under responsibility of the ECOMONDO
** Corresponding author: e-mail: f.ventura@commercialistisalerno.it

systems made possible through a network of satellites has, on the one hand, allowed to improve the mechanisms of telecommunications but, on the other hand, has generated a constellation of hundreds of objects, mostly off, damaged or abandoned, which turning around the planet, could generate a serious threat to future space activities as they can generate collisions with other objects. (Sanna, 2021). For this reason, the management of the c.d. Orbital Space Debris is becoming a very important issue that will necessarily have to be taken into account in the planning of future space missions. But what is meant by Space Debris and how does international regulation deal with the problem? In reality, there is, to date, no unambiguous definition of spatial rejection.

The main reason why international legislation is deficient in this area is that the international legal regime that currently governs space law considers the environmental aspect only with regard to the efficient use of resources This is particularly true in the field of space, or for aspects related exclusively to the development of new Research & Development opportunities. This doctrine finds its raison d'être in the fact that the international regulation governing space is the daughter of the Cold War, a historical period in which the two superpowers then involved in the race in space, the United States and the Soviet Union, for fear of a military use of this environment, they accepted an international regulation of the use of Space exclusively for peaceful purposes. The stated goal of both countries was to transform every successful enterprise into a political-propaganda tool in its favor to be used in the continuous confrontation between the two Superpowers (Biagini and Bizzari, 2013). In this context it is useful to recall the Treaty on Principles Governing the Activities of State in the Exploration and Use of Outer Space, including the Moon and Outer Celestial Bodies (Outer Space Treaty), signed and entered into force in 1967. This treaty, together with the other documents constituting the normative corpus of international space law, will be the basis of the study presented here.

Analyzing the different definitions of "Space Debris" present in the International Treaties and in the other documents issued by the Organizations involved in the space race, it emerges that space waste, is defined as "any object made by man and sent into space that is no longer able to perform its primary function" (Viikari, 2015). The first element characterizing the proposed definition is the concept of "spatial object". The concept of "spatial object" has its legal basis in the Convention on International Liability for Damage caused by Space Objects, where Article 1 letter d) defines "...the spatial object comprises its component parts as well as the launch vehicle and its parts...". So, in the group of space waste, fall, the c.d. inactive payloads (e.g. space probes no longer under human control), operational service debris (e.g. rocket carcasses and launcher stages), fragments of debris generated by explosions or any other voluntary or accidental event that has caused the disintegration of space objects). It is the latter that constitutes the main collision threat that can occur during a space mission (Johnson, 2010). In particular, it has been shown that, in the c.d. Low Earth Orbit, where most of the debris insist, objects with a speed of 7/8 Km/s, may, in the event of collisions with other objects cause an impact of high energy value even if extremely small. Although the Low Earth Orbit, compared to the Geostationary Orbit (GEO), would allow a progressive decrease over time of space debris given its proximity to the Earth’s atmosphere, this orbit is the most studied for the resolution of problems related to the management of space waste, as it is that it contains most of the commercial, government and military satellites (Schaub et al., 2015).

Analyzing from a literal point of view the definition of Space Debris, it is clear that it constitutes rejection not only the satellite turned off, but also any other element necessary for space activity including the bodies of the launch vectors and its component parts. This principle must, at this point, be incorporated into the more complex corpus of norms of international space law which, as has been said, foresees the possibility of using Space in peace and of having it fully available during the phases of exploration. This principle, contained in

the Outer Space Treaty, is not without practical consequences for operators in the sector. First of all, this principle is linked to Article VIII of the Treaty, according to which "the State of launch retains jurisdiction and control over both the space object and the personnel on board. This implies an obligation on that State to avoid any form of pollution resulting from its activity which may lead to changes to the earth's environment. This is a far-reaching principle, however, which not only fails to define precisely the causes for the active intervention of the State for the protection of the environment, leaving the latter wide discretion on how to intervene to protect the latter (Viikari, 2015). To ensure a correct census of space objects by the States of Launch, it is necessary to recall another important document of international law, the Registration Convention of 1975, which regulates, within itself, the launch status obligation to register any object launched into Space in a special register kept by the Office for Outer Space Affairs (OOSA). The weakness of this document is linked to the fact that Article IV of the Treaty, which governs the content and modalities of communication, It says nothing about the management of space waste, and therefore it would be desirable for international action to deal comprehensively with waste management, since the State of Takeover is similar to a waste producer and therefore responsible for its disposal.

An incentive that could push States from an update of international space waste legislation is the possibility of considering Space Debris as assets capable of generating benefits for States of Launch, also only for the information assets that it can potentially contain (Viikari, 2015). For this reason, it will be necessary to define a series of Key Performance Indicators capable not only of evaluating the "technical functionality of the waste" but also the profit capabilities of the asset itself, in order to evaluate, as widely as possible, whether it should be qualified as space junk. In conclusion, what needs to be taken into account when approaching the problem of space waste management is that the number of debris is constantly increasing and that this increase is particularly evident at certain altitudes (Kessler and Cour-Palais, 1978; Schaub et al., 2015); that the orbits to be observed, by number of elements, are those placed at an altitude between 600-800 km and 1000-1500 km (Schaub et al., 2015); particularly delicate is the management of small objects, in particular of a size between 0,5 and 10 cm, which constitute the greatest danger for active satellites because of their number, the energy they can release in the event of a collision and the impossibility of tracking them (Schaub et al., 2015).

The aim of this work is to create a Risk Analysis model to be applied in the design phase of a space mission useful to create mitigating and preventive systems in the management of micro space debris, so as to reduce its impact during operational activities. The proposed Risk Analysis system is based on the combination of two methodologies: the c.d. "Bow Tie" and the "FMEA" method. In particular, the evaluation of the parameters of the FMEA methodology will be based on a fuzzy mathematical model capable of making more objective the brainstorming activity useful to understand the types of "failure" which may be encountered during the evaluation of the process under consideration. The novelty requirement lies in the fact that, in addition to the mathematical-statistical techniques used for the determination of Probability, Magnitude and Detection Capacity associated with risk, a fourth variable will also be introduced, called "Expected Failure Cost" (Rhee and Ishii, 2003) to determine the economic impact related to the type of failure examined. The fourth variable, calculated both before and after the introduction of preventive actions aimed at the mitigation of residual risk, will be built with the help of linear programming techniques and constrained optimization.

3. Materials and methods

In addition to the treaties of public international law, the management of the techniques of mitigation of c.d. space waste has also been followed by the c.d. Regulatory Bodies. In particular, the International Standard Organization has issued some standards that help organizations to manage different space debris mitigation. Focusing on an evaluation of the ISO 24113:2019 standard entitled "Space Debris Mitigation Requirements", two elements draw the reader's attention: the first is the structure used in the construction of the standard. The second is the orientation towards the construction of a risk analysis system capable of helping the company in the declination of operational and control procedures to be applied in the management of the space mission.

As regards the modality identified by the ISO for the drafting of the standard, the international body, notes, for the purposes of our analysis Point 6 " Technical requirements "where particular attention is paid to the concept of mitigation of the negative effects related to space debris related to space mission. To do this efficiently, the organization tasked with managing the mission will have to base its action on the risk-based thinking c.d. as "Ability of the organization to define and foresee, already in the planning phases of the management system, a system in order to manage the risks and to seize the opportunities". The implementation of Risk Based Thinking takes place through two standards specifically issued by the ISO for Risk Analysis: ISO 31000:2018 "Risk management Guidelines" and ISO 31010:2019 "Risk Management-Risk Assessment techniques". In the proposed study, two techniques will be considered:

"BOW TIE": The Bow Tie is a graphical visualization system of the risk connected to a critical event. The Bow Tie consists of two elements: a fault tree, which allows you to show, for the critical event, the set of causes that can lead to the occurrence of such an event and an event tree, which shows, instead, the possible "incidental sequences" which may originate from the event. For every reason that originates the event as for every accidental sequence, the bow tie allows the operator to visualize, with immediacy respective the prevention measures and the mitigation measures connected to the event that the company will put in field. Another advantage connected to the Bow Tie methodology is to highlight, for each preventive/mitigating action, also any factors that may reduce the effectiveness of these mechanisms to protect the process. For this reason, the Bow Tie system is very often used in all those sectors where the graphic vision of the evaluated event is very important for the management of the risks associated with the considered process (Eg. Chemical Industry).

"FMEA": Born in the United States during the "Space Race", the FMEA allows to verify, for every possible fault identified in the system, the causes, the magnitude, as well as the consequences related to the occurrence of the harmful event. For each element, this method involves the identification of potential fault modes that may occur during the process; the determination of the causes related to the fault modes; the assessment of the effects of the fault modes; the identification of appropriate corrective/preventive actions for the mitigation of effects and their effective impact on risk indices. These variables are identified thanks to interdisciplinary teams that, through brainstorming, arrive at a complete analysis of the system and the definition of possible modes of failure inherent in the process considered. In particular, the team, for each cause of failure, will assign a value within a predetermined scale of values, in order to determine, respectively, the probability of the occurrence of the event, the magnitude of the effects related to the event, the ability to understand upstream of the considered fault mode.

The value of the risk derived from the combination of these elements will then be evaluated, again by the working group, according to the technical specifications of mitigation/ prevention that the latter will define in its brainstorming activities. From the analysis of these

operating indications, one will obtain, therefore, a new value of the risk, defined residual risk, that it will show the risk appetite that the company will intend to bear as a result of the introduction of the previewed procedures of control.

4. Model discussion

The proposed mathematical model starts from the creation, for each considered event, of a graphic model of type "Bow Tie", derived from brainstorming activities and such as to highlight prevention measures as well as mitigation measures related to a possible harmful event Then we will move to a phase of "objectification of risk" expressed during the activities of brainstorming ante and post individuation of the procedures of control of the identified failures. In particular, the risk index calculated before the implementation of the risk mitigation procedures will be a function of the following elements (Eq. 1):

$$R_{pre} = f(P, G, C,) \tag{1}$$

where:

- P is the probability of the occurrence of the event. Its determination will take place using fuzzy logic, logic that allows to attribute to a given proposition a certain degree of truth or belonging between 0 and 1 and determined through an appropriate function of belonging;
- G is the magnitude of the effects related to the event. Its determination will take place using fuzzy logic, logic that allows to attribute to a given proposition a certain degree of truth or belonging between 0 and 1 and determined through an appropriate function of belonging;
- C is the ability to understand by the organization the mode of failure considered. Its determination will take place using fuzzy logic, logic that allows to attribute to a given proposition a certain degree of truth or belonging between 0 and 1 and determined through an appropriate function of belonging.

Why do we use fuzzy logic? To exploit its ability to represent and treat concepts or information expressed in qualitative form through a linguistic representation. Consider the classical theory and in it we indicate with A set crisp (well defined). Within A consider an x collection of elements belonging to the U universe. The characteristic function or membership is defined as that μ function of set A such that the x element belonging to the U universe can assume, as values 1 (TRUE) or 0 (FALSE). Introducing at this point the fuzzy logic, a new paradigm is introduced that extends the concept expressed in the classical theory of necessary belonging either to the TRUE or to the FALSE, leading it to verify the hypotheses proposed even partially. In other words, the proposition that "x is a member of A" is true with a degree of uncertainty ranging from 0 to 1. The degree of certainty is measured through the c.d. Degree of Fulfilment (DOF). The function that expresses, for each x, the degree of DOF is called characteristic function or membership function. Among the most famous are the triangular one (most used and defined by two extreme parameters equal to 0 and the vertex equal to 1);

Once the operational methods of risk mitigation have been defined, the residual risk model will depend on the following parameters (Eqs. 2, 3).

$$R_{post} = f\left(P_{post}, G, C,\right) \tag{2}$$

$$P_{post} = f(\alpha, \beta, \gamma) \tag{3}$$

where:

- $P_{post}$is a value between 0 and 1, determined by Bayesian inference methods. This value is obtained through the a priori probability α which reflects the information available prior to the collection of sample data); the likelihood function β such probability distribution

that would be assigned to the observed data at the specific value that the parameter of interest may assume) and the "ex post" distribution γ expressing updated probability of the investigated phenomenon) and will determine the response capacity of the organization to the occurrence of a given event;

- G is the magnitude of the effects related to the event. Its determination will take place using fuzzy logic, logic that allows to attribute to a given proposition a certain degree of truth or belonging between 0 and 1 and determined through an appropriate function of belonging;
- C is the ability to understand by the organization the mode of failure considered. Its determination will take place using fuzzy logic, logic that allows to attribute to a given proposition a certain degree of truth or belonging between 0 and 1 and determined through an appropriate function of belonging.

For both R and R_{post} an algorithm will be defined capable of solving the following linear optimization problem (Eq. 4):

$$F.O: \max \sum_{i=1}^{N} R_{post} \cdot C_{post} - \sum_{i=1}^{N} R_{pre} \cdot C_{pre} \quad (4)$$

This Objective Function wants to express the economic advantage connected to the implementation of a preventive action capable of reducing the risk associated with a given event. The function described above will be accompanied by "n" mathematical constraints/relationships that will define the conditions of eligibility of the solutions.

5. Concluding remarks

The model may have several application implications. First, the proposed model is proposed as an evolution of the FMEA model used by NASA in the development phases of Project Apollo. The approach used allows a broader risk management, such as to investigate the economic problems related to the mission. Moreover, the proposed model could be useful in order to define the goodness of the countermeasures to be adopted for the optimal management of the c.d. mission pay load that would be estimated also from a point of view of costs connected to the management of the risk of the operation.

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This work is dedicated to the memories of two Italian Air Force Instructor Pilots Gen. Paolo Caruso and Gen. Gino Fischione. May their souls rest in peace forever!

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COMPARISON OF AERATED BINS AND SEALED CONTAINERS. EVAPORATION EFFECT AND ODOUR CONTROL IN PRIVATE HOUSEHOLD BIOWASTE COLLECTION*

Hanna Virpiranta[1], Mikko Ahokas, Anna Belenikhina, Outi Laatikainen[2]**

[1]Macon Oy, Teknologiantie 18, 90590 Oulu, Finland
[2]KAMK University of Applied Sciences, Ketunpolku 1, 87101 Kajaani, Finland

Abstract

Temperature and humidity conditions were monitored for two to ten weeks in the spring and summer 2021 in three aerated and two conventional sealed bins for collection of organic waste from five private households in Oulu, Finland. Moisture inside the bins was detected to stay lower in the aerated bins (approx. 50%) when compared to the sealed bins (approx. 80%). Temperature inside the aerated and sealed bins did not much differ from the ambient temperature. Usage of the aerated bins during both summer and winter time can be recommended for private households, as the evaporation of the moisture decreases the weight of the collected waste. In addition, unpleasant odors or growth of fly maggots were not detected in aerated bins. User experiences were positive, and all the test groups would recommend the usage of aerated bins for collection of organic waste.

Keywords: aerated bin, biowaste, odor control

1. Introduction

In Finland, a significant fraction of the compostable waste still ends up in incineration. In 2018, mixed waste collected from households contained 40% of organic waste and 15% of plastic packaging (HSY, 2018). When utilized for energy and heat in combustion, the material of waste is lost, while it could be used for new products, materials, and substances. Thus, the aim in Finland is to increase the fraction of recycling.

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** Corresponding author: e-mail: hanna.virpiranta@macon.fi

Finnish waste legislation is being reformed in accordance with the directives concerning the waste sector accepted by the European Union in June 2018. The key objective of the reform is to reduce the amount of waste produced and to increase the fraction of the reuse and recycling of municipal and packaging waste as well as to reduce the landfilling of municipal waste. According to the reformed directive, in Finland 55%, 60%, and 65% of the municipal waste should be recycled in 2025, 2030, and 2035, respectively (hiips://ym.fi/jatesaadospaketti). In 2018, the rate of recycling in Finland was 42% (hiips://www stat fi/til/jate/index_en.html). Along with the reformation, from the beginning of 2024, collecting or composting of organic waste will be mandatory for population centres larger than 10 000 people, and disposal of organic waste with mixed waste would be prohibited (hiips://ym.fi/jatesaadospaketti). In many localities, collection or composting of organic waste is mandatory for detached houses also (hiips://www.kuusamo.fi/tiedostot/kuusamon-kaupungin-jatehuoltomaaraykset/). The amount of separately collected organic waste will increase in the next few years. Thus, the storage system for the organic waste needs to be improved. Technical characteristics of various types of waste containers have been scarcely studied.

Usually, organic waste bins are collected once a week in summertime. However, as the amount of organic waste produced in private households is small, there is need for longer collection intervals. In this study, aerated bins for collection of organic waste were compared with the conventional sealed containers, and the possibilities for using longer collection intervals with aerated bins with passive aeriation were studied.

2. Materials and methods

Aerated Bio Select bins (Fig. 1) developed by company PWS and sealed bins with capacity of 140 L for collection of organic waste from five private households in Oulu, Finland were monitored for two to ten weeks in the spring and summer 2021 as described in Table 1. Temperature and moisture inside the bins were monitored throughout the test periods with wireless RuuviTag sensors. In the case of the aerated bins, also weight of the collected waste was measured. Degree of filling in the bins was calculated according to the weight of the waste. Organic waste was collected into the bins at intervals of one to five days. After the test periods, test groups were interviewed about their user experiences. Also, both collection systems were evaluated using a grading table and evaluation matrix as described previously by Toivari (2021). Twelve parameters and features were selected from the main categories (background information and regional suitability, technical features and performance, costs, and customer satisfaction) for the evaluation and graded from 0 to 3 (Appendix 1).

Fig. 1. Aerated PWS Bio Select bin for collection of organic waste used in this study

Table 1. Testing arrangement for comparison of aerated and sealed bins for collection of organic waste of five private households

Bin	***1***	***2***	***3***	***4***	***5***
Size of the household	2 adults, 1 under 15 years old	4 adults, 1 under 15 years old	3 adults, 1 under 15 years old	Terraced house	Terraced house
Aeration	Yes	Yes	Yes	No	No
Type of the bag	Paper bag	Paper bag	Paper bag	Plastic bag	Plastic bag
Test period	24.4.–12.5.2021	24.4.–8.5.2021	27.4.–27.5.2021	17.4.–29.6.2021	17.4.–29.6.2021
Duration (d)	18	14	31	73	73
Collection during the test period	No	No	13.5.2021 (16 d)	Once a week	Once a week

3. Results and discussion

In Fig. 2, temperature, moisture, and degree of filling in the aerated bins 1, 2, and 3 for collection of organic waste is shown. The outdoor temperature was also measured in the case of the bin 3 between 27.4. and 27.5.2021. The highest moisture detected in the aerated bins was 85%. However, the average moisture in the aerated bins was 50% during the test periods. The lowest moisture was detected in the bin 3 at the beginning of the test period (15%) and in the bin 1 at the end of the test period (18%).

The average humidity in the sealed bins 4 and 5 during the test period was 80% and the highest humidity detected was 95% (Fig. 3). The lowest humidity was detected at the beginning of the test period (40%). Significant difference in the temperature and moisture conditions between the two sealed bins was not observed. The temperature in both the sealed and aerated bins did not much differ from the ambient temperature measured in the case of the bin 3. The approximate amount of organic waste formed during monitoring of the bin 3 was 28 kg per one month, which is equal to an average amount of organic waste produced by a family with three adults and one under 15 years old child in Finland. Separate bulking material was not added. The evaporation of moisture from the aerated bins significantly reduces the weight of the collected organic waste. Even reduction of 10% in four days has been detected when paper bags and aerated bins have been used for the collection of organic waste (Puyuelo et al., 2013).

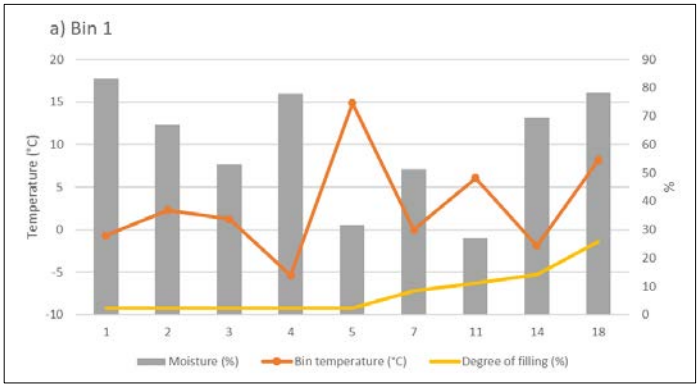

Fig. 2. Degree of filling and temperature and moisture conditions inside the aerated bins during the test periods: a) 1, 24.4.–12.5.2021; b) 2, 24.4.–8.5.2021; c) 3, 27.4.–13.5.2021 (before collection); and d) 3, 15.5.–27.5.2021 (after collection)

Karnchanawong and Suriyanon (2011) studied the performance of several types of organic waste bins with different passive aeration design. It was concluded that waste bins

with lateral ventilation around the bottom part of the bin combined with a ventilation pipe in the center of the bin resulted in highest rate of compost mass reduction compared to sealed bins or bins with only lateral ventilation or ventilation tube.

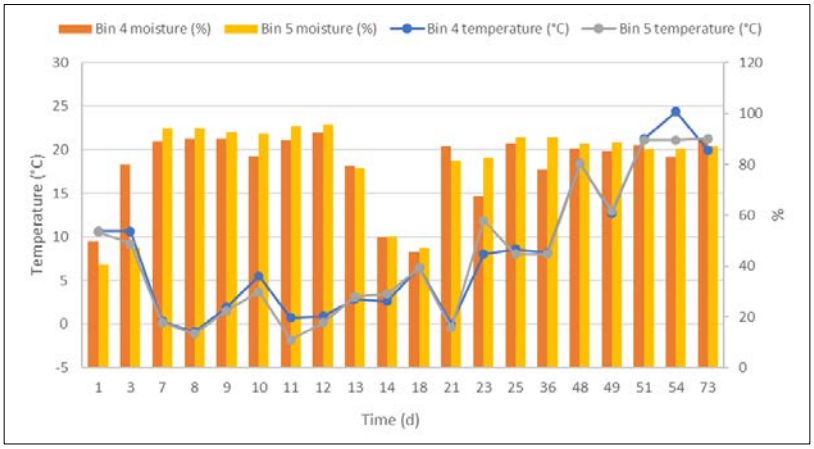

Fig. 3. Temperature and moisture inside the sealed bins 4 and 5 during the test period of 10 weeks on 17.4.–26.6.2021. The sealed bins were collected once a week

Aeration of compost assists the degradation of organic waste fraction, enabling high oxygen supply to the waste matter and contributing to the increase in the emitted VOCs (volatile organic compounds). The most frequent VOCs identified in green food decomposition are terpenes (di-limonene), sulfides (dimethyl disulfide), aromatics, alkanes, ketones, esters and alcohols. It is important to note that the perception of malodor on the human nose is a result of a combination of various VOCs. Nevertheless, di-limonene and disulfide dimethyl are widely associated with the odour nuisance. They are often detected in waste management operations and during green food waste aerobic decomposition process respectively (Agapiou et al., 2016). Sundber et al. (2009) also noted that even small amounts of sulphuric compounds as well as butaneodine and acetoin impact the perception of malodour from composting materials. Rajamäki et al. (2005) points out that despite relatively low VOCs, odour level could be high when emitted VOCs are characterized by very low odour threshold, e.g. acetoin and mercaptan.

Aeration of waste bins prevents anaerobic conditions of organic waste that could be linked to the formation of malodorous sulfur compounds (hydrogen sulfide, dimethyl sulfide, dimethyl disulfide) (Agapiou et al., 2016).

Delgado-Rodriguez et al. (2012) established that aeration rate of waste bins affects VOCs to a bigger extent compared to moisture. In the aerated bins, any fly maggots were not observed during the test periods. Moisture in the aerated bins was probably too low for the growth of fly maggots, as the growth is usually efficient when moisture is around 70% (Zhu et al., 2012). Also, sun light entering the aerated bins might have inhibited the reproduction of flies (Park, 2016). In the bin 3, unpleasant odour was observed when the bin was full. Also, ants were observed in the bins 1 and 3. However, on the average, the usage of aerated bins for collection of organic waste was experienced more pleasant as odours were usually generated less than in the conventional sealed bins. Also, the aerated bins achieved more points from the evaluation matrix (32 points from total of 36) than the sealed bins (23 points from total of 36).

The average of all points was 2.67 with the aerated bins and 1.92 with the sealed bins. The grading distribution is shown in Fig. 4.

In Scandinavia, food waste composting is characterized by slow waste decaying during prolonged low pH-conditions at the start of the composting process. The low pH level is a result of high concentration of lactic acid bacteria found in the incoming food waste. Both dominant acids (lactic and acetic) in waste material are considered to be odourous. Number of lactic acid bacteria goes down as the pH and temperature rises in the composting process. To reduce odour in food waste composting, it is important to rapidly overcome the initial low-pH phase, which could be achieved by combining high aeration and additives, such as recycled compost (Sundberg et al., 2013). Sundberg et al. (2009) in the study on enhancing composting of biowaste and optimizing process control stated that biowaste odour could be controlled by adding the substances increasing pH levels, such as recycled compost/bulking material and ash and/or lime. Bhave and Kulkarni (2019) conducted additional research where they established that active aeration (enforced aeration) is suitable for household conditions due to low odour and fly nuisance in addition to a compost of higher quality compared to passive aeration.

The aerated bins are feasible for detached houses but also for small housing co-operatives and the system works both in urban and dispersed settlements. With aerated bins, there is a possibility of longer collection intervals when compared to the sealed bins, which reduces driving with collection vehicles. The aerated bins and paper bags are evaluated to work in a cold climate better than the sealed bins and plastic bags, as when breathable paper bags are used, the bags are not stuck on the inner surface of the bin, which would make the collection easier. Collection of the waste was evaluated to work well in the case of aerated bins, as the light weight of the bins increase the collection ergonomics and safety. In this study, the conditions inside the aerated and sealed bins for collection of organic waste were monitored only in spring and summer with collection interval of two weeks. In winter, the organic waste stored outdoor would freeze and a significantly longer collection interval could be used.

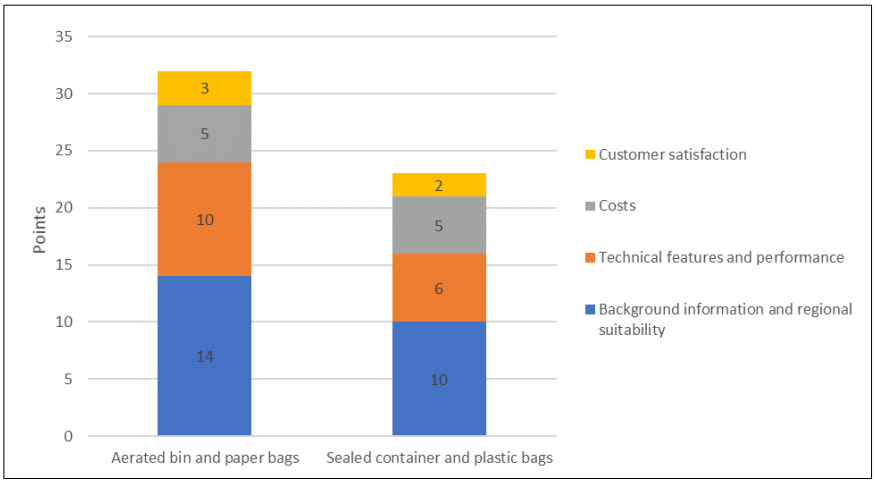

Fig. 4. The grading distribution of the aerated and sealed bins

5. Conclusion

Moisture inside the bins for collection of organic waste was detected to stay significantly lower when aerated bins were used (approx. 50%) compared to the conventional

sealed bins (approx. 80%). The evaporation of the moisture significantly decreases the weight of the collected waste and simultaneously the number of waste collection times, and the waste charges. The recommended collection interval for the aerated bins is two weeks in summer. In wintertime, the interval can be significantly longer, as the organic waste will freeze due to good aeration. In this study, unpleasant odours or growth of fly maggots were hardly observed in the aerated bins. Conditions in the aerated bins were not favourable for the growth of fly maggots. Thus, the usage of aerated bins for collection of organic waste from private households is recommended when the amount of separately collected organic waste will increase along with the reformation of directives concerning the waste sector accepted by the European Union. The usage of aerated bins is suitable especially for small households.

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