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21st International Trade Fair of Material & Energy Recovery and Sustainable Development, ECOMONDO, 7th-10th November, 2017, Rimini, Italy

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Aims and Scope

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

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

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

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GUEST EDITORS

Fabio Fava, born in 1963, is Full Professor of "Industrial & Environmental Biotechnology" at the School of Engineering of University of Bologna since 2005. He has about 130 papers on medium/high IF peer-reviewed international journals of industrial and environmental biotechnology, sectors in which he coordinated the FP7 projects NAMASTE and BIOCLEAN and participated in other 7 FP7 collaborative projects. He is vice-chairman of the "Environmental Biotechnology" section of the European Federation of Biotechnology (EFB). He is the Representative of the Italian Ministry of Education, University and Research in the "Working Party on Biotechnology, Nanotechnology and Converging Technologies" at OECD (Organisation for Economic Co-operation and Development), Paris, in the "European Strategy for the Adriatic and Ionian Region" (EUSAIR) and in the "Western Mediterranean Initiative" (WEST MED). He is member of the "Expert Group on Biobased Products" (DG GROW, European Commission, EC) and is the Italian Representative in the a) H2020 Programming Committee "European Bioeconomy Challenges: Food Security, Sustainable Agriculture and Forestry, Marine, Maritime and Inland Water Research" (SC2, DG RTD, EC), b) "States Representatives Group" of the "Public Private Partnership BioBased Industry" (BBI JU)(DG RTD, EC) and c) BLUEMED Strategic Board (DG RTD and DG MARE, EC). Finally, he is the scientific coordinator of the International Exhibition on green and circular economy ECOMONDO held yearly in Rimini (Italy).

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

She worked at the R&D Centre of Basell Polyolefins in Ferrara for 2 years in the frame of a project addressed to the development of a novel methodology for qualitative and quantitative analysis of additives in polymers. She also worked at ARPA, Regional Agency for Environment in Ferrara, division Water Analysis.

Then she started working at the school of Engineering of the University of Bologna for a Ph.D. in Materials Engineering (2007-2010). After that, she had a scholarship "Spinner 2013" in cooperation with Reagens spa (San Giorgio di Piano) on novel PVC nanocomposites. Now she is post doc fellow at the same school on new polymer-based nanocomposites from renewable sources and inorganic fillers. She also worked at the laboratoire de Chimie et Biochimie Pharmacologique et Toxicologique (Université Réné Descartes) in Paris in 2001 and was visiting professor at the Ecole Nationale Superieure de Chimie (Université Blaise Pascal, Clermont Ferrand, FR) in 2012 and 2015. Dr. Totaro has about 25 scientific papers and several participations at conferences and scientific schools. She collaborates on Ecomondo from 2013.

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DEFINITION OF PRICE IN CIRCULAR RAW MATERIALS IN THE DISPOSAL OF HAZARDOUS INDUSTRIAL WASTE*

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Abstract

Greenpeat is a new sustainable material that can be produced from wet biodegradable organic waste, both solid and liquid, through a very efficient process, studied and developed by HBI Srl, an innovative startup founded by a researcher and an entrepreneur, who works in the field of the innovative green technologies. Greenpeat has been produced from agro-industrial organic by-products and optimized according to its potential different uses, namely for energy production or as a highly performing material for agronomic uses. At specific process conditions, it is possible to give to Greenpeat calorific values in the range of 22 - 28 MJ/kg, which represent interesting values for renewable and clean energy production applications. Furthermore, by using Greenpeat as a substitute of common solid fossil fuels, both the emissions related to fossil resources extraction and those produced during combustion are interestingly lowered. On the other hand, when ligno-cellulosic residues are treated in other particular conditions, the Greenpeat obtained can be used as a soil conditioner. Its application in soil can reduce the non-CO2 greenhouse gas emissions, while sequestering organic carbon. Moreover, due to its chemical and physical characteristics, both the water and nutrient holding capacities of soil are improved, allowing a reduction of water for irrigation and a reduction on the use of chemical fertilizers. These fertilizers, especially nitrogen, usually diffuse in the underground waters and can create healthy problems to the population, to fishes, plants and animals. Greenpeat can reduce all these impacts. In this study, a brief summary of the state of the art on HTC and a case study on a real scale application of the technology developed by HBI Srl are presented.

Keywords: environmental impact, LCA, recovery, special waste

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1. Introduction

Management theories suggest that incorporating environmental practices into business operations can lead to sustainable competitive advantages and a more integrated business and environmental value creation (Ruan and Xu, 2011). In a market economy, attention is focused on the value of economic products, while the depletion of natural resources and the resultant accumulation of economic waste are typically ignored. (George, 2015) Sustainability researchers argued that if one were to focus on final user needs or the service a user wants, rather than the product, it would become much easier to design need-fulfilment systems with radically lower impacts. (Tukker,2015) Over the last decade growing attention has been paid worldwide to the new concept and development model of the Circular Economy, CE, with the aim to provide a better alternative to the dominant economic development model, so called "take, make and dispose" (Ness, 2008). The circular economy is seen as a new business model expected to lead to a more sustainable development and a more harmonious society (Feng and Yan, 2007). The relationship between industry and environment is crucial for industrial business performance. (Lieder and Rashid, 2016)

CE promotes a more appropriate and environmentally sound use of resources aimed at the implementation of a greener economy, characterized by a new business model and innovative employment opportunities, (www.ellenmacarthurfoundation.org, 2012) as well as by improved wellbeing, evident impacts on equity within among generations in terms of both resource use and access. Results show that CE origins are mainly rooted in ecological and environmental economics and industrial ecology. The ultimate goal of promoting CE is the decoupling of environmental pressure from economic growth. The implementation of CE worldwide still seems to be in the preliminary stages, mainly focused on recycling rather than reusing Important results have been achieved in some business sectors (e.g. in waste management, where large waste recycling rates are achieved in selected developed countries). CE implies the adoption of cleaner production patterns at company level, an increase of producer and consumer responsibility and awareness, the use of renewable technologies and materials (wherever possible) as well as the adoption of suitable, clear and stable policies and tools. The lesson learned from successful experiences is that the transition towards CE comes from the involvement of all actors in society and their capacity to link and create suitable collaboration and exchange patterns. Management of hazardous solid wastes has become a grave concern for both environmental protection and public health reasons, due to the increased quantity of hazardous materials that need to be treated and disposed or recycled in a safe, economical way. This problem is widely encountered with incineration of waste materials resulting from municipal and industrial processes. It is a widespread practice for the residues of combustion, such as bottom and fly ashes, to be disposed in land filling areas (Barbieri et al., 2000). However, this method generates problems for storage, groundwater contamination and weathering. In view of the latest environmental norms, new recycling, or treatment processes should be developed and applied. These processes must not only be capable of transforming ashes to non-hazardous materials, but also of producing useful and marketable products, e.g. building materials or new ceramic, glass and glass-ceramic materials. All these treatments aim at ash inactivation by reducing the quantity or the mobility of heavy metals. One of the most promising waste management techniques in this field is the application of the principle of the eddy current.

Eddy current tests in sinusoidal mode are of great interest to detect flaws in metallic structures. A limitation of this classical method concerns the detection of deep defects in very conductive materials. However, such a drawback can be reduced by operating in the transient mode, using a pulsed eddy current technique. Eddy current separation (ECS) is a physical technology of separating nonferrous metallic particles from other particles (Ruan and Xu, 2011). In an eddy current separator, an alternating eddy current was induced in nonferrous metallic particles when meeting variable magnetic field generated by the rotation of magnetic drum of eddy current separator.

Eddy currents circulate in conductors like swirling eddies in a stream. They are induced by changing magnetic fields and flow in closed loops, perpendicular to the plane of the magnetic field. They can be created when a conductor is moving through a magnetic field, or when the magnetic field surrounding a stationary conductor is varying i.e. anything which results in the conductor experiencing a change in the intensity or direction of a magnetic field can produce eddy currents. (https://www.rare-earth-magnets.com/blog/what-are-eddy-currents) The size of the eddy current is proportional to the size of the magnetic field, the area of the loop and the rate of change of magnetic flux, and inversely proportional to the resistivity of the conductor. Eddy currents can also be removed by cracks or slits in the conductor, which break the circuit and prevent the current loops from circulating. This means that eddy currents can be used to detect defects in materials. The magnetic field produced by the eddy currents is measured, where a change in the field reveals the presence of an irregularity; a defect will reduce the size of the eddy current, which in turn reduces the magnetic field strength. (Ruan et al, 2017). The aim of this paper is to define the price of particular raw materials, coming from the process of incineration of hazardous industrial waste, after being properly treated using the technique of the eddy current. These materials refer in particular to heavy and precious metals, like Aluminium, Copper, Silver, Gold and Palladium. A heavy metal is one which has a number of higher atomic weight elements, which has the properties of a metallic substance at room temperature (https://www.sciencedaily. com/terms/heavy_metals.htm). In this case the definition of the price is fundamental to put these new raw materials on the market. The innovative methodology used in this paper to achieve this goal consists in analysing flows and existing prices of this material from some special market.

2. Material and methods

The outcome of the incineration process by burning a ton of waste is: 230kg of dry bottom ash, 20 kg filter ash and a lot of energy. The energy amount is about 500 kWh of electric energy. The 230kg bottom ash will receive further treatment, while the filter ash gets landfilled. The energy, which is created when the oven heats up secondary water, becomes steam and turns a turbine, is basically green electricity. Additionally, a part of the steam is used for district heating (Böni, 2013).

Ashes resulting from the process of incineration can be dry or wet depending on the treatments chosen by firms. Dry ashes are preferred because they are less expensive to be disposed and transported. Another advantage of using dry ashes instead of wet ashes is they are safer for the environment. The investment needed to buy technology capable of obtaining dry ashes from wet ashes is quantified in 3 million Euros. Ashes are composed in different percentages of metals and an inert material; inert material is used in sectors like the construction industry, and it has an almost insignificant price. Instead, metals like Aluminium, Copper, Silver, Gold and Palladium, which can be extracted from either dry and wet ashes, have a significant market value; for this reason, they can represent a way of obtaining a competitive advantage for a firm in the sector which has decided to use a specific technology. Simon (Simon, 1996) wrote a cover article for a Swiss newspaper on the economic potential of valuable metals in bottom ash. He referred to his own measurements in bottom ash which showed 40–400 times higher levels of silver compared to earth crust levels (Simon, 1996). Aluminium is used in many industries and is very important for the world economy. It is mainly used in aeronautics and aerospace, automotive, nautical and mechanical engineering, transportation, packaging, construction, household appliances, machinery, electrical wiring, mirrors, and telescopes. Currently, the aluminium quotation is moving in the $ 1900 area. Looking at past quotation rates, however, it can be noticed that in

2008 the price of aluminium had reached up to a maximum of $ 3200. Copper is of fundamental importance in the economy because it is indispensable in many areas of application. Its consumption has risen sharply in recent years due to the rapid economic development of emerging countries, particularly China. According to the International Copper Study Group (EGG) data, the world's refined copper market recorded a production deficit of around 306,000 tonnes in the first half of 2016. The consumption of red metal grew in the 5% period to 570,000 tonnes. In the first six months of this year, the average copper price was LME at $ 4,700.58 per ton, down 14.4% over the average price of 2015. Gold is the main well-being for investors. Yellow metal is traditionally appreciated in times of crisis or high inflation.

The gold price reached an historic record in September 2011 at about $ 1,921 an ounce. After recent developments, business banks have become more cautious about the prospects of gold. However, despite downturns, forecasts for 2017 remain in most cases above current quotes. Bloomberg's survey of 26 investment houses revealed that analysts expect on average that the gold price will end this year at $ 1,300 an ounce. Silver is, after gold, preferred by investors. After falling in 2015 by more than 11%, the silver price rose significantly in 2017. Grey metal went on in the first six months of 2016 by about 35%. The deficit on the physical market also pushed up prices. According to a Metals Focus study, the silver supply should exceed 1,005-ton demand in 2017. Palladium is a rare metal, silvery-white colour, characterized by good ductility, malleability and resistance to corrosion. It is most common uses are in the automotive industry for catalytic converters, telecommunications, dentistry, watch making, electrical industry, photography, and as a catalyst. Palladium, moreover, is used in jewellery and by goldsmiths: alloyed with gold , it forms the so-called "white gold". In 1990, the price of palladium was around $ 150 per ounce, while in 1998 it was worth $ 350, thanks to the strong demand for its use in the manufacture of catalytic converters. In 2000, it exceeded $ 800 and only one year later, in January, it reached its highest historic level at $ 1,125 per ounce.

The price of this metal is currently around $ 840 an ounce (http://www.borsainside.com). In industries, there are different systems used to accumulate certain Non-Ferrous (NF) metals out of the NF fraction. The Eddy Current separator is a device known for its possibility to separate NF metals from non-metals. It has been used in the recycling industry for a long time. Recycling of waste materials is highly desirable from many viewpoints, not the least of which are financial and ecological (file:///CGESPI/BIBLIOGRAFIA%20PROF/Brevetto.htm). A selective separation of the metals from non-metals in a rotating eddy current separator is effected by a vector difference between the magnetic deflecting force and all competing forces due to gravity, centrifugal acceleration, friction and particle–particle interaction (Zhang et al, 1998). The rotating magnetic field in the device’s drum creates in every electric conductive NF particle an eddy current which itself creates its own magnetic field.

These two magnetic fields are repulsive to each other. The magnetised NF particle is repulsed by the drum and therefore can be separated accurately because it flies further while the non-conductive particles such as minerals just fall off the belt because of gravity. It is important that ferrous metals are removed beforehand because they could disturb the magnetic field and worsen the results. The repulsion for a certain metal is calculated by dividing its electric conductivity σ by its density ρ. A high repulsion figure guarantees a very efficient separation by the eddy current. Thus, the aluminium can be easily separated even though the setup of the machine is not perfect. A repulsion figure below 7000 m2/kg Ω needs a perfect setup of the Eddy Current Separator to achieve a high efficiency rate. It is of importance that the efficiency of the Eddy Current’s separation is judged by every single metal (Morf et al, 2013).

3. Experimental: GE.S.P.I srl

GE.S.P.I SRL was founded in 1960 as a cooperative firm of local families, situated in the port of Augusta. Its initial role was to gather and burn waste coming just from ports. After the incineration of waste was legalized, GE.S.P.I started to work with other market niches of waste, that is to say waste coming from other production activities, in the field of special and hazardous waste. For special waste incineration is the last possibility of disposal before dumping, it is more expensive than other activities but it is preferred when there are no other chances of recycling. Now GE.S.P.I is a multitasking, family run business, in form of a limited liability company. After the Presidential Decree n°915/1982 (Decree, 1982) was approved, the main plant moved to its current position. Its core business focuses on an incineration plant, where waste from ports, healthcare, pharmaceutical companies and the petrochemical industry is brought. Its waste management activities include: gathering waste coming from ships passing through Augusta's port, land reclamation and commercial brokering with other local firms, consisting mainly in waste management. Until some year ago, another activity was the transport of hazardous waste from other structures to the incineration plant. Today this secondary activity has been replaced by security and supervision of oil terminals. Among other activities, the company also makes innovative use of storage: differently from the other firms in the sector, it works as a logistic support for the core business. This type of storage is useful in case of the quantity of waste that the firm has to deal with is higher than the quantity that can be daily treated on the basis of the plant's capacity. The stock prescription of waste is of 48 hours. GE.S.P.I is also involved in financial services, making agreements with seven different financial institutes, in order to improve the distribution of risk. GE.S.P.I has implemented an Integrated Management System. The firm also possesses some certification such as ISO 9001, version (ISO 9001, 2015), ISO 14001 (2015) by Certiquality and is going to implement OHSAS 18001 (http://www.gruppogespi.com/).

All the activities are strictly connected with the incineration plant, which makes the disposal of hazardous waste possible. The first step is the incineration that creates steam; steam passes through a turbine to generate energy. The combustion chamber is formed by a rotary drum oven. Waste is completely burnt in the chamber and the combustion slag is extracted by an extractor tape. The plant is controlled by a Programmable Logic Controller (PLC), a technological system, whose function is to monitor constantly all the parameters of the process; legally, the parameters cannot be lower than 850°C or higher than 1200°C (Amara G.,2016). An important step in the history of GE.S.P.I is the introduction of auto-production of electric energy thanks to the incineration process. This step gives GE.S.P.I the possibility to become a company of energy services, reducing costs and increasing benefits.

4. Results and Discussion

For every 1000 kg of waste which is introduced into the incineration plant, 200 kg of dry ash is produced. Dry ash is preferable than wet ones because for the same amount of waste to be incinerated, almost twice as much wet ash is produced (35/40 %). Definitely, it can be said that dry ash is more suitable for the aim of extracting heavy metals than wet ones. Moreover, dry ash is easier and cheaper to dispose of, whereas the disposal of wet ash can be very expensive. For these reasons this kind of treatment was started by GE.S.P.I in 2016. Ashes coming from the incineration plant can be divided into two groups on the base of the diameter of the particles: the first group includes particles bigger than 8mm in diameter; the second group contains only particles whose diameter is smaller than 8mm. The second group represents 75% of the ashes coming from the incineration process (so, if there were 200kg of ash, 150kg would be made up of the smaller particles). From this quantity, 4% of heavy and precious metals can be extracted (6 kg), the other 96% is composed by an inert material, which can be used in other sectors like the construction sector, and whose price is too low to be considered relevant. The group composed by ashes with particles bigger than 8 mm represents 25% of all the ashes (almost 50 kg). Analysing this last group, it can be noticed that it includes 20%, so about 10 kg of iron and the remaining 80 % (40 kg) of inert material. The main advantage of a similar technology has to be intended mainly as a reduction of costs, but also as an environmental advantage, because with the same quantity of waste, there is a significant reduction of the quantity of ashes obtained, so a small quantity of them to be disposed. Considering the costs of implementing similar technology, there is an initial investment of 3 million Euros to pass from a machinery to treat wet ashes to one more suitable for the production of dry ashes (adding 300000 Euros of maintenance of the plant). What is noticeable that in 2016 the costs of disposal of wet ashes were about 210 Euros/tonne, for a total price of 84 Euros (considering 400 kg of wet ashes). With the new technology, the price would be about 42 Euros, so half the original price. Through this analysis it can be demonstrated how the profit obtained by the new technology in terms of reduction of costs can affect the total profit of the firm. Furthermore, considering that the price for disposal of inert material is about 80 Euros/tonne, and of the heavy and precious metals which can be extracted in different combinations, it can be definitely stated that it would be worthwhile to implement this technology in the GE.S.P.I plant. The implementation of a similar technology, consisting in the extraction of wet bottom ashes to dry ash, near the incineration plant would be advantageous for two reasons:

1. Firstly, for the Environment, because with the same quantity of waste brought to the incineration plant, there is a lower production of dry ashes instead of wet ones (about a half). Consequently, the disposal of dry ashes is easier in terms of transportation, because of a significant reduction of volume and weight transported. The disposal is made easier also because of the lower weight of dry ashes due to absence of water. Lastly, eventual successive treatments are made easier by the choice of dry ashes.
2. Secondly, for the Profits, not intended as increasing revenues but as a reduction of costs. Profits coming from the sale of heavy and precious metals coming from dry ashes could be used to cover the initial technological investment. Only after some years, the sale of precious metals could influence significantly the profit, making the firm obtain a competitive advantage.

Overall, the results of this paper can be explained in a series of points: first, the low contents in the solid waste suggests that if the recovery of these precious and rare metals were possible, there would be only small potential for economic and environmental benefit. To resolve the problem of dwindling economic resources, it is necessary to develop an integrated perspective of the economy, namely, a circular economy.

However it should be said that other firms in the sector, even if they share the same core business as GE.S.P.I, mainly treat urban waste. This feature has some relevant consequences on the different percentage of metals which can be extracted from ashes (urban waste contains high percentages of aluminium and lower of gold).

5. Conclusions

A new perspective has been proposed for achieving sustainable growth and treating waste as a useful economic resource and it implies the conventional concept of resources and products in the market, named Circular economy.

These advantages have been obtained by other leading firms in this sector, thanks to investments in modern technologies like eddy current separators, capable of adding value to ashes, letting firms obtain competitive advantages in the long-term. The eddy current separator system could be an innovative way of giving value to ashes, intended as waste of a production cycle, according to the principles of CE.

References

Amara G., (2016), "*Il processo innovativo in azienda per la chiusura dei cicli attraverso la simbiosi industriale: il caso della Gespi di Augusta",* in Atti del XX Convegno Ecomondo Green and Circular Economy: Ricerca, Innovazione e Nuove Opportunità, Maggioli, 8-11, Novembre, 2016, Rimini.

Barbieri L., Bonamartini A.C., Lancellotti I., (2000), Alkaline and alkaline- earth silicate glasses and glass-ceramics from municipal and industrial wastes, *Journal of the European Ceramic Society*, **20**, 2477–2483.

Böni L., (2013), Accumulation of recovered gold from bottom ash, How waste management can turn into resource management, On line at: https://zar-ch.ch/fileadmin/user_upload/Contentdokumente/Oeffentliche_Dokumente/2013_Maturitaetsarbeit_L_Boeni.pdf.

BS OHSAS 18001, (2007), Standard of Occupational Health and Safety Management (OHS), On line at: https://www.bsigroup.com/en-GB/ohsas-18001-occupational-health-and-safety/.

Decree, (1982), Decreto del Presidente della Repubblica 10 settembre 1982, n. 915, Attuazione delle direttive (CEE) n. 75/442 relativa ai rifiuti, n. 76/403 relativa allo smaltimento dei policlorodifenili e dei policlorotrifenili e n. 78/319 relativa ai rifiuti tossici e nocivi, pubblicata nella Gazzetta Ufficiale n. 343 del 15 dicembre 1982.

Donald A.R.G., Chi-ang Lin B, Chen Y., (2015), A circular economy model of economic growth, *Environmental Modelling & Software*, **73,** 60-63.

Feng Z., Yan N., (2007), Putting a circular economy into practice in China, *Sustainability Science*, **2**, 95-101.

Ghisellini P, Cialani C., Ulgiati S., (2016), A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems, *Journal of Cleaner Production*, **114**, 11-32e.

ISO 9001, (2015), Quality Management System, Standards, Fundamentals and vocabulary, On line at: http://www.srac.ro/calitate-iso-9001?gclid=CPbzgNyL5tYCFcMeGwodj3UPBw.

ISO 14001 (2015), Environmental Management Systems Standards, Requirements with guidance for Use, On line at: http://www.srac.ro/mediu-iso-14001?gclid=CL2Irt2M5tYCFZvKsgodiXcFAw.

Lieder M., Rashid A., (2016), Towards circular economy implementation: a comprehensive review in context of manufacturing industry, *Journal of Cleaner Production*, **115** 36-51.

Morf L., Gloor R., Haag O, Haupt M., Stefan Skutan S., Di Lorenzo F., Böni D., (2013), Precious metals and rare earth elements in municipal solid waste – Sources and fate in a Swiss incineration plant, *Waste Management*, **33**, 634–644.

Ness D., (2008), Sustainable urban infrastructure in China: towards a factor 10 improvement in resource productivity through integrated infrastructure system, *International Journal of Sustainable Development & World Ecology*, **15**, 288-301.

Park J., Sarkis J., Wu Z., (2010), Creating integrated business and environmental value within the context of China's circular economy and ecological modernization, *Journal of Cleaner Production*, **18** 1494-1501.

Ruan J., Dong L., Zheng J., Zhang T., Huang M., Xu Z, (2017), Key factors of eddy current separation for recovering aluminum from crushed e-waste, *Waste Management*, **60**, 84–90.

Ruan J., Xu Z., (2011), A new model of repulsive force in eddy current separation for recovering waste toner cartridges *Journal of Hazardous Materials*, **192**, 307–313.

Simon F.G., (1996), Geld in der Kehrichtschlacke, Neue Zürcher Zeitung, Forschung und Technik, Mittwoch, 12. Juni 1996, Nr. 134.

Tukker A., (2015), Product services for a resource-efficient and circular economy – a Review, *Journal of Cleaner Production*, **97** 76-91.

Zhang S., Forssberg E., Arvidson B., Moss W., (2002), Aluminum recovery from electronic scrap by high-force eddy-current separator, *Resources, Conservation and Recycling*, **37**, 55–60.

Zhang S., Forssberg E., Arvidson B, Moss W., (1998), Aluminum recovery from electronic scrap by High-Force eddy-current separators, *Resources, Conservation and Recycling*, **23**, 225–241.

Web sites:

file:///CGESPI/BIBLIOGRAFIA%20PROF/Brevetto.htm
http://www.borsainside.com
http://www.ellenmacarthurfoundation.org/business/reports
http://www.gruppogespi.com/
https://www.rare-earth-magnets.com/blog/what-are-eddy-currents
https://www.sciencedaily.com/terms/heavy_metals.htm

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GREENPEAT: AN INNOVATIVE SUSTAINABLE MATERIAL RECOVERED FROM WASTE*

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Abstract

Greenpeat is a new sustainable material that can be produced from wet biodegradable organic waste, both solid and liquid, through a very efficient process, studied and developed by HBI Srl, an innovative startup founded by a researcher and an entrepreneur, who works in the field of the innovative green technologies. Greenpeat has been produced from agro-industrial organic by-products and optimized according to its potential different uses, namely for energy production or as a highly performing material for agronomic uses. At specific process conditions, it is possible to give to Greenpeat calorific values in the range of 22 - 28 MJ/kg, which represent interesting values for renewable and clean energy production applications. Furthermore, by using Greenpeat as a substitute of common solid fossil fuels, both the emissions related to fossil resources extraction and those produced during combustion are interestingly lowered. On the other hand, when ligno-cellulosic residues are treated in other particular conditions, the Greenpeat obtained can be used as a soil conditioner. Its application in soil can reduce the non-CO2 greenhouse gas emissions, while sequestering organic carbon. Moreover, due to its chemical and physical characteristics, both the water and nutrient holding capacities of soil are improved, allowing a reduction of water for irrigation and a reduction on the use of chemical fertilizers. These fertilizers, especially nitrogen, usually diffuse in the underground waters and can create healthy problems to the population, to fishes, plants and animals. Greenpeat can reduce all these impacts. In this study, a brief summary of the state of the art on HTC and a case study on a real scale application of the technology developed by HBI Srl are presented.

Keywords: environmental impact, LCA, recovery, special waste

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1. Introduction

The world population has doubled in the last 50 years, and it is predicted to reach 9.1 billion people by 2050 (FAO, 2009). FAO estimates that this fact will require a 70% increase in crop production from the current levels, which should be achieved in a context where the global agricultural area is continuously shrinking due to urbanization, climate change, water scarcity, and nutrient exhaustion. This target can be reached by optimizing the productivity of the currently available lands. Beside that, the increase in the use of soil for agricultural purposes is strictly linked to the use of chemical fertilizers. However, the intensive use of chemical fertilizers can be dangerous both for human health and the environment (Boyd et al., 1999; Jiao et al., 2012; Mann et al., 2009; Nolan et al., 1997; Rajkovich et al., 2012). Moreover, nitrogen fertilizers are based on energy-intensive production processes entailing non-renewable resources, and fertilizers have been reported to contribute to water eutrophication (Savci, 2012). This takes place when rivers, seas and lakes are overloaded with nutrients, leading to the massive growth of algae, some of which are toxic (Glibert at el., 2005). This situation creates a shock in the water environment, since oxygen is mostly used for algae metabolism, causing bottom-dwelling animals die and fish to either die or leave the area. Directly linked to the future increase in food production, the amount of water required in agriculture is expected to increase (IPCC, 2014). Within this context, after the latest issue in 2003, the European Commission is currently finalizing the new EU Fertilizers Regulation, which aims to make fertilizers more sustainable and resource–efficient. The focus is on balancing the share of mineral and organic fertilizers, particularly favoring the introduction of circular approaches for the large scale transformation of bio-waste into nutrients for crops. The upcoming regulation is spurring a revolution in this field, indirectly pushing agriculture to adopt more sustainable and effective practices for food production.

On the other side, biodegradable organic wastes are commonly produced by agro-industrial companies and/or municipalities. These residues still contain valuable materials that can be extracted and used as soil conditioners and improvers. Nowadays, composting is recognized as the most common treatment used to produce a material (*i.e.*, the compost) exploitable in agriculture, starting from biodegradable organic waste. This biochemical process is usually performed in 30 – 60 days and can be affected both by environmental conditions, such as external temperature, and by inhibiting substances, that can be present within the waste. Moreover, composting is reported to potentially produce negative environmental impacts: emissions of CH_4, N_2O and NH_3 from methanogenic and denitrification process (Boldrin et al., 2009), and emissions of CO_2, produced both from the composting plant itself and from the activities of waste collection and transportation. Moreover, Bong et al. (2017) reported that composting can contribute to global warning; while Oliveira et al. (2017) evaluated that composting plants can contribute to the increase of particulate matter formation and freshwater ecotoxicity, because of air emissions.

A viable alternative for the treatment of wet biodegradable organic wastes is represented by hydrothermal carbonization (hereinafter, HTC). HTC is a thermochemical process that has been widely described by many authors (Basso et al., 2016; Basso et al., 2015; Fang et al., 2017; Libra et al., 2011). The HTC process is used to treat residues in wet conditions (*i.e.*, humidity higher than 60%) at quite mild operational conditions, namely temperatures between 180 °C and 250 °C. The pressure inside the reactor is held high enough to maintain the water in its liquid state. During this process, dehydration and decarboxylation reactions occur, producing a decrease of both the oxygen and the hydrogen of the treated residue, and consequently enhancing its carbon content. Polymerization reactions occur within the liquid phase formed during the process and composed by several organic compounds. The main product of HTC is called hydrochar, a solid carbonaceous material that presents many interesting characteristics (Basso et al., 2013). In particular, two main possible applications of hydrochar have been investigated: its use as a substitute of common solid fuels, such as fossil coal, and its use as a soil conditioner. Starting from data found in literature and after several tests performed in bench scale batch reactors (Fiori et al., 2014), the innovative startup HBI Srl developed its own technology to produce hydrochar exploitable for both the purposes previously described. HBI Srl decided to use the name "Greenpeat" as the commercial brand of the hydrochar, produced through its technology, which implements the hydrothermal carbonization process in an innovative and improved way (the technology is not described here because it is under patent revision).

2. Objectives

The main objective of this work is to briefly review the state of the art concerning the use of hydrochar both for energy production and as a soil improver, and to present preliminary results on a possible real application of the technology developed by HBI Srl. The case study here reported, concerns the use Greenpeat for renewable and clean energy production.

3. Outline of the work

This work is divided in two main parts:

- brief state of the art and main results regarding the use of hydrochar both for energy production and as a soil improver;
- one case study regarding a real scale application of the technology developed by HBI Srl.

4. Brief state of the art

The use of hydrochar as a substitute of solid fossil fuels have been widely reported by many authors (Kambo and Dutta, 2015; Kang et al., 2012; Libra et al., 2011; Lin et al., 2017; Liu and Balasubramanian, 2012; Liu et al., 2016; Lu et al., 2011; Mumme et al., 2011; Prawisudha et al., 2012; Román et al., 2012; Yang et al., 2016).

Several authors reported heating values for hydrochars averagely ranging between 22 and 28 MJ/kg, although Mumme et al. (2011) reported values up to 36 MJ/kg when carbonizing anaerobically digested maize silage. The differences between the energy content of hydrochars primarily depend on the type of feedstock, namely on the percentage of lignin, cellulose and hemicellulose within it. As a matter of fact, usually the higher the lignin content within the feedstock, the higher the heating value of the produced hydrochar. Moreover, the operational HTC conditions were reported to play an important role on the physic and chemical characteristics of hydrochar. In particular, temperature seems to play the most important role. Rising temperatures promote the carbonization process enhancing the higher heating value of the obtained hydrochar. However, higher temperatures tends even to promote the degradation of the solid phase into both the liquid and gaseous phases, lowering the amount of hydrochar obtainable downstream of the process. Thus, temperature represent a very important parameter, especially when considering real scale applications, both because of its influences on the product yield and energy density and because of the energy requirements to reach and maintain it inside the reactor. Another parameter that has been reported to have an influence on the process is the biomass to water ratio (B/W), namely the ratio between the initial amount of dry feedstock and water. Many authors agree on the fact that the higher the B/W parameter, the higher the energy content of the hydrochar, although few authors have reported almost negligible effects (Álvarez-Murillo et al., 2015; Sabio et al., 2016). Residence time has been reported as the HTC parameter that apparently has the lower influence on the final characteristics of the hydrochar. As a matter of fact, several experimental results (here not reported) show that after 3 to 5 hours of carbonization, the variations on the physical and chemical characteristics of hydrochars are very few and, when considering the economic aspects regarding an industrial scale application, the efforts needed to perform the HTC process for longer residence times result economically unjustified. Finally, Liu et al., (2016) suggested to use hydrochar in blends with lignite, in order to increase tensile strengths of lignite pellets, enhance thermal efficiency and decrease air pollution.

For what concerns the use of hydrochar a soil improver, Bargmann et al. (2014a) and Zavalloni et al. (2011) demonstrated in their studies that hydrochar can decrease soil mineral nitrogen to different degrees, due to their immobilization and adsorption effects. Wiedner et al. (2013) and Malghani et al. (2013) illustrate by means of 13C NMR spectroscopy, scanning electron microscopy and energy-dispersive X-ray spectroscopy, that hydrochars have low proportions of aromatic compounds: however, their stability in soil results to be higher if compared to that of compost. These findings were confirmed by Eibisch et al. (2013) and Bamminger et al. (2014), that performed soil incubation experiments. Moreover, the application of chars with low C:N ratios and higher mineral nitrogen, decrease nitrogen fertilizers inputs (Bargmann et al., 2014; Raikovich et al., 2012; Steiner et al., 2008). However, to reduce the risks of negative effects on plant growth, hydrochars should not be applied fresh, but after different pretreatments (Buss et al., 2015; Gajić and Koch, 2012; George et al., 2012). Optimal strategies might be soil incubation with bio-active substrates, like compost or digestate prior to sowing, or co-composting with fresh organic materials like crop residues or farm fertilizers from animal manure, with the objective to reduce phytotoxic substances, which are formed during thermal degradation of the feedstocks and to enhance functional groups activation and inner surfaces with plant-available nitrates and other nutrient ions (*i.e.*, ammonium and phosphates) (Kamman et al., 2015). Hydrochars are considered by many authors to be suitable as soil amendments and conditioners. Hydrochars could also be applied as a kind of slow-release organic fertilizer and as soil conditioners to improve the soil organic-matter content in compensation for the removal of harvest residues (Bargmann et al., 2014b), and they can be used to increase the water-holding capacity of sandy soils, due to their porous structure (Basso et al., 2013; Karhu et al., 2011; Laird et al., 2010).

5. Real scale application

5.1 Application for energy production

In this paragraph, the technology developed by HBI Srl is applied to a big size wine company, located in the North of Italy. In this case, the Greenpeat produced is used for energy production. It has been hypothesized a plant that treats 10,000 ton/y of exhausted grape marc, working for 8,000 h/y. The feedstock has 65% of humidity, the process is performed at a biomass to water ratio (B/W) equal to 0.4 and the reaction time is set at 3 h. On the basis of the data recovered from the bench scale batch tests, around 70% of the dry mass of the feedstock is supposed to be converted into Greenpeat, which exits the plant with a humidity content of around 8% and pelletized. Thus, in these conditions, the hourly production of Greenpeat is around 305 kg/h. In Table 1, data regarding the treatment plant are reported.

Greenpeat is then used for thermal energy production, through combustion of pellets of Greenpeat in a boiler. Considering an average efficiency of the boiler of around 90%, the yearly thermal power produced is around 15,164 MWh_{th}. In Table 2, the main results have been reported.

Table 1. Main operational data regarding a treatment plant

Description	*Value*	*Unit of Measurement*
Inner reactor volume	7.5	m^3
Greenpeat produced	2,440	ton/y
Specific thermal consumption	1,100	$kWh_{th}/ton_{Greenpeat}$
Specific electrical consumption	200	$kWh_{el}/ton_{Greenpeat}$
Total thermal consumption	2,684	MWh_{th}/y
Total electrical consumption	488	MWh_{el}/y
Thermal energy cost (methane)	0.04	$€/kWh_{th}$
Total thermal energy cost	107,360	€/y
Electrical energy cost	0.16	$€/kWh_{el}$
Total electrical energy cost	78,080	€/y

Table 2. Thermal energy produced

Description	*Value*	*Unit of Measurement*
Higher heating value of Greenpeat	24,860	MJ/ton
Thermal energy produced annually	15,164	MWh_{th}/y
Thermal energy produced / Thermal energy consumed	5.687	--

From the data regarding thermal energy both in Table 1 and in Table 2, it is possible to state that the thermal energy produced is more than five times the thermal energy required by the system.

5.2 Economical analysis

The capital investment for an HTC plant that can treats around 10,000 ton/y of residue was estimated to be around € 3,000,000. The plant produces around 2,000 ton/y of process water that has to be sent to a waste water treatment plant, with a cost that is around 14 €/ton (reference cost in the North of Italy). Thus, the operational costs of the plant can be summarized as in Table 3. For the calculation of both thermal and electric energies, the costs for the kWh considered were: 0.045 $€/kWh_{th}$ and 0.16 $€/kWh_{el}$.

Table 3. Operational costs of an HTC plant.

Description	*Cost (€)*
Thermal energy	120,780
Electric energy	78,000
Employees	50,000
Ordinary maintenance	10,000
Process water treatment	28,000
TOTAL OPEX	286,780

The incomes coming for the selling of thermal energy were calculated considering a yearly production of Greenpeat being equal to 2,400 ton/y, corresponding to a 6.9 MWh/ton of energy. If the thermal energy is sold at 0.040 $€/kWh_{th}$, the corresponding incomes are 606,000 €/y. Furthermore, the market of thermal energy is sustained in Italy by the government (DM 20/07/2004), through the "Titoli di Efficienza Energetica" (hereinafter, TEE), also known as "Certificati Bianchi" (in English, *White Certificates*). If thermal energy is produced from biomass, the value of one TEE is around 80 €/TEE. One TEE corresponds to one TOE (*i.e.*, ton of oil equivalent) saved. Thus, the income deriving from the selling of the TEEs produced was calculated to be around 300,720 €/y.

In this case, considering both these two incomes, the payback time of the plant was calculated at 3.3 years.

6. Concluding remarks

Hydrothermal conversion processes represent viable alternatives to common processes used for the treatment of wet organic residues. Among these processes, hydrothermal carbonization (HTC) can be applied to directly transform these wastes into a solid carbonaceous material, that can be used both for clean energy production and as a soil improver. To meet the legislative requirements needed for it to be used in these two applications, the innovative startup HBI Srl has developed a new technology, which improves the HTC process and produces the Greenpeat. Depending on both its final use and the characteristics of the raw residue, Greenpeat can have interesting calorific values or physical and chemical characteristics for it to be used as a soil improver. In this paper, a case study on a real scale application of the technology developed by HBI is presented. Considering all the financial incomes, the payback time of the plant has been calculated at 3.3 years.

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References

Álvarez-Murillo A., Román S., Ledesma B., Sabio E., (2015), Study of variables in energy densification of olive stone by hydrothermal carbonization, *Journal of Analytical and Applied Pyrolysis*, **113**, 307-314.

Bamminger C., Marschner B., Jüschke E., (2014), An incubation study on the stability and biological effects of pyrogenic and hydrothermal biochar in two soils, *European Journal of Soil Science*, **65**, 72–82.

Bargmann I., Martens R., Rillig M.C., Kruse A., Kücke M., (2014a), Hydrochar amendment promotes microbial immobilization of mineral nitrogen, *Zeitschrift für Pflanzenernährung und Bodenkunde*, **177**, 59–67.

Bargmann I., Rillig M.C., Kruse A., Greef J.M., Kücke M., (2014b), Effects of hydrochar application on the dynamics of soluble nitrogen in soils and on plant availability, *Zeitschrift für Pflanzenernährung und Bodenkunde*, **177**, 48–58.

Basso D., Castello D., Baratieri M., Fiori L., (2013a), *Hydrothermal Carbonization of Waste Biomass: Progress Report and Prospects*, Proc. of the 21st European Biomass Conference and Exhibition, June 3th-7th, Copenhagen, Denmark.

Basso A.S., Miguez F.E., Laird D.A., Horton R., Westgate M., (2013b), Assessing potential of biochar for increasing water-holding capacity of sandy soils, *GCB Bioenergy*, **5**, 132–143.

Basso D., Hortala E.W., Patuzzi F., Castello D., Baratieri M., Fiori L., (2015), Hydrothermal carbonization of off-specification compost: A byproduct of the organic municipal solid waste treatment, *Bioresource Technology*, **182**, 217-224.

Basso D., Patuzzi F., Castello D., Baratieri M., Rada E.C., Hortala E.W., Fiori L., (2016), Agro-industrial waste to solid biofuel through hydrothermal carbonization, *Waste Management*, **47**, 114-121.

Boldrin A., Andersen J., Møller J., Christensen T., (2009), Composting and compost utilization: accounting of greenhouse gases and global warning contributions, *Waste Management & Research*, **27**, 800-812.

Bong C.P.C., Lim L.Y., Ho W.S., Lim J.S., Klemeš J.J., Towprayoon S., Ho C.S., Lee C.T., (2017), A review on the global warning potential of cleaner composting and mitigation strategies, *Journal of Cleaner Production*, **146**, 149-157.

Boyd C.E., Massaut L., (1999), Risks associated with the use of chemicals in pond aquaculture, *Aquacultural Engineering*, **20**, 113-132.

Buss W., Mašek O., Graham M., Wüst D., (2015), Inherent organic compounds in biochar--Their content, composition and potential toxic effects, *Journal of environmental management*, **156**, 150–157.

Eibisch N., Helfrich M., Don A., Mikutta R., Kruse A., Ellerbrock R., Flessa H., (2013), Properties and degradability of hydrothermal carbonization products, *Journal of environmental quality*, **42**,1565–1573.

Fang J., Zhan L., Ok Y.S., Gao B., (2017), Minireview of potential applications of hydrochar derived from hydrothermal carbonization of biomass, *Journal of Industrial and Engineering Chemistry*, doi:org/10.1016/j.jiec.2017.08.026 (in press).

FAO, (2009), How to Feed the World in 2050 , On line at: http://www.fao.org/fileadmin/templates/wsfs/docs/expert_paper/How_to_Feed_the_World_in_2050.pdf.

Fiori L., Basso D., Castello D., Baratieri M., (2014), Hydrothermal carbonization of biomass: Design of a batch reactor and preliminary experimental results, *Chemical Engineering Transactions*, **37**, 55-60.

Gajić A., Koch H.J., (2012), Sugar beet (L.) growth reduction caused by hydrochar is related to nitrogen supply, *Journal of Environmental Quality*, **41**, 1067–1075.

George C., Wagner M., Kücke M., Rillig M.C., (2012), Divergent consequences of hydrochar in the plant–soil system. Arbuscular mycorrhiza, nodulation, plant growth and soil aggregation effects, *Applied Soil Ecology*, **59**, 68–72.

Glibert P.M., Seitzinger S., Heil C.A., Burkholder J.M., Parrow M.W., Codispoti L.A., Kelly V., (2005), Eutrophication in the global proliferation of harmful algal blooms, *Oceanography*, **18**, 198-209.

IPCC, (2014), Climate Change 2014: Impacts, adaptation, and vulnerability. Part A: Global and sectorial aspects, Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, On line at: http://www.hko.gov.hk/climate_change/ed_package/doc/impacts_av.pdf

Jiao W., Chen W., Chang A.C., Page A.L., (2012), Environmental risks of trace elements associated with long-term phosphate fertilizers applications: A review, *Environmental Pollution*, **168**, 44-53.

Kambo H.S., Dutta A., (2015), A comparative review of biochar and hydrochar in terms of production, physico-chemical properties and applications, *Renewable and Sustainable Energy Reviews*, **45**, 359-378.

Kammann C.I., Schmidt H.P., Messerschmidt N., Linsel S., Steffens D., Müller C., Koyro H.W., Conte P., Joseph S., (2015), Plant growth improvement mediated by nitrate capture in co-composted biochar, *Scientific reports*, **5**, 11080.

Kang S., Li X., Fan J., Chang J., (2012), Solid fuel production by hydrothermal carbonization of black liquor, *Bioresource Technology*, **110**, 715–718.

Karhu K., Mattila T., Bergström I., Regina K., (2011), Biochar addition to agricultural soil increased CH4 uptake and water holding capacity – Results from a short-term pilot field study, *Agriculture, Ecosystems & Environment*, **140**, 309–313.

Laird D.A., Fleming P., Davis D.D., Horton R., Wang B., Karlen D.L., (2010), Impact of biochar amendments on the quality of a typical Midwestern agricultural soil, *Geoderma*, **158**, 443–449.

Libra J.A., Ro K.S., Kammann C., Funke A., Berge N.D., Neubauer Y., Titirici M.M., Fühner C., Bens O., Kern J., Emmerich K.H., (2011), Hydrothermal carbonization of biomass residuals. A comparative review of the chemistry, processes and applications of wet and dry pyrolysis, *Biofuels*, **2**, 71–106.

Liu Z., Balasubramanian R., (2012), Hydrothermal Carbonization of Waste Biomass for Energy Generation, *Procedia Environmental Sciences*, **16**, 159–166.

Liu Z., Guo Y., Balasubramanian R., Hoekman S.K., (2016), Mechanical stability and combustion characteristics of hydrochar/lignite blend pellets, *Fuel*, **164**, 59-65.

Lin Y., Ma X., Peng X., Yu Z., (2017), Hydrothermal carbonization of typical components of municipal solid waste for deriving hydrochars and their combustion behaviour, *Bioresource Technology*, **243**, 539-547.

Lu L., Namioka T., Yoshikawa K., (2011), Effects of hydrothermal treatment on characteristics and combustion behaviors of municipal solid wastes, *Applied Energy*, **88**, 3659–3664.

Malghani S., Gleixner G., Trumbore S.E., (2013), Chars produced by slow pyrolysis and hydrothermal carbonization vary in carbon sequestration potential and greenhouse gases emissions, *Soil Biology and Biochemistry*, **62**, 137–146.

Mann R.M., Hyne R.V., Choung C.B., Wilson S.P., (2009), Amphibians and agricultural chemicals: Review of the risks in a complex environment, *Environmental Pollution*, **157**, 2903-2927.

Mumme J., Eckervogt L., Pielert J., Diakité M., Rupp F., Kern J., (2011), Hydrothermal carbonization of anaerobically digested maize silage, *Bioresource Technology*, **102**, 9255-9260.

Nolan B.T., Ruddy B.C., Hitt K.J., Helsel D.R., (1997), Risk of nitrate in groundwaters of the United States – A national perspective, *Environmental Science & Technology*, **31**, 2229-2236.

Oliveira L.S.B.L., Oliveira D.S.B.L., Bezerra B.S., Pereira B.S., Battistelle A.G., (2017), Environmental analysis of organic waste treatment focusing on composting scenarios, *Journal of Cleaner Production*, **155**, 229-237.

Prawisudha P., Namioka T., Yoshikawa K., (2012), Coal alternative fuel production from municipal solid wastes employing hydrothermal treatment, *Applied Energy*, **90**, 298–304.

Rajkovich S., Enders A., Hanley K., Hyland C., Zimmerman A.R., Lehmann J., (2012), Corn growth and nitrogen nutrition after additions of biochars with varying properties to a temperate soil, *Biology and Fertility of Soils*, **48**, 271–284.

Román S., Nabais J.M.V., Laginhas C., Ledesma B., González J.F., (2012), Hydrothermal carbonization as an effective way of densifying the energy content of biomass, *Fuel Processing Technology*, **103**, 78–83.

Sabio E., Álvarez-Murillo A., Román S., Ledesma B., (2016), Conversion of tomato-peel waste into solid fuel by hydrothermal carbonization: Influence of the processing variables, *Waste Management*, **47**, 122-132.

Savci S., (2012), An agricultural pollutant: Chemical fertilizer, *International Journal of Environmental Science and Development*, **3**, 77-80.

Steiner C., Glaser B., Geraldes T.W., Lehmann J., Blum W.E.H., Zech W., (2008), Nitrogen retention and plant uptake on a highly weathered central Amazonian Ferralsol amended with compost and charcoal, *Journal of Plant Nutrition and Soil Science*, **171**, 893–899.

Wiedner K., Rumpel C., Steiner C., Pozzi A., Maas R., Glaser B., (2013), Chemical evaluation of chars produced by thermochemical conversion (gasification, pyrolysis and hydrothermal carbonization) of agro-industrial biomass on a commercial scale, *Biomass and Bioenergy*, **59**, 264–278.

Yang W., Wang H., Zhang M., Zhu J., Zhou J., Wu S., (2016), Fuel properties and combustion kinetics of hydrochar prepared by hydrothermal carbonization of bamboo, *Bioresource Technology*, **205**, 199-204.

Zavalloni C., Alberti G., Biasiol S., Delle Vedove G., Fornasier F., Liu J., Peressotti A., (2011), Microbial mineralization of biochar and wheat straw mixture in soil. A short-term study, *Applied Soil Ecology*, **50**, 45–51.

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EFFECT OF REACTIVE MATS ON IN-SITU REMEDIATION OF CONTAMINATED MARINE SEDIMENT*

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Abstract

The management and treatment of contaminated sediment is a considerable environmental issue recognized worldwide, that poses major technical and economic challenges. Nowadays, there is an acute need for remedial technologies that can address both a variety of contaminants in a range of aquatic environments and provide permanent solutions by reducing contaminant toxicity. Among the remediation options, *In Situ Capping* (ISC) turns out to be a less expensive and disruptive, and more durable approach. However, by using low adsorption capacity materials, passive caps do not always fulfil the reduction of risks. Further alternative called *active capping* involves the use of chemically reactive materials (i.e., activated carbon, apatite, zeolite, organoclay) that sequestrate and/or degrade sediment contaminants in order to reduce their mobility, toxicity, and bioavailability. This study provides a review on the types of active materials tested in recent active capping studies. A special focus was devoted to reactive mat: It is a new class of in situ sediment remediation technique consisting of a reactive layer containing one or more neutralizing or otherwise reactive materials that is confined between two permeable geotextile layers.

Keywords: active capping, contaminated marine sediments, reactive mat, sediment remediation

1. Introduction

Anthropogenic factors associated with industrial, urban, agriculture, and recreational activities have led to increasing the emissions of many hazardous chemicals to the aquatic environment and aquatic sediments have been identified as an ultimate receptor for these pollutants (Zhang et al., 2017). Sediment-bound pollutants pose major concerns for human

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health and the environment, because these contaminants can be re-enter the overlying water and become available to benthic organisms and subsequently enter aquatic food chains. Thus, sediment acts as both carriers and long-term secondary sources of contaminants to aquatic ecosystems.

Sediment management strategies may involve *in situ* and *ex situ* options. *In situ* remedial alternatives generally involve: (i) Monitored Natural Recovery (MNR), which based on the assumption that, although sediments pose some risk, it is low enough that natural processes can reduce risk over time in a reasonably safe manner (De Gisi et al., 2017); (ii) *in situ* containment and treatment, in which contaminated sediment is physically and chemically isolated from aquatic ecosystems or the contaminants in sediment are sequestered and degraded. *Ex situ* remedial alternatives typically require several component technologies to dredging or excavation, transport, pre-treat, treat, and/or dispose sediments and treatment residues (De Gisi and Notarnicola, 2016). Among the remediation options, in many cases with highly contaminated sediments, In Situ Capping (ISC) turns out to be a less expensive, less disruptive, and more durable approach, compared to the costly dredging.

Capping is the process of placing a layer of clean materials over contaminated sediments to isolate the contaminant from the overlying water column and biota, to reduce contaminant flux into the biologically active portion of the sediment, and to create new habitats for aquatic organisms (Reible et al., 2003). Conventional (passive) caps consist of placing a layer of clean neutral materials (as sand, silt, clay, and crushed rock debris) rely on containment, rather than treatment, of contaminated sediment. The cap may also include geotextiles to aid in layer separation or geotechnical stability, amendments (that is of chemically reactive materials) to enhance protectiveness, or additional layers to armor and maintain its integrity or enhance its habitat characteristics. When these amendments are added to cap material, the remedy is called an “Active Cap”, and the amendments enhance the performance of the cap material. The use of chemically reactive materials allows sequestrating and/or degrading sediment contaminants, reducing their mobility, toxicity, and bioavailability, performing both containment and treatment to contaminated sediment. The comparison between passive capping and active capping is listed in Table 1.

Table 1. Comparison between passive capping technology and active capping technology (adapted upon Zhang et al., 2017).

Aspect	*Capping*	
	Passive	***Active***
Materials	Neutral materials such as sand, silt, clay, crushed rock debris, clean dredged sediments	Active materials such as activated carbon, organoclay, zero-valent iron, zeolite, apatite, biopolymer,
Thickness	About 30–100 cm	About 10–30 cm
Functions	Containment: 1. Physical isolation of contaminated sediment 2.Stabilization of contaminants in sediment 3.Reduction of the flux of dissolved contaminants into the overlying water	Containment and treatment: 1. Physical and chemical isolation of contaminated sediment 2. Sequestration and degradation of contaminants in sediment 3. Reduction of the flux of dissolved contaminants into the overlying water under more complicated conditions
Development stage	Practical stage	Initial stage
Field testing	Substantial	Limited

A variety of materials are proven to achieve the goals of cap; however, few demonstrated options exist for enhancing contaminant adsorption and degradation processes.

Several laboratory experiments and recent field studies demonstrated that a centimeter thick layer of activated carbon can effectively decrease contaminant flux from sediment to the overlying water (Josefsson et al., 2012; Murphy et al., 2006). Other reactive amendments, such as calcite, zeolite, apatite, organoclay, and biopolymers, can also sequester a variety of contaminants and control their mobility to the water column (Berg et al., 2004; Knox et al., 2012; Lin et al., 2011).

This paper provides a review on the types of active materials employed in recent active capping studies. A special focus was devoted to one main technological cluster identified for in situ remediation: Reactive mat. This is a new class of in situ sediment remediation technique consisting of a reactive layer that contain one or more neutralizing or otherwise reactive materials (i.e., activated carbon, apatite, zeolite, organoclay) that is confined between two permeable geotextile layers.

2. Reactive mat

The use of active materials into ISC allows increasing low adsorption capacity of sand caps and reducing the cap thickness in order to achieve the remediation goals.

Amendments can be contained in a mat (Fig. 1), applied in bulk onto the sediment surface, mixed in the sediment, added as part of a sand cap, or as a layer within a sand cap.

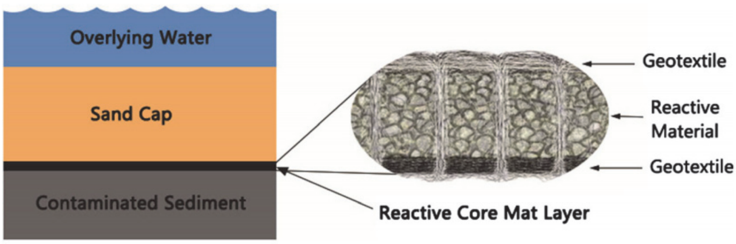

Fig. 1. Field application and schematic of reactive core mat (Zhang et al., 2017)

The same amendment used in the same proportions is generally more effective at isolating contaminants when used in a cap than when placed directly into sediments. Additionally, amendments delivered in a thin layer can minimize an amount of costs since these materials are usually more expensive than traditional materials.

Mats consist of an amendment (or amendments) that are confined between two permeable geotextile layers. These mats allow for accurate placement of amendments with high total organic content and low density that could otherwise become suspended during placement. Synthetic geotextiles also provide a bioturbation barrier, prevent mixing of amendments with underlying sediments, allow a more uniform application of amendments, and reduce erosion. As they are composed of synthetic fibers, they do not easily biodegrade (Olsta and Darlington, 2005).

These mats are generally covered with conventional capping materials and, if needed, armoring layers to provide physical stability and further isolation. A thickness of 10–15 cm of sand or soil acts as an armor layer to protect the underlying thin sorbent layer from erosion forces and provides a habitat for benthic organisms to colonize and lengthen contaminant breakthrough paths (Lampert et al., 2013). Before mat is installed, it is important to remove rocks and debris from the sediment surface to minimize potential damage to the mat and provide a more even surface for placement (Barth and Reible, 2008). Differential settling of the mat could lead to ruptured seams and contaminant migration through the seams. In addition, depending on the amendments and components of the mat, they may not sink readily. Although some amendments enclosed in the geotextiles are buoyant, it is possible to use geotextiles with a higher specific gravity or mix a fraction of sand with the amendment to create a mat that is easier to sink (Olsta and Darlington, 2005). Such amendment mats are commercially available from a limited number of companies. However, this approach has been adopted at several US EPA superfund site projects with typical thicknesses of 6 and 11 mm.

3. Reactive cap materials

Table 2 summarizes several reactive amendments and the target contaminant classes treated. Typical organic contaminants targeted include dioxins/furans, PAHs, PCBs, and pesticides. Typical inorganic contaminants targeted include metals, such as arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc. Specific cap materials are selected based on the remedial objectives, the characteristics of the site, the nature of the contaminated sediments, and the type(s) of contamination present. Reactive capping amendments generally fall into two primary categories: amendments that sequester contaminants (i.e., physically bind and reduce the mobility or availability of contaminants); and amendments that degrade contaminants (i.e., directly alter contaminants into less toxic forms).

Table 2. Reactive Amendments for Sediment Capping

Function	*Amendment*	*Contaminant targeted*
Sequestering	Activated Carbon (AC)	organics (dioxins/furans, PAHs, PCBs, pesticides)
	Apatite	metals (lead)
	Bauxite	metals (arsenic, cadmium, chromium, lead, mercury, nickel, zinc)
	Barite	metals
	Biochars	organics
	Coal	organics
	Coke	organics (PAHs, PCBs)
	Engineered Polymers	inorganics, organics
	Limestone	metals
	Organoclays	metals, NAPLs, organics (PAHs, PCBs)
	Zeolites	metals (copper, lead, zinc)
Degrading	Bioremediation agents	organics (dioxins/furans, PCBs)
	Biopolymers	metals, organics
	Palladium	organics (chlorinated hydrocarbons, PCBs)
	Zero-Valent Iron (ZVI)	organics (chlorinated hydrocarbons, PCB)

In order to enhance current capping technologies, different authors have been developed specific formulations of sequestering and degrading amendments. For instance, Choi et al. (2009) focused on the development of AC impregnated with reactive iron/palladium (Fe/Pd) bi-metallic nanoparticles (NPs) (Reactive AC, RAC). RAC is a smart composite for dechlorination of PCBs. Due to its high adsorption capacity; RAC actively attracts hydrophobic PCBs from sediment matrix (Lofrano et al, 2017).

3. Discussions

Active capping technology is a new approach for containing and treating contaminated sediments in situ. In particular, reactive mat is an inexpensive and effective method to deliver difficult-to-place, high-value, and sorptive media into thin-layer caps accurately. In contrast with traditional capping, the introducing of active materials reduces the cap thickness but increases the adsorption and degradation capacity of active capping and makes it better constructed and more resistant to erosive forces.

In the last two decades, several authors evaluated in situ amendment introducing various sorbents such as activated carbon, organoclay, apatite, biochar, coke, zeolites, and zerovalent iron (ZVI) into contaminated sediments (USEPA, 2013a). Amendments tend to modify sediment geochemistry increasing contaminant binding and stability in order to reduce its risk to human health and the environment. Among all, AC, organoclay, and apatite were identified as particularly promising sorptive amendments for in situ sediment remediation (USEPA, 2013b). But several data about their potential side effects are still missing. Except for AC and ZVI, (eco-) toxicity data are scarce or still unavailable (Lofrano et al., 2017).

The effectiveness of some amendments, such as AC and organoclay, has been demonstrated just in a small number of field applications, while other amendments, such as zerovalent iron, phosphate additives, and biopolymers, are still in the bench-scale or pilot-testing phase. Even though some of these materials have been used in other environmental applications, such as groundwater and off-gas treatments, there are a limited number of projects and available performance data on their effectiveness in treating contaminated sediments (Lofrano et al., 2017).

It can be utilized preliminary laboratory experiments and modeling study in a mimic real site condition to examine candidate materials' performance and select appropriate materials for the capping project. Randall et al. (2013) reported a three-stage sequence of bench-scale experiments to select a capping material in the case of mercury-contaminated sediments. Several experiments have modeled the contaminants' fate and transport in the caps or cap performance of several kinds of active capping materials for a large range of sediment contaminants to provide information on their applicability to cap design (Go et al., 2009; Viana et al., 2008; Yin et al., 2007). The particle size and dosage of materials should also be determined in the preliminary experiments since the particle size and dosage are relevant to the treatment efficiency in reducing contaminant concentration (Zimmerman et al., 2005). The way of active materials combined with microorganisms also provides more opportunities for biodegradation of contaminants. Specifically, biotransformation of contaminants is designed to occur within the cap matrix producing environmentally friendly reaction by-products. Biologically based active caps have the potential to keep reactivity over long time periods serving as potentially sustainable remedial options especially when degrading microorganisms are present and the necessary metabolic requirements are met (Himmelheber et al., 2011).

4. Conclusions

Based on the consulted literature, capping with active mats could represent a viable contaminant containment technology. However, the long-term permanence of amendments and their ability to retain contaminants over time are not well understood.

Frequently, due to the lack of real scale applications, costs are not available as well as the full range of drawbacks. For future improvement more field data and pilot scale experiments are essential to make active capping a more reliable option of remediation activities. Further active capping materials should be invented taking into account the following guidelines: (a) available at low cost, and easily placement in the field; (b) efficiently retention of targeted contaminant(s); (c) no or less detrimental effects to the aqueous environment and the benthic organisms; and (d) beneficial to recolonization of organisms.

References

Berg U., Neumann T., Donnert D., Nüesch R., Stüben D., (2004), Sediment capping in eutrophic lakes–efficiency of undisturbed calcite barriers to immobilize phosphorus, *Applied. Geochemistry*, **19**, 1759–1771.

Cho Y-M, Ghosh U., Kennedy A.J., Grossman A., Ray G., Tomaszewski J., Smithenry D., Bridges T., Luthy R.G., (2009), Field application of activated carbon amendment for in-situ stabilization of polychlorinated biphenyls in marine sediment, *Environmental Science and Technology*, **43**, 3815–3823.

De Gisi S., Notarnicola M., (2016), Waste minimization in the remediation of contaminated sites: using the oil belt skimmer technology for the removal of heavy hydrocarbons from groundwater, *Environmental Science and Pollution Research.*, **23**, 24092-24106.

De Gisi S., Minetto D., Todaro F., Lanzolla A.M., Notarnicola M., (2017*), Monitored Natural Recovery of Contaminated Marine Sediments. Proposal of a Monitoring Plan for in Situ Continuos Testing and Sensing* Proc. of International Instrumentation and Measurement Technology Conference, May 22th-2th5, Torino, Italy.

Go J., Lampert D.J., Stegemann J.A., Reible D.D., (2009), Predicting contaminant fate and transport in sediment caps: mathematical modelling approaches, *Applied Geochemistry*, **24**, 1347–1353.

Himmelheber D.W., Pennell K.D., Hughes J.B., (2011), Evaluation of a laboratory-scale bioreactive in situ sediment cap for the treatment of organic contaminants, *Water Res.*, **45**, 5365–5374.

Knox A.S., Paller M.H., Roberts J. (2012). Active capping technology – new approaches for in situ remediation of contaminated sediments, *Remediation Journal*, **22**, 93–117.

Lampert D.J., Lu X., Reible D.D., (2013), Long-term PAH monitoring results from the Anacostia River active capping demonstration using polydimethylsiloxane (PDMS) fibers, *Environmental Science: Processes & Impacts*, **15**, 554–562.

Lin J., Zhan Y., Zhu Z., (2011), Evaluation of sediment capping with active barrier systems (ABS) using calcite/zeolite mixtures to simultaneously manage phosphorus and ammonium release, *Scence of the Total Environment,* **409**, 638–646.

Lofrano G., Libralato G., Minetto D., De Gisi S., Todaro F., Conte B., Calabrò D., Quatraro L., Notarnicola M., (2017), In situ remediation of contaminated marine sediment: an overview, *Environmental Science and Pollution Research*, **24**, 5189-5206.

Murphy P., Marquette A., Reible D., Lowry G.V., (2006), Predicting the performance of activated carbon-, coke-, and soil-amended thin layer sediment caps, *Journal of Environmental Engineering,* **132**, 787–794.

Randall P.M., Yates B.J., Lal V., Darlington R., Fimmen R., (2013), In-situ subaqueous capping of mercury-contaminated sediments in a freshwater aquatic system, Part II-evaluation of sorption materials, *Environmental Research*,**125**, 41–51.

Reible D., Hayes D., Lue-Hing C., Patterson J., Bhowmik N., Johnson M, Teal J., (2003), Comparison of the long-term risks of removal and in situ management of contaminated sediments in the Fox River*, Soil and Sediment Contamination*, **12,** 325–344.

USEPA, (2013a), US Environmental Protection Agency, Use of amendments for in situ remediation at superfund sediment sites, Office of Superfund Remediation and Technology Innovation, OSWER Directive 9200.2–128FS, April.

USEPA, (2013b), US Environmental Protection Agency Superfund remedial program review action plan, Washington DC, November.

Viana P.Z., Yin K., Rockne K.J., (2008), Modeling active capping efficacy. 1. Metal and organometal contaminated sediment remediation, *Environmental Science and Technology*, **42**, 8922–8929.

Yin K., Viana P., Zhao X., Rockne K., (2007), *A Monte Carlo Simulation Approach for Active Caps in Mixed Contaminant Environments*, Proc. of the 4th International Conference on Remediation of Contaminated Sediments.

Zhang C., Zhu M., Zeng G., Yu Z., Cui F., Yang Z., Shen L., (2016),Active capping technology: a new environmental remediation of contaminated sediment, *Environmental Science and Pollution* Research, **23**, 4370–4386.

Zimmerman J.R., Werner D., Ghosh U., Millward R.N., Bridges T.S., Luthy R.G., (2005), Effects of dose and particle size on activated carbon treatment to sequester polychlorinated biphenyls and polycyclic aromatic hydrocarbons in marine sediments, *Environmental Toxicology and Chemistry,* **24**, 1594–1601.

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PURE OXYGEN-BASED MSW BIO-STABILIZATION: PRELIMINARY RESULTS OF A FULL SCALE INVESTIGATION*

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Abstract

Municipal Solid Waste (MSW) bio-stabilization usually involves the use of air for the biological treatment of the residual fraction of separate collection. Air is the suitable solution when the system is operating normally. However, frequently emergencies, such as the overload of the plant and the resulting longer waste treatment times, suggest the need to reduce the times of the stabilization cycle. The pure oxygen used with air may represent an interesting solution for this aim.
This paper deepens the bio-stabilisation of waste by means of a full-scale experiment involving the combined use of air and pure oxygen. The activities were carried out at the Massafra mechanical-biological treatment (MBT) plant, in the Southern-Italy, characterized by a treatment capacity of 220,000 tons per year. The preliminary results highlighted the technical feasibility of the proposal. However, future investigations have to be carried out with the primary purpose of enhancing the oxygen diffusion into the waste.

Keywords: mechanical-biological plant, municipal solid waste, pure oxygen, residual fraction

1. Introduction

Bio-stabilization represents the biological process implemented in a mechanical-biological treatment (MBT) plant to achieve the stabilization of the organic matter present in

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the solid waste (De Feo et al., 2012). The feeding is composed by unsorted municipal solid waste (UMSW) that is the residual fraction of separate collection.

The UMSW cannot be used for the production of compost because of the presence of other fractions in addition to the organic one (De Gisi et al., 2016). The mechanical treatment involves screening of all incoming waste in order to separate the different merchandise fractions. Usually, the mechanical section consists of (i) reception and storage, (ii) opening of the bags by means of "open-bag devices", (iii) screening and (iv) iron removal (Godio et al., 2015).

Bio-stabilization is aimed at (i) stabilizing the organic matter by means of the mineralization of the more easily degradable components with final production of water and carbon dioxide and stabilized material, (ii) sanitizing the waste (temperatures are not lower than 55°C) and (iii) reduce the volume and mass of the treated materials with weight loss of 20-30% due to evaporation (Arvanitoyannis and Ladas, 2008; Di Maria et al., 2014).

In terms of technological solutions, currently in Italy and Europe it is possible to identify two types of MBT plant: (i) separated-stream treatment, (ii) single-stream treatment. The main valuable output of a MBT plant is the SRF (Solid Recovered Fuel) characterized by high calorific value (De Gisi et al., 2017; Nasrullah et al., 2014). The state-of-the-art suggests the use of air for biological treatment of waste. Furthermore, air represents the suitable solution in the case of an ordinary operation of the MBT plant.

Nevertheless, frequently emergencies such as the overload of the plant with the resulting longer times for the waste to be treaded, suggests the need to reduce the times of the stabilization cycle. The pure oxygen used with air may represent an interesting solution for this aim as highlighted in De Gisi et al. (2016).

This paper deepens the bio-stabilization of UMSW by means of a full-scale investigation involving the combined use of air and pure oxygen. In detail, the following sub-objectives have been investigated: (i) Reduced treatment-cycle time compared to the traditional cycle; (ii) Evaluation of the quality of the biostabilized product compared to that of the conventional (with air) system.

2. Materials and methods

The activities were carried out at the Massafra MBT plant managed by CISA Spa and characterized by a treatment capacity of 220,000 tons/year.

Considering the framework of the experimentation, the main steps were the following: (i) characterization of the inlet UMSW, (ii) parallel conduction of bio-stabilization tests in two separate bioreactors and, (iii) characterization of biostabilized products and comparison.

2.1. MSW composition

The waste composition, described according to a compositional and proximate analysis is reported in Table 1. The UMSW consists of the residual fraction of separate collection that was collected in the Province of Taranto, Southern Italy.

The compositional analysis identifies paper and cardboard, plastic and rubber and cellulosic material as largest fractions with values of 27.2, 24.2 and 17.5%, respectively. The organic matter was about 4.4%.

The waste had moisture and total solids content of 25.1 and 74.9% while, the content of volatile solids and ashes was of 85.4 and 14.6%, respectively. The potential dynamic respirometric index was of 3,965 $mgO_2/kgSV/h$. The Low Heating Value (LHV) was, instead, of 12,200 kJ/kg (w/w).

Table 1. Characteristics of the inlet UMSW according to the Italian Law D.M. 22/2013

Parameter	***Unit***[(a)]	***Value***	***St. Dev.***
Compositional analysis			
Fraction <20 mm	% d/w	18.10	±2.53
Cellulosic material	% d/w	17.50	±2.40
Paper and cardboard	% d/w	27.20	±3.81
Inert waste (glass, ceramics, stones, etc.)	% d/w	4.25	±0.60
Metals	% d/w	4.65	±0.65
Plastic and rubber	% d/w	24.20	±3.39
Organic matter	% d/w	4.45	±0.62
Proximate analysis			
Moisture tq	% w/w	25.1	±3.1
Moisture	% d/w	46.8	±5.3
Total solids tq	% w/w	74.9	±3.1
Total solids	% d/w	53.2	±5.1
Volatile solids	%ST	85.4	±1.1
Ashes	%ST	14.6	±1.5
Dynamic respirometric index			
pH[(b)]	-	7.3	±0.5
Potential dynamic respirometric index	mgO_2/kgSV/h	3965	±1965
Heating value			
LHV[(c)]	kJ/kg (w/w)	12,200	±2240

[(a)](w/w) = wet weight; (d/w) = dry weight; [(b)]Limit: 6.0-8.5; [(c)]LHV = Low Heating value

2.2. Full-scale experimental investigation

The bio-stabilization occurs in HEROF bioreactors (biocells) with an 8-day biological cycle. The typical treatment cycle involves an initial heating phase of the waste pile, a sanitization step, a maintenance phase and a final cooling phase of the pile.

The first phase typically lasts for 1 day. The second phase must have a minimum duration of 3 days: the waste must be at a temperature of at least 55°C. The third stage does not have a clearly defined duration. Generally, Italian law (2013) suggests that the sanitization and maintenance phase must have duration, overall, of at least 6 days. Finally, the cooling phase consists of injecting cold air into the waste pile in such a way as to lower the temperature to at least 30-35°C. The total cycle time is therefore 8 days.

During the stabilization process, the exhaust air goes to the air treatment line (and then to the biofilter) while the leachate is removed and then stored in suitable tanks. The leachate is then treated as an industrial wastewater (De Gisi and Notarnicola, 2017).

Fig. 1a shows the main components of the conventional system. The reactor is flown with air from the bottom. Instead, the innovative reactor that has been tested provides for the following specially designed components: (i) Oxygen storage, supply and distribution plant; (ii) Gaseous oxygen flow control and regulation instrumentation and (iii) Oxygen transport piping. Differently from the conventional reactor, the test involves the combined use of pure oxygen and air. With reference to 1 hour of operation, a distribution of pure oxygen and air was planned for 10 minutes and 50 minutes, respectively. The details of the innovative reactor are shown in Fig. 1b. Each reactor was supplied with 400 tons of inlet waste.

3. Results and discussion

A first result concerned the temperature profile during the test. The use of the innovative system has reduced the heating phase time from about 29.4 h to 25.4 h (Fig. 2).

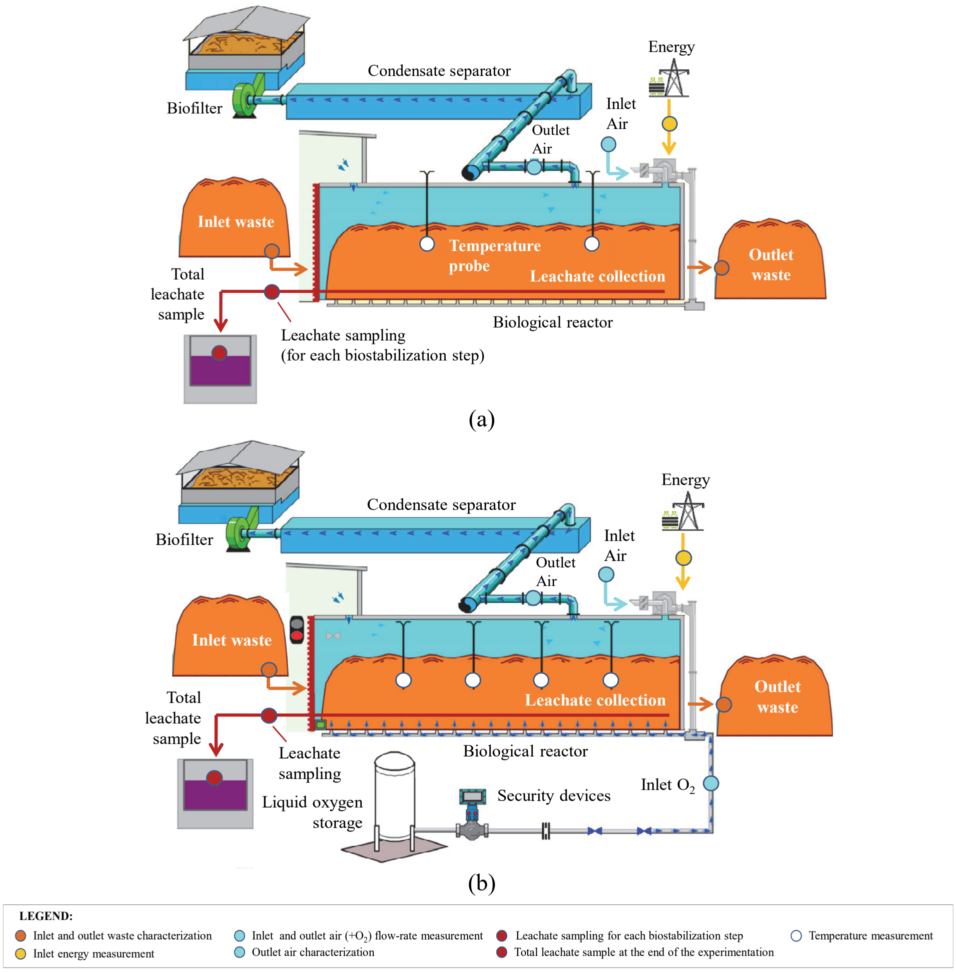

Fig. 1. Flow-chart and position of sampling points for (a) conventional and (b) Air + pure oxygen biostabilization

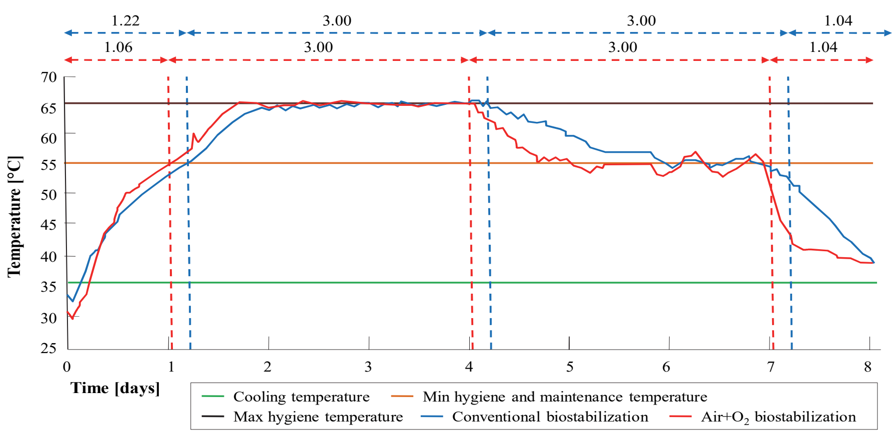

Fig. 2. Comparison of temperature profiles during bio-stabilization tests

The temperature of 55°C was therefore reached with less time than in the conventional system. The duration of the other phases was broadly similar. The cycle duration was 8.1 and 8.6 days for the innovative and conventional system, respectively (Fig. 2).

Table 2 shows preliminary results in terms of biostabilized product quality. The potential dynamic respirometric index was 785 and 750 mgO_2/kgSV/h for the innovative and conventional systems, respectively. The lower calorific value, on the other hand, was slightly higher in the case of the innovative system, with a value of 17,100 kJ/kg compared to 16,000 kJ/kg in the case of conventional one. Therefore, the two outputs have substantially similar qualities.

It is interesting to note that the supply of pure oxygen is not constant over time as reported above. Therefore, theoretically, an increase in the quantities added could lead to an improvement in biological process and consequently to a better stabilized product.

However, field trials are necessary. Higher oxygen content could negatively affect the evolution of the biological process.

Table 2. Quality of biostabilized waste with the conventional (air) and improved (air + pure oxygen) system

Parameter	***Unit***[(a)]	***System***	
		Conventional	***Air + O_2***
Moisture tq	% w/w	27.3	30.1
Moisture	% d/w		
Total solids tq	% w/w	72.7	69.9
Total solids	% d/w		
Volatile solids	%ST	83.8	80.8
Ashes	%ST	16.2	19.2
pH[(b)]	-	7.1	7.1
Potential dynamic respirometric index[(c)]	mgO_2/kg SV/h	750 (±375)	785 (±400)
LHV[(d)]	kJ/kg (w/w)	16,000 (±3200)	17,100 (±3420)

[(a)](w/w) = wet weight; (d/w) = dry weight; [(b)]Limit: 6.0-8.5; [(c)]Limit = 800 mgO_2/kg SV/h; [(d)]LHV = Low Heating value

3. Concluding remarks

The experimental cycles carried out on a full scale with the use of oxygen, compared with traditional air based cycles, showed promising - even if still interlocutor - results, regarding the possibility of optimizing, in terms of time and/or yield, the bio-stabilization process of UMSW.

In particular, referring in particular to the heating phase, the cycle showed an interesting reduction in the time needed to reach the expected sanitization temperature (55° C). The first results suggest that the outputs have substantially similar qualities in terms of potential dynamic respirometric index and low heating value.

The comparative analysis suggests that the use of oxygen leads to a greater and faster biological oxidation of the organic substance, on condition that its distribution is as homogeneous as possible within the waste pile.

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References

Arvanitoyannis I.S., Ladas D., (2008), Meat waste management: treatment methods and potential uses of treated waste, *Waste Management for the Food Industries*, **43**, 543-559.

De Feo G., De Gisi S., Galasso M., (2012), Solids Waste. Design and Management of Installations for the Treatment and Disposal (in Italian: Rifiuti Solidi. Progettazione e gestione di impianti per il trattamento e lo smaltimento), Dario Flaccovio Editore, Palermo, Italy.

De Gisi S., Chiarelli A., Tagliente L., Notarnicola M. (2017), Energy, environmental and operation aspects of a SRF-fired fluidized bed waste-to-energy plant, *Waste Management*, doi: org/10.1016/j.wasman.2017.04.044, (in press).

De Gisi S., Todaro F., Carella C., Fedele G., Notarnicola M. (2016), Pure oxygen-based municipal solid waste (MSW) bio-stabilization: Energy, engineering, environmental and process safety aspects, *Procedia Environmental Science, Engineering and Management*, **3**, 41-47.

De Gisi S., Notarnicola M., (2017). Industrial wastewater treatment. In book: Encyclopedia of Sustainable Technologies, Edition: 1st, Chapter: Reference Module in Earth Systems and Environmental Sciences 2017, Publisher: Elsevier Ltd, Editors: Martin Abraham (doi: 10.1016/B978-0-12-409548-9.10167-8).

Di Maria F., Micale C., Morettini E., (2014), Alternative residual municipal solid waste management scenarios in areas with deficiency or absence of incinerators, *Procedia Environmental Science, Engineering and Management*, **1**, 7-11.

Godio A., Arato A., Chiampo F., Ruggeri B., Di Addario M., Fischetti M., Perissinotto E., (2015), Liquid injection to enhance biogas production in landfills for pretreated municipal solid wastes - BIO.LEA.R. Project (Life+ Program), *Environmental Engineering and Management Journal*, **14**, 1623-1636.

Italian law, (2013), Regulation concerning the cessation of waste status of certain types of secondary solid fuels, (in Italian) (CSS), Italian Law n. 22 of 14 February 2013, Rome, Italy.

Nasrullah M., Vainikka P., Hannula J., Hurme M., Kärki J., (2014), Mass, energy and material balances of SRF production process. Part 1: SRF produced from commercial and industrial waste, *Waste Management*, **34**, 1398-1407.

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ENVIRONMENTAL BENEFITS ARISING FROM THE SUBSTITUTION OF THE ENERGY CROPS WITH BIO-WASTE AS FEEDSTOCK FOR ANAEROBIC DIGESTION: A REAL CASE STUDY*

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Abstract

Two different scenarios aimed to energy recovery from biodegradable substrates, represented by energy crops and bio-waste, via anaerobic digestion (AD) was compared in a life cycle (LCA) perspective. In the base scenario 17,1760Mg/year of energy crops were processed in an existing AD facility generating about 7,700 MWh/year whereas 23,000 Mg/year of bio-waste were processed in an existing composting facility for organic fertilizer production. In the modified scenario the bio-waste was used for replacing the energy crops as feedstock for the AD facility. In the base scenario the amount of energy recovered was of about 9.600 MWh/years whereas in the modified scenario the amount of energy recovered was of about 5.600 MWh/year. The LCA detected a general reduction of the impacts for the modified scenario. Global warming emission for single kWh recovered in the two scenarios resulted practically the same.

*Keywords: a*naerobic digestion, bio-waste, cumulative energy demand, energy crops, Life cycle assessment

1. Introduction

Aerobic and anaerobic biological processes are widely exploited for the management of bio-waste and biomasses. In general aerobic processes such as composting are of particular interest because of their robustness and ability to return stabilized materials

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exploitable as soil improvers even if energetic consumption is high (Di Maria, 2012). On the other hand, investment costs are higher for anaerobic digestion (AD) (Di Maria et al., 2012), but biodegradable substrates can be converted into two main streams: a biogas composed mainly of methane and carbon dioxide exploitable as fuel for renewable energy production; a quite stabilized soil improver for agricultural use (Martins das Neves et al., 2009). Furthermore AD is also an important process for achieving the 2020 EU objectives (Beurskens et al., 2010) on greenhouse gas (GHG) reduction and renewable energy production. Concerning renewable energy production, waste materials like manure, crop residues, sewage sludge, the organic fraction of municipal solid waste (OFMSW) and fruit and vegetable waste are of particular interest since they do not compete with food crops as substrates for AD (Apples et al., 2011). AD of different biomasses resulted already investigated (Kovacik et al., 2010; Poschl et al., 2010). Similarly for the environmental benefits of AD (Alburquerque et al., 2012; Bernstad and La Cour Jansen, 2011; Di Maria and Micale, 2015; Khoo et al., 2010; Moller and Muller, 2012; Nkoa, 2014; Sonesson et al., 2000).

2. Objectives

The present study aims to investigate the energetic and environmental consequences arising from the substitution of energy crops with bio-waste as feedstock for an existing AD facility. The study was implemented on the basis of full-scale and experimental data using also a LCA approach.

3. Outline of the work

This work is divided in three main parts:

- Analysis of the current scenario in which energy crops are processed in an existing AD for electrical energy production and the OFMSW is processed in a composting facility for recycling goals;
- Evaluation of the energetic performances and plant modifications for the replacement of energy crops with bio-waste in the existing AD facility. Evaluation of environmental aspect by the LCA;
- Analysis of results, drawing conclusion and formulation of recommendations for policy and decision makers in the sector of bio-waste management.

4. Material and methods

The comparative study was performed between two different scenarios. The first consisted in the separate treatment of OFMSW by composting and energy crops by AD. In the modified scenario the OFMSW was used for substitution of the energy crops in the AD.

In the current scenario (Fig. 1) the 23,000 Mg/year of OFMSW are processed in an existing composting facility for recycling aims by the production of an organic fertilizer. Waste generated by this process, about 6,200 Mg was incinerated with energy recovery (Di Maria and Micale, 2014). Main features concerning the composting facility are reported in Table 1.

On the other hand the AD facility, located about 50 km far from the composting one, processed about 17,000 Mg/year of energy crops (Table 2) generating about 4,000,000 m3/year of biogas and about 8,000 MWh of electricity. AD digesters are of wet type operate with TS of 9%. Both solid and liquid digestate are used as feriliazers. The modified scenario (Fig. 2) consisted in the substitution of the energy crop with the OFMSW for feeding the AD.

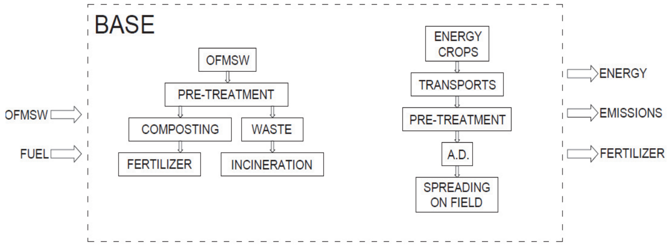

Fig. 1. System boundaries and flow chart of the base scenario

Table 1. Main features of the composting facility (2016)

Parameter	*Amount*	*Unit*
OFMSW	23,000	Mg
Waste	6,210 to incineration	Mg
Energy consumption	920	MWh
Energy from incineration of waste	300	kWh/Mg
N	14	kg/Mg compost
P2O5	6.74	kg/Mg compost
KO2	19.3	kg/Mg compost
C sink	201	kg/Mg compost

Table 2. Main features of the AD facility (2016)

Parameter	*Amount*	*Unit*
Maize	6,332	Mg
Sorghum	5,802	Mg
Triticale	3,740	Mg
Alfalfa	1,793	Mg
Fuel for crops	69	Mg
Fuel for transport on fields	82	Mg
Fuel for spreading	23	Mg
Fuel for plant manag.	14.5	Mg
Fertilizer 60% N 40% diammonium phosphate	155	Mg
Net energy	7,738	MWh
N	0.34	kg/m3 digestate
P2O5	0.05	kg/m3 digestate
KO2	0.28	kg/m3 digestate
Csink	1.46	kg/m3 digestate

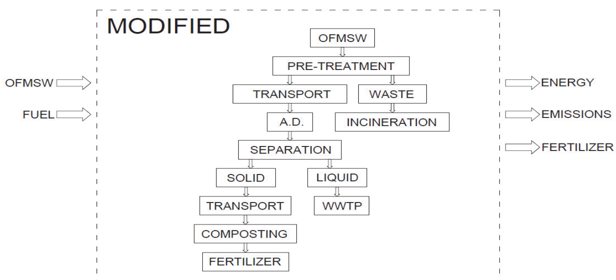

Fig. 2. System boundaries and flow chart of the modified scenario.

After adequate pre-treatment the OFMSW is transported by truck to the AD (Table 3). Also in this case the waste generated by the pre-treatment, about 6,200 Mg, is incinerated with energy recovery. The resulting digestate is firstly separated in solid and liquid fractions, then the solid fraction is transported back to the composting facility. OFMSW is diluted to 9%TS by a given amount of the liquid fraction of the digestate. The remaining amount is moved to waste water treatment plant (WWTP) 130 km far. therwise the energetic potential of the OFMSW was determined by experimental tests. OFMSW was withdrawn in different period from the existing composting facility then ground after bulky materials removal.

The bio-methane yield (BMP) (NLCH4/kgVS) was determined, on fresh OFMSW by digesting 100 ml of each substrate in 500 ml anaerobic bottles at mesophilic conditions. TS concentration was maintained ≤4% w/w by dilution with demineralized water, if necessary. For the BMP test, inoculation was carried out with 300 ml of digestate (Table 4) coming from the full-scale digester in order to maintain a VS of inoculum to VS of substrate ratio of about 2. Bio-methane was determined by adopting a volume displacement system with a solution of 2N NaOH in demineralized water for CO2 capture. From the environmental point of view the goal of the present study was to compare two different scenarios. In the first scenario 23,000 Mg of OFMSW and 17,667 Mg of energy crops were processed separately by composting and AD, respectively (Fig. 1). In the second scenario the OFMSW substituted the whole amount of energy crops in the AD facility (Fig. 2). System boundaries were expanded for taking into account multifunctionality of the systems and the life cycle inventory (LCI) framework was consequential. Backgrounds were represented by OFMSW, fuels and mineral fertilizers. Foregrounds were represented by energy, nutrients and emissions. LCI was retrieved from Ecoinvent 3.0 database (Wernet et al., 2016) and adjusted on the basis of the experimental and direct observed data. Foregrounds were not able to influence the background for which average market values were used. In accordance with (Turconi et al., 2011), natural gas was considered as marginal energy to be substituted with the one generated by AD and incineration. As impact assessment method was used ILCD midpoint (EC, 2012) (Table 5). For obtaining an impression of which of the impact categories was most affected by the scenarios considered, normalization factors of the EU 27 domestic extraction of resources and emissions per person with respect to the year 2010 were used.

Table 3. Modified scenario mean features

Parameter	***Values***	***U.M.***
OFMSW	23,000	Mg
Waste to incineration	6,210	Mg
OFMSW Pre-treat.	50	kWh/Mg
Solid digestate	0.909	Mg/Mg
Liquid digestgate to WWTP	0.091	Mg/Mg

Table 4. Inoculum and OFMSW characterization

Parameter	***Inoculum***	***OFMSW***
TS (%w/w)	3.46	26.6±0.09
VS (%w/w)	86.2	90.3±0.03
N (%TS)	-	2.88±1.13
BMP (NLCH4/kgVS)	-	523±95

5. Results and discussion

In the base scenario the amount of electrical energy recovered from AD of energy crops and from incineration of waste from OFMSW pre-treatment were 1,863 MWh and 7,738 MWh, respectively.

Table 5. Impact assessment categories

Imp.cat.	***Unit***	***Normalization***	***Unit***
GWP	kgCO2 eq.	1.10E- 04	kgCO2 eq./a.
ODP	kgCFC-11 eq.	46.3	kgCFC-11 eq./a.
PM	kgPM2.5 eq.	2.63E -01	kgPM2.5 eq./a.
POF	kgNMVOC eq.	3.15E -02	kgNMVOC eq./a.
A	molc H+ eq.	2.11E -02	molc H+ eq./a.
ET	molc N eq.	5.68E -03	molc N eq./a.
FWE	kg P eq.	6.76E -01	kg P eq./a.
RD	kg Sb eq.	9.9	kg Sb eq./a.

In the modified scenario the amount of energy recovered from the AD of OFMSW resulted of 4,109 MWh whereas the amount of energy recovered from incineration of waste from OFMSW was the same of the base scenario. From the environmental point of view the modified scenario showed lower level of impact (Fig. 3) and in some cases as for RD and ODP avoided impacts. PM resulted the impact category most affected by the base scenario mainly due to the fuels consumptions and for mineral fertilizer production. Process emissions were the main causes of the high values detected for the GWP (Fig. 3). On the other hand the amount of greenhouses emissions evaluated as GWP per unit of kWh recovered in the two scenarios (Fig. 4) showed quite similar values.

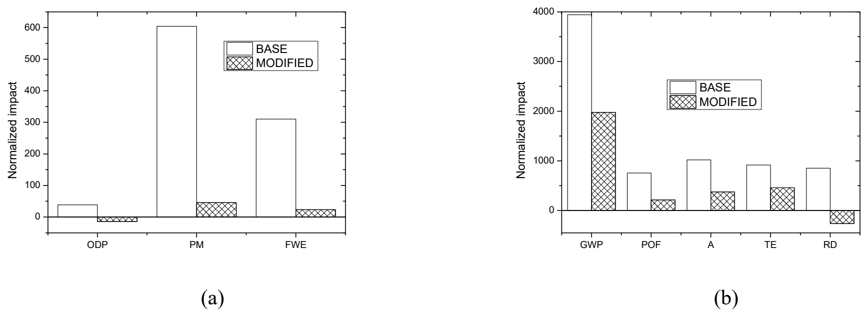

Fig. 3. Normalized impact categories for the two scenarios: (a) , (b)

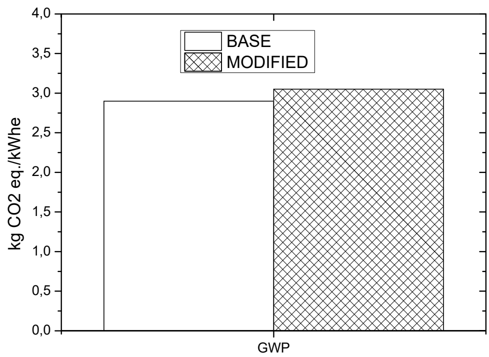

Fig. 4. GWP per kWh of energy recovered in the two scenarios

6. Concluding remarks

The study detected a general reduction of the impact when energy crops are replaced with bio-waste for energetic recovery via anaerobic digestion. For some specific impact categories as ozone and resource depletion negative values indicating the possibility of avoiding emissions were also detected. On the other hand the amount of energy recoverable resulted decreased. By the way the amount of kg CO_2eq emitted per kWh of electrical energy recovered resulted practically the same for the two scenarios. This result indicated that the replacement of energy crops with bio-waste results recommended from the environmental point of view. In any case of particular relevance resulted the quality of the bio-waste returned after collection since the presence of impurities could affect relevantly both the energetic balance and the emissions.

References

Alburquerque J.A., de la Fuente C., Ferrer- Costa A., Carrasco L., Cegarra J., Abad M., Bernal M.P., (2012), Assessment of the fertilser potential of digestate from farm and agroindustrial residues, *Biomass & Bioenergy*, **40**, 181-89.

Apples L., Lauwers J., Degreve J., Helsen L., Lievens B., Willems K., Van Impe J., Dewill R., (2011), Anaerobic digestion in global bio-energy production: Potential and research challenges, *Renewable and Sustainable Energy Reviews*, **15**, 4295-301.

Bernstad A., La Cour Jansen J., (2011), A life cycle approach to the management of household food waste – A Swedish full-scale case study, *Waste Management*, **31**, 1879-96.

Beurskens L.W.M., Hekkenberg M., Vethman P., (2010), ECN – Renewable Energy Projection as Published in the National Renewable Energy Action Plans of the European Members States, On line at: http://www.ecn.nl/docs/library/report/2010/e10069.pdf.

Di Maria F., (2012), Upgrading of a Mechanical Biological Treatment (MBT) plant with a Solid Anaerobic Digestion Batch: A Real Case Study, *Waste Management & Research*, **30**, 1089-94.

Di Maria F., Sordi A., Micale C., (2012) Energy production from mechanical biological treatment and composting plants exploiting solid anaerobic digestion batch: an Italian case study *Energy Conversion and Manag*ement, **56**, 112-20.

Di Maria F., Micale C., (2015), Life cycle analysis of incineration compared to anaerobic digestion followed by composting for managing organic waste: The influence of system components for an Italian district, *The International Journal of LCA*, **20**, 377-88.

EC, (2012), European Commission., Characterization factors of the ILCD Recommended Life Cycle Impact Assessment methods, Database and Supporting Information, On line at: http://eplca.jrc.ec.europa.eu/uploads/LCIA-characterization-factors-of-the-ILCD.pdf.

Khoo H.H., Lim T.Z., Tan R.B.H., (2010), Food waste conversion options in Singapore: Environmental impacts based on an LCA perspective, *Science of the Total Environment,* **408**, 1367-73.

Kovacik B., Topaloglu B., (2010), Biogas production from co-digestion of a mixture of cheese whey and dairy manure, *Biomass & Bioenergy* **34**, 321-29.

Martins das Neves L.C., Concert A., Vessoni Penna T.C., (2009), Biogas production: new trends for alternative energy sources in rural and urban zones, *Chemical Engineering and Technology*, **32**, 1147-53.

Moller K., Muller T., (2012), Effects of anaerobic digestion on digestate nutrient availability and crop growth. A review, *Engineering in Life Science*, **12**, 242-57.

Nkoa R., (2014), Agricultural benefits and environmental risks of soil fertilization with anaerobic digestate: a review, *Agronomy for Sustainable Development*, **34**, 473-492.

Poschl M., Ward S., Owende P., (2010), valuation of energy efficiency of various biogas production and utilization pathways, *Applied Energy*, **87**, 3305-21.

Sonesson U., Bjorklund A., Carlsson M., Dalemo M., (2000), Environmental and economic analysis of management system for biodegradable waste, *Resource Conservation and Recycling*, **28**, 29-53.

Turconi R., Butera S., Boldrin A., Grosso M., Rigamonti L., Astrup T., (2011), Life cycle assessment of waste incinerations in Denmark and Italy using two LCA models, *Waste Management & Research*, **29**,78-90.

Wernet G., Bauer C., Steubing B., Reinhard J., Moreno-Ruiz E., Weidema, B., (2016), The ecoinvent database version 3 (part I): overview and methodology, *The International Journal of Life Cycle Assessment*, **21**, 1218–1230.

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THE CONTRIBUTION OF HUMAN LABOUR ON THE WHOLE IMPACT OF WASTE COLLECTION: A REAL CASE STUDY*

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Abstract

This study is focused on the analysis and evaluation of environmental impacts generated by human labour due to the collection of waste. This was performed by analyzing the relevant data for an existing waste management company operating in central Italy. The personnel involved in the waste collection consist of 103 working force whereas the amount of waste collected on yearly base resulted of about 43,000 Mg. All the main materials, equipment and energy used by the workers for the execute of their job were accounted including private transports. Specific life cycle inventories were also developed. Main results indicate that the major contribution to the impact was generated by the production of the personal protection equipment (PPE) and by the private transports. Disposal of PPE and wastewater from clothes washing resulted relevant only for resource depletion and fresh water eutrophication whereas the impact due to PPE washing was practically negligible.

Keywords: environmental impact, human labour, LCA, waste collection

1. Introduction

One of the most debated and controversial aspect concerning the life cycle analysis (LCA) and consequently the impact on the environmental of product and service is represented by the contribution arising from the human labour (Xu et al., 2009). Generally human labour represents and impact embodied in manufacture and services an industry that

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is usually neglected in performing LCA. On the other hand, according to most recent literature the omission of labour effects may constitute a bias affecting the results of the studies and leading to possible incomplete information for decision making.

Some previous studies were already performed concerning the assessment of human labour for different sectors and with different approaches. Xu et al., (2009) assessed the embodied impact for the manufacturing and labour input for the China-US trade. Fukuda (2003) quantified the production of exergy from labour. Costanza (1980) adopted an input-output analysis to calculate both the direct and indirect energy required to produce good and service in the US. Kamp et al. (2016) analyzed the potential of human labour by an Emergy approach whereas Rocco (2016) proposed a novel input-output approach for accounting human labour in LCA.

All these studies are mainly focused on industrial activities associated to the production of goods but there is a lack of knowledge for specific sectors as the waste collection. Most investigated aspects due to waste collection still remain focused on to the materials and energy consumed for the specific collection activities due to trucks and bins (Di Maria and Micale, 2013; Di Maria et al., 2016). No specific study resulted now available on the impact of the work force involved in the collection activities.

2. Objectives

The main objective of this study is to quantify the embodied impact associate to the human labour for an existing waste collection company operating in central Italy. The results of the LCA were referred to the single tonne of waste collected in the considered area. The result of this study will be of particular interest for assessing the incidence of embodied impact in the waste collection sector.

3. Outline of the work

This work is divided in three main parts:

- Analysis of materials and energy flows directly associated to the working force for the execution of their job;
- Development of specific inventories;
- Assessment of the related impact;
- analysis of results.

4. Materials and methods

The LCA study was performed using SimPro software and inventories of processes of the Ecoinvent database. The impact categories considered were chosen among those of the Midpoint assessment method of the ILCD 2001+ (EC, 2012) (Table 1).

Table 1. Impact assessment categories

Imp.cat.	***Unit***
GWP	kgCO2 eq.
ODP	kgCFC-11 eq.
PM	kgPM2.5 eq.
POF	kgNMVOC eq.
A	molc H+ eq.
ET	molc N eq.
FWE	kg P eq.
RD	kg Sb eq.

The personnel involved in the waste collection was of 103 unit, whereas the amount of waste collected in the considered area was of about 43,000 Mg/year. The share of waste separated at source was of about 55% and the population served was of about 80,000 inhabitants.

The number, the weight and the composition of the personnel protection equipment (PPE) used by workers during collection activities was duly analyzed (Table 2). An average of 3,500 washing cycles per year, performed by washing machines, was detected. Each average washing cycle consisted of about 2.5 kg of PPE. Another important aspect considered in the present study was the use of private transports, expressed as km/year, used by workers for driving from their own homes to the working place. Also the euro class of the vehicles was assessed (Table 3).

Table 2. Compositions of Protective Personal Equipment (PPE)

PPE	***(g)***	***Component (%)***				
		A	B	C	D	E
Shoes		20% leather	10% polyest	40% polyur	22% alum	8% silicon
Summer						
T-shirt	287	100% cotton				
Polo	376	100% cotton				
Short-sleeve shirt	259	100% cotton				
Sweatshirt	810	50% cotton	50% polyest			
Light Trousers	913	100% cotton				
Trousers	626	60% cotton	40% polyest			
Jacket	691	60% cotton	40% polyest			
Vest	140	100% polyest				
Cap	73	100% cotton				
Winter						
Pullover	1755	50% Wool	50% acrylic			
Jersey	972	100% cotton				
Long-sleeve Shirt	421	100% cotton				
Blouson	972	100% polyest				
Trousers	1008	60% cotton	40% polyest			
Jacket	691	60% cotton	40% polyest			
Windbreaker	904	100% polyest				
Scarf	65	100% polyest				
Cap	78	100% polyest				
Gloves	150	40% cotton	60% polyur			

Table 3. Euro Class for the vehicles used for private transport and relative distance travelled per day.

Euro Class	***Distance range covered by car***				
	0-5 (km)	6-20(km)	21-40 (km)	41-50 (km)	>50 (km)
3	6	13	11	2	
4	8	11	17		2
5	2	8	15	4	4

It is important to highlight that practically nobodies makes use of public transports. At the end of the lifetime PPE were assumed to be disposed by incineration whereas the wastewater from washing machine was processed in wastewater treatment plant (WWTP) before being discharged.

Backgrounds of the system were represented by PPE, private transports and clothes washing, foregrounds were represented by emissions (Fig. 1). Hence system resulted not in expansion and the life cycle inventory framework resulted attributional.

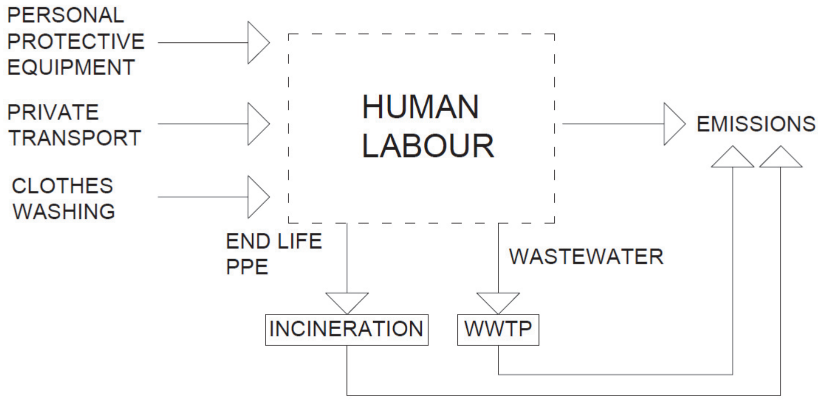

Fig. 1. System boundaries

5. Results and discussion

Characterization analysis highlights that in general emissions from private transports and from PPE production were the ones affecting to a relevant measure the values of the impact categories. The contribution of clothes washing resulted in general negligible whereas the emissions due to incineration of end life PPE and of WWTP of wastewater from washing machine resulted relevant in particular for FWE and RD. The comparison of these impact with those reported by other authors concerning the waste collection and treatment highlighted some interesting aspect in particular for the global warming potential. Di Maria and Micale (2013) detected global warming emissions due to fuel consumption for waste collection ranging from 10 up to 25 kgCO2 per each Mg of waste collected. Comparing these figures with the ones reported in Fig. 2 indicates that embodied emissions due to human labour can represent up to 30% of the whole GWP due to waste collection. Similar figures were also reported by Tanskanen and Kaila (2001) for the municipality of Helsinky and Sonesson (2000) for the municipality of Uppsala in Sweden. Referring to a single Mg of municipal solid waste landfilled Di Maria et al. (2013) reported a GWP ranging from about 100 kgCO_{2eq} up to 700 kgCO_{2eq}. This indicates that the human labour for waste collection may represent up to about 8% of the GWP associated to landfilling of waste.

At the level of implementation of the present study these figures resulted somewhat under estimated. In fact other components strictly associated to the activities of the workers can increase the embodied energy and materials consumption together with the related emissions. An example of these further aspects is represented by the consumption of energy, water and material for: showers, toilette, heating, lights and similar activities associated to the workers locker rooms; canteens and relax rooms; other administrative working forces.

Furthermore the above mentioned components implies also disposal of the resulting waste increasing consequently the associated impacts.

All these aspects will be investigated in future works.

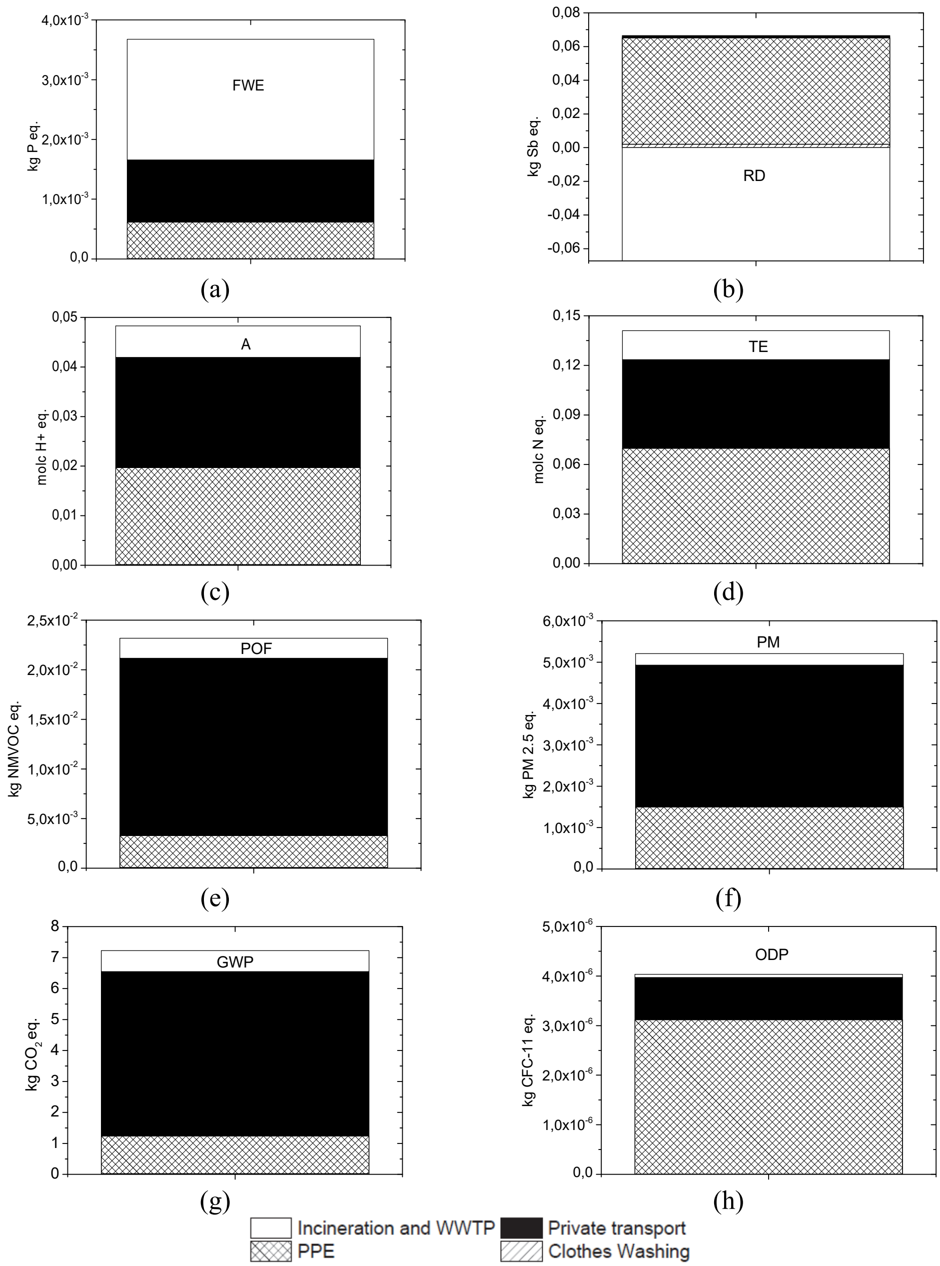

Fig. 2. Characterization of the impact categories and relative contribution of the main activities per Mg of waste collected

6. Concluding remarks

The results of the present study confirmed that the omission of the human labour in the life cycle assessment can represent a relevant bias. In particular the comparison of the emissions associated to the human labour fo the working forces for the execution of waste collection to those associated to vehicles and means used for waste collection showed that the former can represent up to 30% of the whole greenhouse emissions. Similar results were also detected in the comparison with waste treatment and disposal. In particular emissions associated to human labour for waste collection can represent up to 8% of the ones associated to the landfilling of waste.

On the basis of these finding the following recommendation can be drawn:

- Investigation of the embodied impact resulted necessary for having representative results in the life cycle assessment of waste management;
- Huma labour in waste collection result a key factor worthy to be investigated for reducing the whole impact of the waste management sector.

Future study concerning the aspect investigated in the present work will be focused on the evaluation of other embodied energetic and material consumptions associated to the human labour as the ones due to working force lockers rooms, canteens and relax area.

References

Costanza R., (1980), Embodied energy and economic valuation, *Science*, **210**, 1219-1223.

Di Maria F., Sordi A., Micale C., (2013), Experimental and life cycle assessment analysis of gas emission from mechanically–biologically pretreated waste in a landfill with energy, *Waste Management*,**33**, 2557-2567.

Di Maria F., Micale C., (2013), Impact of source segregation intensity of solid waste on fuel consumption and collection costs, *Waste Management*, 33, 2170-2176.

Di Maria F., Micale C., Morettini M., (2016), Impact of pre-collection of pre-collection phase at different intensities of source segregation of bio-waste: An Italian case study, *Waste Management*, **53**, 12-21.

EC, (2012), European Commission, Characterization factors of the ILCD Recommended Life Cycle Impact Assessment methods, Database and Supporting Information, First edition, Joint Research Centre, Institute for Environment and Sustainability, Publications Office of the European Union, Luxembourg.

Fukuda K., (2003), Production of exergy from labour and energy from resource, *Applied Energy*, 76, 435-448.

Rocco M.V., (2016), *Accounting for Human Labour in LCA: a Novel Input-Output Approach*, Proc. Of X Convegno Rete Italiana LCA, June23th-24th, Ravenna, Italy.

Sonesson U., (2000), Modelling of waste collection – a general approach to calculate fuel consumption and time, *Waste Management & Research*, **18**, 115–123.

Tanskanen J.H., Kaila J., (2001), Comparison of methods used in the collection of source-separated household waste, *Waste Management & Research*, **19**, 486–497.

Xu M., Williams E., Allenby B., (2009), Assessing environmental impacts embodied in manufacturing and labour input for the China-Us trade, *Environmental Science Technology*, **44**, 567-573.

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A TECHNICAL AND ECONOMIC ANALYSIS OF METHOD OF RECYCLING WASTE BY SICILIAN COMPANIES RECYCLE*

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Abstract

Industrial symbiosis, as part of the emerging field of industrial ecology, demands particular attention to the flow of materials and energy through local and regional economies. Industrial symbiosis engages traditionally separate industries in a collective approach to a competitive advantage involving the physical exchange of materials, energy, water, and/or by-products. The expression "symbiosis" builds on the notion of biological symbiotic relationships in nature, where at least two otherwise unrelated entities exchange materials, energy, or information in a mutually beneficial manner-the specific type of symbiosis known as mutualism. The development of the Circular Economy would be a more efficient solution for the improvement productivity of resource if it shifted its focus from recycling waste to adjusting industrial structure, developing new technology, and reforming industrial policy.
This paper aims to analyze the reuse of special waste, derived from the Sicilian citrus fruit production, in the livestock sector.
The study deals the possibility to create a network industrial symbiosis through the establishment of a consortium of manufacturing companies belonging to the Sicilian citrus fruit production chain.
The subject of the study will be the company Coa s.r.l., whose production process generates special waste. The objective is to evaluate the existence and extent of any mutual benefit between the investigated company and livestock enterprises. A local processing company will also be involved in order to transform citrus fruit waste into a by-product and reuse it as animal feed.

Keywords: Agro-filter, Circular Economy, Industrial Symbiosis, Livestock Industry, Special Waste.

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1. Introduction

Industrial symbiosis is defined as "engaging traditionally separate industries in a collective approach to competitive advantage involving physical exchange of materials, energy, water, and/or by-products" (Ohnishia et al., 2017; Tamburino and Zema, 2009). This approach allows economic, environmental and social advantages to be achieved for the firms involved and for the entire community (Kim et al., 2017). Industrial symbiosis regards the relationship between two organisms which can be considered as a form of "biological barter": one organism obtains at least one resource from the other organism in return for at least one service provided. Such an exchange allows both the organisms benefit from symbiotic relationship because of their performance improvements (Fraccascia et al., 2017). Industrial symbiosis has been proposed as a strategy to encourage industrial eco-innovation to decouple economic growth from resource consumption (Tseng and Bui, 2017). In industrial ecosystems efficiency and optimization of resources energy, waste minimization enhancement of the products represents an important strategy in a perspective of circular economy, as part of the industrial symbiosis (Cellura and Cusenza, 2014). One of the most important challenges that the circular economy has to face, which the European Union has also underlined, is the necessity of designing indicators those asses the level of efficiency in terms of reduction, reutilization, and recycling of waste generated in the linear economy model (Molina-Moreno et al., 2017). In Italy, a new law was introduced about the waste that comes from the citrus fruit production chain; it is not special waste but a food by-product (Legge 9 agosto, 2013). The agricultural sector plays a key role both in the production of food and feed, as well as in that of renewable energy (Cerruto et al., 2016). From a recent study, it emerged that citrus fruits are consumed by humans principally as fresh fruit or processed juice. The residues that remain after the juice is extracted from the fruit comprise peel, pulp and seeds (Todaroa et al., 2017). These components, either individually or in various combinations, are the source materials from which citrus by-product feedstuffs are produced. Such products are suitable energy sources for ruminant feed in many areas of the world because ruminants are able to ferment highly fibrous feeds in the rumen (Bampidis and Robinson, 2006).

An important benefit of citrus by-product feedstuffs is its relatively low cost. Reduction of feed costs, while maintaining high productivity, is a primary strategy to achieve economic efficiency in ruminant production (Bampidis and Robinson, 2006). Fresh citrus pulp can meet some of the water requirements of ruminants, which can be important in areas characterised by hot, dry summers (Paya et al., 2015). Therefore, the resources are widely used as raw material for the livestock industry. In the past waste management was only dealt with in a waste disposal perspective, the objective pursued today is to try to reduce its quantity through recovery and recycling operations that enable it to be valued (Tamburino and Zema, 2009). The purpose is to encourage research and development projects in the agricultural sector of the Eastern-Sicily production areas, to sustainable reuse of waste from industrial processing of citrus fruits. In Italy, the Law 98/ 2013, this contains some novelties about waste, in particular regarding "citrus pulp" as defined as the residue of the citrus processing process in order to allow its agricultural and zootechnical use as a by-product. Italian legislation makes a distinction between refuse and by-product. The former is defined as any substance or object which the firm has to discard the latter as any substance or object generated by the production process, and whose primary purpose is not the production of that substance or object but that the firm can use them in a new production process. There are many uses of citrus pulp, for example as feedstuffs, fertilizers or as the basis for compost production for agronomic purposes and fuel for extracting bioethanol or biogas.

This paper will study the possibility of creating an industrial symbiosis network through the establishment of a consortium of manufacturing companies belonging to the Sicilian citrus fruit production chain.

The actors involved will be the citrus waste processing companies, which need to create trade agreements that allow producers to exploit the production waste, and transformation companies to employ these resources in another production process that mainly focuses on juice production.

Moreover, the ultimate aim will be to use the waste which has become citrus pulp to produce animal feed, thanks to an innovative processing plant. The benefits that an integrated, complex supply chain will have on the citrus and livestock chain will be analyzed.

2. Material and methods

The economic valorisation of citrus pulp resulting from the citrus processing process minimizes waste through the use of special waste disposal and extraction techniques for chemical compounds. Citrus pulp in fact is rich in acids, vitamins, water and other biologically valid substances such as flavonoids, enzymes and minerals, and in recent years it has been studied and analyzed. In order to use this resource, it is necessary to develop a new technological process that enables the production of a syrup by fermentation with special enzymes that allow the industrial production of feed for livestock industry.

The Association of Sicilian Municipalities in accordance with the Local Development Systems and thanks to the intervention of the Local Healthcare Company of the territory of Palagonia (Catania) has introduced the pilot project Scale-Up, which is responsible for implementing processes of innovation for the agri-food and zootechnical chains. It aims at stimulating eco-sustainable and eco-efficient productive poles (PSR Sicilia, 2014).

The objectives of the project are:

- The definition of new EU-participative organizational models allowing for the recovery and optimization of the reuse of biomass waste production and the competitiveness of the regional production system;
- The realization of processes of transformation of biomass waste to demonstrate that citrus pulp production through process and product innovation can become a high added value resource for all the involved industries: citrus production, processing industries, types of livestock production and services connected;
- Obtaining certified applications for resources from the livestock chain in order to get quality certified meat products by means of the involvement of several Sicilian Pilot Farms, which, by monitoring the use of citrus pulp, will be able to demonstrate the healthy characteristics of the meat produced as being antibiotic-free. Therefore, this would be a worldwide innovation.

The project has four phases (Fig. 1):

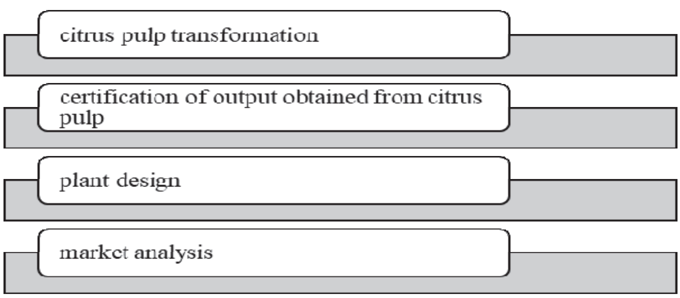

Fig. 1. Pilot project operational phases

The Pilot Project is used to implement industrial and product innovations at the industrial level, which enhance the agro-zootechnical regional production chain that is experiencing a deep crisis today.

3. Experimental case: Coa s.r.l.

The process of exploiting Sicilian citrus fruit resources is the starting point for the management of the production waste that comes from the Coa s.r.l citrus company, located in Scordia (Catania), which has produced high quality citrus fruit for 30 years in its citrus groves located in Sicily. From an analysis conducted on the Coa machining cycle s.r.l. it emerges that the selection phase the product is divided into 2 categories: marketable and non-marketable. The latter includes all production waste or the non-marketable products which have defects due to the shape, mechanical spatter and cochineal traces. It is estimated that such waste is equal to 10-15% of annual output. They represent the raw material that the company sells to specific processing companies. The latter will generate additional output as described in the Fig. 2.

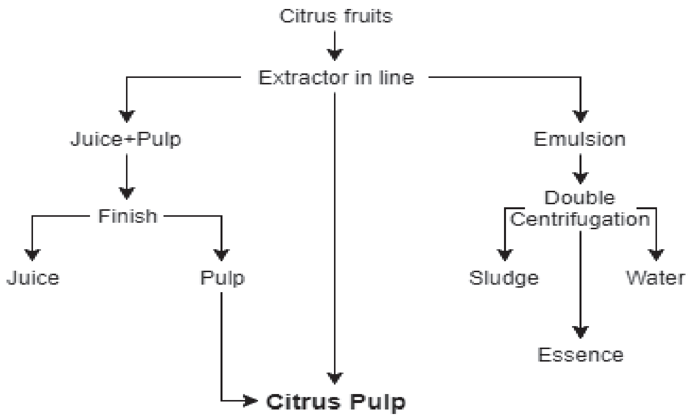

Fig. 2. Juice extract, essence and extraction pattern of citrus pulp

What emerges is the process of exploiting the production waste of Coa s.r.l., which the processing company obtains the following outputs from: juice, essence and a further waste of production.

Citrus pulp will be further exploited thanks to the consortium's participation. The consortium will manage this process through the implementation of the citrus pulp plant, where additional output will be allocated to the animal husbandry sector. The implementation will take place following the operational phases described in the Scale-up project.

The Fig. 3 shows the generic industrial symbiosis network by integrating all the companies involved.

In particular, the consortium will take care of the agro-processing phase of the citrus pulp, through special techniques for disposal and extraction of chemical compounds. The consortium aims to achieve a processing plant capable of transforming 1,000 tonnes per day of citrus pulp. The supply will be guaranteed thanks to the participation of all the producers belonging to the consortium. The products that will be obtained are:

- 244.4 Tons / day of dry fibrous substance;
- 107.9 Tons / day of syrup concentrated to 70% dry matter.

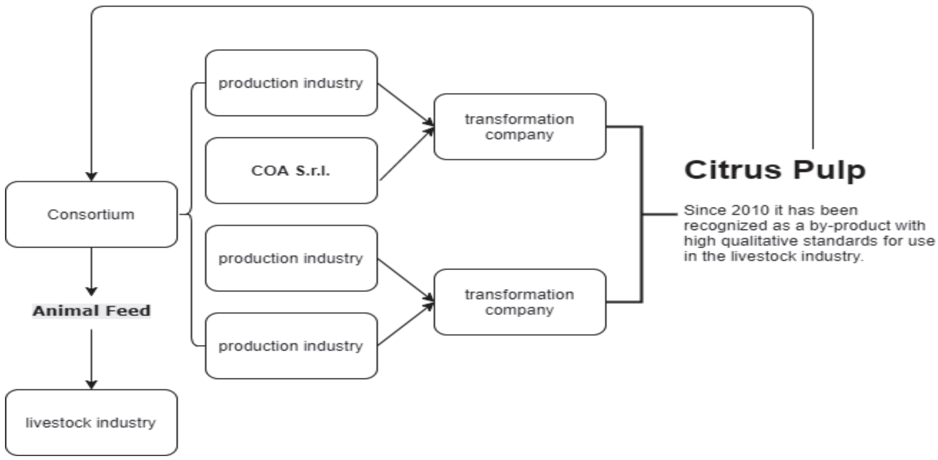

Fig. 3. Example of Industrial Symbiosis involving the citrus, zootechnical and processing industries

The system involves the use of storage tanks for both citrus pulp and concentrated syrup. Shipment to customers, mainly zootechnical industries, can be carried out by tanker trucks that will be pumped directly from storage tanks or in 2000 or 1000 boxes. The fibrous portion will be stored in silos or directly packaged once dried and transported by tankers or articulated lorries. Fig. 4 shows the steps of the transformation process described:

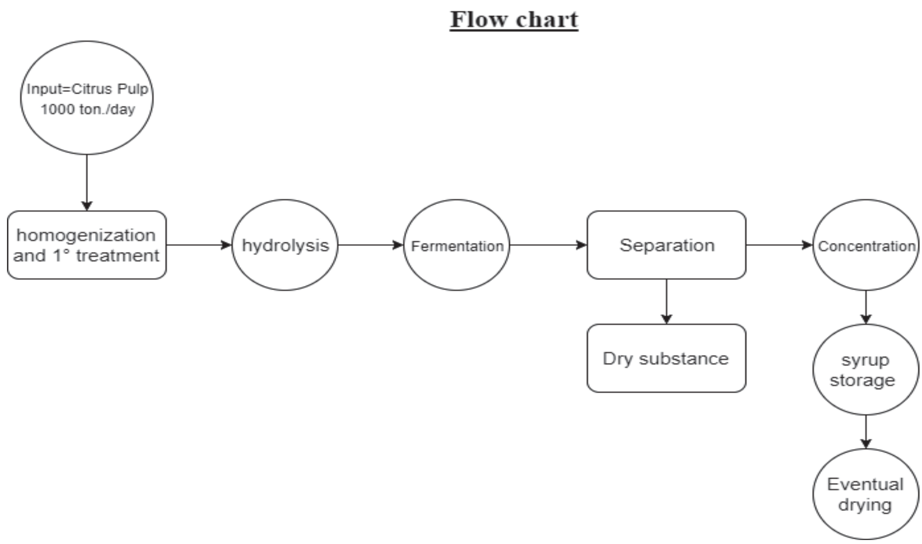

Fig. 4. Flow diagram for citrus pulp selection

The substances obtained will mainly contain Vitamin B12, folic acid, lactic acid, and ammonium lactate and can be used in the food, pharmaceutical, and zootechnical industries.

For the implementation of the Pilot Project, investment costs were divided into: pilot actions for the transformation, which include all the necessary activities for the processing of citrus pulp in raw material; support actions for the start-up of the industrial process, which include costs related to industrial process design and chain agreements; application actions in the zootechnical chain, which include the costs of integrating finished products into different feeding diets, product certifications and pilotage. Table 1 summarizes the investment actions required:

Table 1. Total investment pilot project

Pilot actions for the transformation Support actions for the start-up of the industrial process Application actions in the zootechnical chain	€174.000.00 €134.000.00 €118.000.00
Total investment pilot project "scale-up"	**€426.000.00**

4. Results and discussion

This Project would result in economic, social, environmental development and health improvement, in particular:

- Economic: the aim is to defend and increase the level of citrus pulp's competitiveness, exploiting it more by its further uses for the production of other by-products. This allows the conversion from costs to revenues for the involved chains.
- Social: for employment growth in the area and promotion of responsible work. The citrus pulp from waste to disposal will become value for the whole community.
- Environmental: whole tons of production waste destined for disposal will become second raw material for processing companies. There will be a dual benefit to the environment, the waste will become the second raw material and the citrus pulp will be further promoted by becoming healthy food for the environment.
- Health: there will be an improvement in the quality of feed for animals as the citrus pulp waste will become a natural bacterial integrator and inhibitor.

Moreover, the collaboration between the production and processing companies will allow the former to sell the production waste at an estimated market price of 0.22 cents per kg instead of 0.10 cents per kg. The price difference, 0.12 cents per kg, will include the disposal costs that the processing company has to deal with for the disposal of citrus pulp, which will be handed over to the consortium to be exploited through the production of animal feed. The profits will be distributed among the associates.

The project will also monitor feeding systems on zootechnical chains with the aim of certifying the nutritional value of feed derived from citrus pulp.

6. Concluding remarks

Industrial symbiosis has been proposed as a strategy to encourage industrial eco-innovation to decouple economic growth from resource consumption. In this paper a typical example of an industrial symbiosis network was studied through the implementation of pilot project. The aim is the exploiting of citrus wastes, called citrus pulp, that remain after the juice is extracted from the fruit. The citrus pulp, after a transformation process, can be used as a by-product for the livestock industry. The actor involved will obtain economic, environmental, social and health benefits, in fact the citrus pulp will become value added for the whole community.

References

Bampidis V.A., Robinson P.H., (2006), Citrus by-products as ruminant feeds: A review, *Animal Feed Science Technology*, **128**, 175–217.

Bampidis V.A., Robinson, P.H., (2006), Citrus by-products as ruminant feeds: A review, *Animal Feed Science Technology*, **128**, 175–217.

Cellura M., Cusenza M. A., (2014), *Industrial Symbiosis for Increasing the Efficiency in the Use of Materials and Energy*, Proc. of Conferences promoted by ENEA at Ecomondo, 14-15.

Cerruto E., Selvaggi R., Papa R., (2016), Potential Biogas Production from by-products of citrus industry in Sicily, *in PEEC Quality – Access to Success*, Bucharest, 251.

Fraccascia L., Albino V., Garavelli C.A., (2017), Technical efficiency measures of industrial symbiosis networks using enterprise input-output analysis, *International Journal Production Economics*, **183**, 273-274.

Kim H. W., Ohnishi S., Fujii M., Fujita T., Park H. S., (2017), Evaluation and allocation of greenhouse gas reductions in industrial symbiosis, *Journal of Industrial Ecology*, **01**, 1-2

Legge 9 agosto, (2013), Legge 9 agosto 2013, n. 98, in conversione del Decreto Legge n. 69/2013, in vigore dal 21 agosto 2013, in tema di rifiuti, in particolare, in materia di "pastazzo" quale residuo del processo di trasformazione degli agrumi, al fine di consentirne l'utilizzo agricolo e zootecnico quale sottoprodotto, On line at: https://www.cliclavoro.gov.it/Normative/Legge_9_agosto_2013_n.98.pdf

Molina-Moreno V., Leyva-Díaz J. C., Llorens-Montes F. J, Cortés-García F. J., (2017), Design of Indicators of Circular Economy as Instruments for the Evaluation of Sustainability and Efficiency in Wastewater from Pig Farming Industry, *Water*, 2-3.

Ohnishia S., Dongb H., Gengb Y., Fujiic M., Fujitac T., (2017), A comprehensive evaluation on industrial & urban symbiosis by combining MFA, carbon footprint and emergy methods Case of Kawasaki, Japan, *Ecological Indicators*, **73**, 514-515.

Paya H., Taghizadeh A., Lashkari S., (2015), Effects of Lactobacillus plantarum and hydrolytic enzymes on fermentation and ruminal degradability of orange pulp silage, *Journal of Biotechnology*, **4**, 349-357.

PSR SICILIA, (2014), Allegato B1 – Asse 4 "Attuazione dell'approccio leader", Misura 421 "Cooperazione inteterritoriale, interregionale, transnazionale, (25-28), in Bando per la selezione di progetti di cooperazione, PSR SICILIA , On line at: http://www.psrsicilia.it/Allegati/Bandi/Misura421/Mis.%20421%20-%20Bando.pdf

Tamburino V., Zema D.A., (2009), I sottoprodotti dell'industria di trasformazione: il pastazzo di agrumi, in Citrus, Trattato di agrumicoltura, coordinato da VACANTE V., CALABRESE F., Edagricole, Milano, 459-460.

Todaro M., Alabiso M., Scatassa M.L., Di Grigoli A., Mazza F., Maniaci G., Bonanno A., (2017), Effect of the inclusion of fresh lemon pulp in the diet of lactating ewes on the properties of milk and cheese, *Animal Feed Science and Technology*, **225**, 231-223.

Tseng M.-L., Bui T.-D., (2017), Identifying eco-innovation in industrial symbiosis under linguistic preferences: A novel hierarchical approach, *Journal of Cleaner Production*, **140**, 1376-1377.

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21th International Trade Fair of Material & Energy Recovery and Sustainable Development, ECOMONDO, 7th-10th November, 2017, Rimini, Italy

AN INNOVATIVE APPROACH FOR BIOGAS UPGRADING TO BIOMETHANE*

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Abstract

Currently, in the biogas upgrading field, many technologies are on the market, making use of different principles/unit operations. No one has proven to be definitely better than others, and all the technologies have some pros and cons.
The aim of this study is to test the chemical washing with Hot Potassium Carbonate for the biogas upgrading. Indeed, although Hot Potassium Carbonate washing is extensively used worldwide for the CO_2 Removal, no biogas upgrading plant with this technology has been proposed till now.
In this study the summary data of a biogas upgrading demonstration plant (based on Hot Potassium Carbonate technology) collected in one year of continuous operation are reported.

Keywords: biomethane, BAT, CO_2 removal, hot potassium carbonate, biogas upgrading

1. Introduction

The steps of biogas (BG) upgrading are essentially two: biogas pretreatment and CO_2 removal. For the first step, the selected technology for the pollutant (mainly, H_2S, VOC and siloxane) removal depends essentially on their concentration in the raw biogas (Cozma et al., 2013, 2015; Sun et al., 2015). For the second step there are several methods for CO_2 removal based on these unit operations: (1) absorption (A-physical scrubbing; B-chemical scrubbing), (2) adsorption (Pressure swing adsorption, PSA), (3) permeation (membranes), (4) cryogenic (Miltner et al., 2016). While the Hot Potassium Carbonate (HPC) technology (1-B group) is one of the most utilized in the world for CO_2 removal (Hydrocarbon Processing, 2004; Milidovich and Zbacnik, 2013), and the Hot Potassium Carbonate (HPC) is considered a

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Best Available Technology (BAT, 2014), no biogas upgrading plant with this technology has been proposed till now.

2. Objectives

In this study the data of a biogas upgrading demonstration plant (based on HPC technology) are reported. The main objective is to test the Hot Potassium Carbonate technology (well known in the industrial field among CO_2 Removal processes) to the biogas upgrading field, and verify the effectiveness of its application.

3. Technology description

The upgrading plant has been installed by a Multiutility company in northern Italy. The plant is fed with a side stream of Biogas coming from AD of OFMSW. The plant has been equipped with redundant instrumentation (three different methods for gas analysis) and full PLC automated control in order to have evidence of all operating data, and enable the plant control by remote control station (laptop and/or mobile).

The pretreatment unit is equipped with a scrubber for selective H_2S Removal and two carbon filter in series to complete H_2S and other organic contaminants Removal. After a compression step, the CO_2 Removal Unit is based on the HPC Giammarco-Vetrocoke (GV) process adapted to the biogas upgrading (Fig. 1).

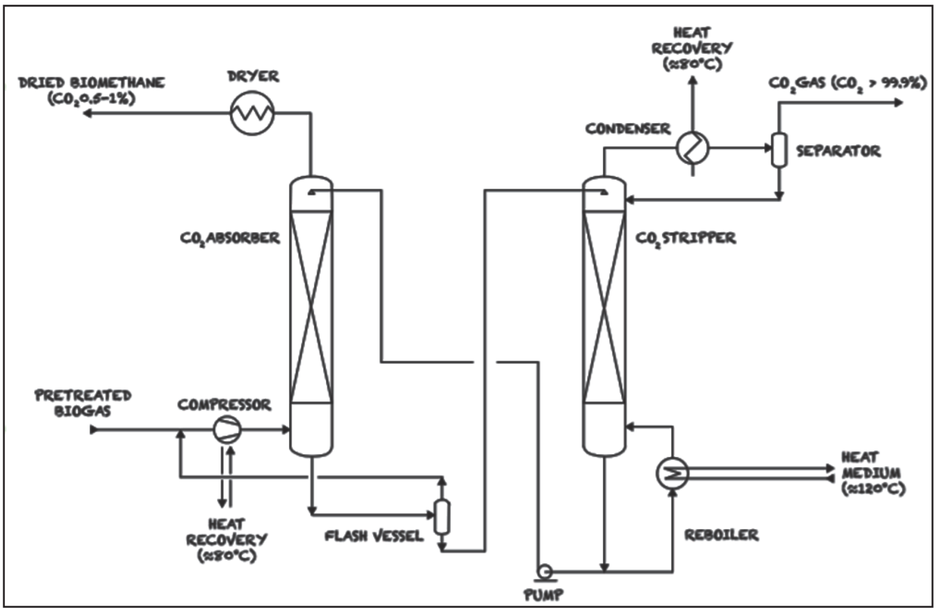

Fig. 1. Giammarco-Vetrocoke (GV) Process Flowsheet for biogas upgrading

The process exploits the reaction (1) in liquid phase:

$$K_2CO_3 + CO_2 + H_2O \Leftrightarrow 2KHCO_3 \quad (1)$$

The reaction takes place from left to right in the CO_2 absorber, and in the opposite direction by heating the solution in the CO_2 stripper, where the CO_2 is released from the top and K_2CO_3 solution collected in the bottom and totally recycled to the CO_2 absorber (Kohl and Nielsen, 1997). Giammarco-Vetrocoke process for CO_2 removal has been recently applied also in design of demonstration plants for SNG production by biomass gasification (Tomasi, 1992, 2016).

4. Tests

Several tests have been conducted in the plant during about 1 year of operation:

Pretreatment efficiency

Assessment of the removal efficiency of all the pollutant compounds contained in the biogas (other than CH_4, CO_2, N_2 and O_2) by the analysis upstream/downstream the Pretreatment section.

Yield in Biomethane (methane losses)

Assessment of the Biomethane recovered at the battery limits with respect to the CH_4 contained in the BG.

Content of CO_2 in Biomethane

Assessment of the residual CO_2 in Biomethane and compliance with the law limits for grid injection.

Off-gas (CO_2 stream) Purity

Assessment of the residual CH_4 in the off-gas and compliance with the local limits for emission/venting of greenhouse gas.

Energy performance and thermal output

Assessment of electric and thermal duties required by the process. Identification of the improvement to be applied in order to minimize the operating cost, based on the availability and price of local resources.

Assessment of the thermal output (in form of hot water at 70-80°C) that the upgrading plant can return to the site for digester heating or other heat consuming activities within or outside the facility (district heating).

5. Results

Typical ranges of the values obtained from the tests are reported in Table 1.

Table 1. Summary of Test Results

Tested Value	*Measured range*
Biomethane Yield	>99.95%
CO_2 in Biomethane	0.5-1.2%
CH_4 in off-gas	0.05-0.10%
Electric Consumption	0.19-0.21 kWh/Nm^3 BG
Thermal Consumption	0.4-0.5 kWh/Nm^3 BG
Heat Recovery	0.34-0.43 kWh/Nm^3 BG

The plant performance confirmed the design values with satisfying and reproducible results over the time.

In order to get the tested data confirmed by an independent laboratory, two sampling campaign were conducted by CNR (CNR IIA - National Research Council of Italy, Institute of Atmospheric Pollution Research). In those campaigns all the gaseous streams (biogas, biomethane and off-gas) have been analyzed in compliance with UNI TR 11537-2016 and EN 16732 confirming the values measured by the analyzers equipped in the upgrading plant.
CNR concluded that the tested technology with such a low methane loss in the off-gas would be desirable not only for its economic advantages, but also for the environmental impact (Petracchini et al., 2017).

As typically happens in biological processes, during our tests the raw biogas from the biological AD of OFMSW had a CO_2 content ranging from 32 to over 40%. Since the plant energy consumption is mainly related to the quantity of CO_2 to be removed, a fully automated system with feedforward-feedback philosophy is under implementation in order to enable the plant to self-adjust to the best efficiency point for any input condition.

6. Conclusions

The tested technology has been proven to be robust, efficient, and reliable, with minimum power consumption and excellent environmental performance. CNR validated the results by a sampling campaign of all the gaseous streams.

The results place the selected process at the highest levels in the field of Biogas Upgrading. The plant is continuously running and whoever wants to verify its performance may please contact the author.

References

BAT, (2014), Large Volume Organic Chemical Industry, Best Available Techniques (BAT) Reference Document, Joint Research Center, Institute for Prospective Technological Studies, Sustainable Production and Consumption Unit, European IPPC Bureau, On line at: http://eippcb.jrc.ec.europa.eu/reference/BREF/LVOC042014.pdf

Cozma P., Wukovits W., Mămăligă I., Friedl A., Gavrilescu M., (2013), Analysis and modelling of the solubility of biogas components in water for physical absorption processes, *Environmental Engineering and Management Journal*, **12**, 147-162.

Cozma P., Wukovits W., Mămăligă I., Friedl A., Gavrilescu M., (2015), Modeling and simulation of high pressure water scrubbing technology applied for biogas upgrading, *Clean Technologies and Environmental Policy*, **17**, 373-391.

Hydrocarbon Processing, (2004), *Gas Processing Handbook,* Gulf Publishing Company, On line at" http://www.aimsgt.com/technicalpapers/GasProcessesHandbook_2004.pdf.

Kohl A.L., Nielsen R., (1997), *Gas Purification*, 5th Edition, Elsevier- Gulf Professional Publishing.

Milidovich S.P.E., Zbacnik E., (2013), Increasing Efficiency of Hot Potassium Carbonate. CO_2 Removal Systems, On line at: https://www.uop.com/?document=increasing-efficiency-of-hot-potassium-carbonate-co2-removal-systems&download=1

Miltner M., Makaruk A., Harasek M., (2016), Selected methods of advanced biogas upgrading, *Chemical Engineering Transaction,* **52**, 463-468.

Petracchini P., Segreto M., Paolino V., (2017), High efficiency biomethane through potassium carbonate, *Biogas Informa,* **22**, On line at: https://www.consorziobiogas.it/wp-content/uploads/2017/11/BIOGAS_INFORMA_n22-web.pdf.

Sun Q., Li H., Yan J., Cheng L., Yu Z., Xinhai Y., (2015), Selection of appropriate biogas upgrading technology-a review of biogas cleaning, upgrading and utilization, *Renewable and Sustainable Energy Reviews*, **51**, 521-532.

Tomasi L., (2016), The Giammarco-Vetrocoke Process for the CO_2 Removal Offers an Appealing Approach to Clean SNG/Syngas from Biomass (RDF) Gasification Units, 6th International Symposium on Energy from Biomass and Waste, Venice, Italy.

Tomasi L., (1992), Energy-efficient CO_2 removal process gv low energy process, *Fertiliser News*, **37**, 25-31.

Procedia
Environmental Science, Engineering and Management
http://www.procedia-esem.eu

Procedia Environmental Science, Engineering and Management, **4** (2017) (1) 53-58

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BREAK-EVEN POINT DEFINITION AND MONITORING OF SUSTAINABLE USE AND SUPPLY OF INDUSTRIAL WASTE*

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Abstract

Waste is unwanted or unusable material. Waste is any substance which is discarded after primary use, or is worthless, defective and of no use. In particular this study is focused on hazardous waste, which is waste that poses substantial or potential threats to public health or to the environment. The characteristic of this type of waste is ecotoxicity. Waste is disposed of efficiently by industrial symbiosis that is a component of industrial ecology. The "Ge.S.P.I. S.r.l." located in Augusta is the leader in the South of Italy for waste reduction that deals with transforming waste into energy, industrial waste and waste from ships. In order to increase the environmental sustainability "Ge.S.P.I S.r.l.". decided to present a waste-to-energy plant at Ecomondo in November 2016. This plant is a waste management facility that composts waste to produce electricity. Waste-to-energy plants can have a significant cost advantage over traditional power options, as the waste-to-energy operator can get revenues for receiving waste as an alternative to the cost of disposing waste in a landfill. This plant decreases ash and CO_2 emissions but also minimizes the introduction of heavy waste into the environment. This paper is based on the experimental analysis of the Breakeven point of different types of waste. In particular the analysis is based on understanding how the Break-even point varies depending on the types of waste, percentage of waste, energy evaluation and chemical components. This is a qualitative method used to optimize the measurements and cost-benefit quantities of amounts of waste, which represent the point where costs and revenues are equal. It is the point where a business, product or project becomes financially viable. The aim of this research is to analyze the costs-benefits and the reduction in costs of incineration after the introduction of this plant and to analyze it in the perspective of implementing sales and new business models.

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Keywords: Break-event Point, Ge.S.P.I., Incineration, Special Waste, Waste to Energy plant.

1. Introduction

The term hazardous waste gained acceptance starting about 1970 with the first national study on the issue (LaGrega et al., 2010). This type of wastes can be any potentially infectious medical waste (PIMW), pollution control waste or industrial process waste (www.epa.gov). The correct management of hazardous waste is one of the principles that the European Union indicated in specific regulations and directives. Major economic and social perturbations have been created by uncontrolled past toxic waste dumping, and adequate long-term management of hazardous waste remains one of the most difficult challenges ever faced by regulatory authorities (Wynne, 1987).

Every Italian region, including Sicily, adopted this norm about management of waste. In this paper, the industrial symbiosis is scrutinized. As revealed by the Ellen MacArthur foundation, industrial symbiosis can be defined "as the exchange of materials of waste streams between companies, so that one company's waste becomes another company' raw material" (www.ellenmcarthurfoundation.gov). In particular it demands resolute attention to the flow of materials and energy through local and regional economies (Chertow, 2000). This paper analyzes the break-even-point and the waste-to-energy plant of the Ge.S.P.I s.r.l. company located in Augusta. It was the first company to introduce an incineration plant in the South of Italy. This company deals with incineration of port and land waste, bunker oil and petroleum terminal. In this process, the heat from combustion is used to generate superheated steam in boilers. The steam is in turn used to drive turbogenerators to produce electricity (Stein, 1997).

An incinerator can be understood as a furnace where waste burnt. In particular modern incinerators are equipped with pollution improvement systems (www.wrfound.org.uk). Refuse incineration plant operations involve many kinds of uncertain factors, such as the variable physical properties of the refuse as fuel and the complexity of the burning phenomena (Ono and Terada,1989). This makes it very difficult to apply conventional control methods to the combustion control of the refuse (Ono et al., 1989). This process offers both technical advantages and benefits to the public. The technical advantages arise from two process features. The first is oxygen-substituted combustion and the second is closed cycle operation (Downs et al., 1994). Other advantages are the reduction of ashes and CO_2 emissions and also the minimization of heavy waste into the environment. Beyond these just listed there are also the reduction of waste volumes by an estimated of 80-95%, and the need for land and landfill space is greatly reduced (www.greentumble.com).

2. Materials and methods

There are several types of waste: urban waste and special waste. When it comes to urban wastes it is delivered directly in the dump, while special wastes undergoes a special administrative assessment, additional processing, special transportation, special packaging and additional disposal techniques due to the quantity of material generated or its unique physical, chemical or biological characteristics (www.wastecom.com). The assessment and classification of waste is based on a combination of chemical and waste legislation (www.sepa.org.uk).

Ge.S.P.I. S.r.l. works on special wastes that can be classified as:

- medical waste;
- docker waste;
- pharmaceutical waste;
- industrial waste;
- solvent waters (www.epa.gov).

Table 1. Classification of special wastes (2016/2017)

Type of waste	*Managed quantity year 2016-2017/ tons*	*Calorific power*	*Movement cost*	*Medium fixed residue*	*Plant reagent costs*
Medical waste	1.900 (2016-2017)	High	High	Low (2016) Null (2017)	Low
Soluble waters – pharmaceutical	6.000 (2016) 5.000 (2017)	Low	Low	Null (2016-2017)	Medium
Reservoir sleeves (physical state 3)	5.500 (2016) 4.500 (2017)	Medium	Medium	Medium (2016) Low (2017)	Medium
Non-flammable sludges	1.000 (2016-2017)	Low	Medium	High (2016) Medium (2017)	Low
Flammable liquids	3.000 (2016-2017)	Very high	Low	Null (2016-2017)	Medium High
Packaging - straces – filters	3.600 (2016-2017)	Medium	Medium	Medium (2016) Low (2017)	Medium
Terraces and rocks contaminated /isolated	1.000 (2016-2017)	Low	Medium	High (2016) Medium (2017)	Low
Flammable floors - inks	1.500 (2016-2017)	Very high	Very high	Medium (2016) Low (2017)	High
Waste treated and stabilized by plants treatment	10.000 (2016) 7.000 (2017)	Medium high	Low	Low (2016) Null (2017)	Low
Chemical substances	200 (2016-2017)	Medium	Very high	Low (2016) Null (2017)	Very high

The total managed quantity of 2016 is 35.000 tons while the total managed quantity of 2017 is 30.000 tons.

In Table 1, about 2016, the type of waste and its characteristics are analyzed such as the managed quantity, heating value, costs and fixed residue to analyze the break-even point, which is the point in time when revenue exactly equals the estimated total cost (www.businessdictionary.com). In Table 2, about 2017, it is hypothesized that even if the quantity of waste is reduced, the break-even Point is better than 2016. This point decrease about 20%, a minor impact of ash and CO_2 and also a reduction of transport costs is registered. In 2017, it is hypothesized that with introduction of a grid it is known that the break-even point is better than the year before, also the ashes are more worked by the plant.

Table 2. Scale of classification of special wastes (2016/2017)

	Calorific power	*Movement cost €/tons*	*Medium fixed residue 210€/tons (2016) 150€/tons (2017)*	*Plant reagent costs €/tons*
Null	-	-	0-5%	-
Low	0-1000	10-35	6-30%	2-3
Medium	1001-3000	36-60	31-65%	3,1-4
Medium High	3001-5000	61-100	66-99%	4,1-5
High	5001-7500	-	-	5,1-6
Very high	7501-10000	101-150	-	6,1-7

Three variables are necessary to calculate a company's break-even point in sales volume (www.thebalance.com):

- Fixed costs;
- Variable costs;
- Selling price of the products.

Analyzing the variable costs of all wastes, it has come that variable costs are equals to 3.000.000 € on average but they are equals to 85.71 € per unit quantity.

Assuming that the price is equal to 300€ per unit and the Q is equal to 35.000 and it has been calculated the fixed cost that is equal to (Eq. 1):

$$FC= Q*(P-VC) \quad (1)$$

FC= 35.000*(300-85.71); FC= 7.500.150.

In 2016 following these data the price has a range that goes from 298 to 302. In fact, P= (7.500.150 / 35.000) + 85.71= 300 with disposal costs about 210€/tons.

Thanks to the introduction of the grid and also a reduction of disposal costs about 150€/tons, it is hypothesized that in 2017 the price has a new range that goes from 291 to 293 and also the variable costs are halved. In fact, P= (7.500.150 / 30.000) + 42,855= 292,855.

3. Experimental

In this paper, the "Ge.S.P.I. S.r.l." which is located in Augusta and is involved in the incineration of waste in environmental sector. There are several types of waste, special waste and urban waste. This company is the leader in the South of Italy for waste incineration. The innovation of this company is demonstrated by the introduction of an incineration grid which is used for dry extraction. The "Ge.S.P.I. S.r.l." is the second company in Europe that adopt this appliance after Switzerland. This grid allows the minimization of the break-even point and a reduction of wastes' emission.

A waste to energy plant is an industrial plant for wastes' incineration via combustion. This plant uses trash as a fuel for generating power, just as other power plants use coal, oil, or natural gas. The burning fuel heats water into steam that drives a turbine to create electricity. The process can reduce a community's landfill volume by up to 90 percent, and prevent one ton of carbon dioxide being released for every ton of waste burned (www.deltawayenergy.com).

The “Ge.S.P.I. S.r.l.” has various certification such as ISO 9001 that concerns the quality aspect of the product certified by "Rina services" (www.riina.org) and ISO 14001 that regards the environment and the protection of it certified by "Certiquality" (www.certiquality.it). “Ge.S.P.I. S.r.l.” intends to implement "Norma 231/2001" in the coming months. It is an Organization and Management Model in this legislative decree is introduced the importance of the principle of the administrative responsibility of the legal person. After the introduction of this decree, the company wants to organize seminars and also more medical checks to specialize the employees.

4. Results and discussion

The most important business of the “Ge.S.P.I. S.r.l.” is combustion which is a rapid, exothermic reaction between fuel and oxygen (www.idc-online.com). Many companies have made considerable progress in recent years to reduce or recycle wastes; one of these is the “Ge.S.P.I. S.r.l.”.

A typical hazardous waste incineration consists of a rotary kiln, an afterburner and an air pollution control system. Both solid and liquid wastes are introduced into the rotary kiln, in which the temperature is usually higher than 1800 the degrees Fahrenheit.

The kiln rotates slowly to ensure that the solid wastes are exposed on all sides to the elevated temperature in the kiln (www.eponline.com). In this paper the break-even point method is analyzed which is a critical number that must be analyzed within a business. It is the point where sales and expenses are the same or when the sales of a company are enough to cover the expenses of the business. The break-even point formula is very straight-forward and easy to calculate and as follows (Eq. 2):

$$Q^* = FC/(P-UVC) \qquad (2)$$

where: "Q" is equal to break-even Point, “FC” is equal to Fixed Cost, “P” is equal to Sales Price, “UVC” is equal to Unit Variable Cost (www.study.com). To simplify theoretically the "P" and "UVC" are considered equal in every waste.

In the disposal of special waste there are different step and incineration represents the last steps but it is also the most expensive. In fact, before it is necessary to verify and control if the special waste can be reused, recovered or tip and if it is not possible the waste is disposed into waste-to-energy plant. Even if it could be more advantageous incinerate only certain type of waste with particular characteristics such as lower costs, low fixed residue, high heating value the “Ge.S.P.I. S.r.l.” must incinerate every type of special waste because this plant was created to incinerate for this, and also it is required by the customer.

5. Conclusions

One advantage for the “Ge.S.P.I. S.r.l.” is represented by an excellent allocative location, because it is near the port and also the industrial area. In particular this company is responsible for dealing with docker waste and almost industry incinerates their wastes in the “Ge.S.P.I. S.r.l.” company. In addition to representing an allocative advantage, this is also a technical, environmental and economic advantage.

Due to this “Ge.S.P.I. S.r.l.” is the leader in the South of Italy for waste reduction.

References

Chertow M.R., (2000), Industrial symbiosis: literature and taxonomy, *Annual Review of Environment and Resources,* **25**, 313-337.

Downs W., Vecci S.J., Warchol J.J., Datsko S.C., Hay G.H., (1994), Incineration of hazardous wastes using closed cycle combustion ash vitrification, *Environment International*, **21**, IX.

LaGrega M.D., Buckingham P.L., Evans J.C., (2010), *Hazardous Waste Management,* Second edition, Waveland Press, Long Grove, USA.

Ono H., Terada Y., (1989), Combustion control of refuse incineration plant by fuzzy logic, *Fuzzy Sets and Systems*, **32**, 193-206.

Ono H., Ohnishi T., Terada Y., (1989), Combustion control of refuse incineration plant by fuzzy logic, *Fuzzy Sets and Systems*, **32**, 193-206.

Stein B., (1997), *Building Technology: Mechanical and Electrical Systems,* John Wiley & Sons, New York.

Wynne B., (1987), *Risk Management and Hazardous Waste. Implementation and the Dialectics of Credibility,* Springer-Verlag Berlin Heidelberg.

Web sites:

http://www.epa.illinois.gov/topics/waste-management/factsheets/hospital/index
https://www.ellenmacarthurfoundation.org/case-studies/effective-industrial-symbiosis
http://www.wrfound.org.uk/articles/incineration
http://greentumble.com/waste-incineration-advantages-and-disadvantages/
http://wastecom.com/Content/Business-Industry/Special-Waste.aspx
https://www.sepa.org.uk/regulations/waste/special-waste/
https://www.epa.gov
http://www.businessdictionary.com/definition/breakeven-point.html
https://www.thebalance.com/how-to-calculate-breakeven-point-393469
http://www.deltawayenergy.com/wte-tools/wte-anatomy/
http://www.rina.org/en/Lists/PageAttachments/rc_c_50_en.pdf
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http://www.idc-online.com/technical_references/pdfs/mechanical_engineering/Combustion.pdf
https://eponline.com/articles/2015/04/20/incinerating-hazardous-waste.aspx
http://study.com/academy/lesson/how-to-calculate-the-break-even-point-definition-formula.html

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

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

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

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

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

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

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

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

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