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Use of Innovative Biochar-Based Filtering Systems for Process Water

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Abstract

The project aims to evaluate alternative washing water filtering systems, through the use of vegetal carbon or commonly called Biochar, for the washing water at the end of the process. This innovative system will be compared with the traditional one currently present. The comparison will be made with pre-filtered and post-filtered washing water.

The activities of the "Re-Water" project are divided:

- Conception: Preliminary evaluation of the feasibility of the project and consideration of the company's internal needs. Definition of the general and specific objectives of the project in line with the objectives of the Company and European regulations regarding recycling, water saving and water protection. Development of a strategy for the integration of technology transfer within the company, identification of possible new markets and definition of innovative services.
- Conceptualization: evaluation of the methodology to be used for the production of biochar with choice of retractable residual biomass also in terms of valorisation. Choice of the thermochemical conversion process most suitable for the production of biochar. Preparation of the organizational structure for research and development involving both public and private laboratories and research institutions. Development of the eco-design plan and evaluation of the methods of recovering materials and using renewable energy.
- Design: Implementation of new technical-operational processes and procedures for the evolution of the technological innovation system. Start of laboratory trials and tests, in particular pyrolysis tests for the production of biochar from vine residues.

- Prototyping: Development and engineering of high quality
prototypes for filtering tests with biochar from vine biomass residues. Scientific publication and dissemination of the results obtained to share the knowledge acquired and promote the adoption of new technologies.

Keywords: Water, Biomass, Biochar, Filters

1. Introduction

The use of biochar-based filtering systems for treating process water is an emerging technology that leverages the unique properties of biochar to improve water quality. Biochar is a stable, carbon-rich material produced through the pyrolysis of organic biomass. It has gained attention for its potential applications in water treatment due to its high porosity, large surface area, and functional surface chemistry. Here’s a detailed overview of this innovative approach:

Properties of Biochar Relevant to Water Treatment

High Surface Area and Porosity:

- Biochar has a highly porous structure, providing a large surface area for the adsorption of contaminants. The micropores and macropores in biochar facilitate the capture of a wide range of pollutants.
- Chemical Composition: Biochar contains various functional groups (e.g., hydroxyl, carboxyl, and carbonyl) that can interact with different contaminants. The surface chemistry can be tailored by modifying the feedstock or pyrolysis conditions.
- Adsorption Capacity: Biochar exhibits a high adsorption capacity for organic pollutants (e.g., dyes, pesticides, pharmaceuticals) and inorganic contaminants (e.g., heavy metals, nutrients like nitrogen and phosphorus).

Applications in Process Water Treatment

- Industrial Wastewater Treatment: Biochar can adsorb heavy metals such as lead, cadmium, and arsenic from industrial effluents. It is effective in removing organic contaminants like phenols, polycyclic aromatic hydrocarbons (PAHs), and other hazardous organic compounds.

Agricultural Runoff:

- Biochar filters can reduce nutrient runoff (e.g., nitrogen, phosphorus) from agricultural fields, mitigating eutrophication in nearby water bodies. It can also adsorb pesticides and herbicides, preventing their entry into groundwater and surface waters.

Municipal Wastewater Treatment:

- Biochar can be integrated into existing wastewater treatment systems to enhance the removal of contaminants. It can help in the removal of pharmaceuticals, personal care products, and other emerging contaminants that are not effectively removed by conventional treatment methods.

Advantages of Biochar-Based Filtering Systems

- Sustainability: Biochar is produced from renewable biomass resources, making it a sustainable option for water treatment. The production process can also sequester carbon, contributing to climate change mitigation.
- Cost-Effectiveness: Biochar can be produced from low-cost feedstocks, including agricultural and forestry residues. The regeneration and reuse of biochar can further reduce operational costs.

Environmental Benefits:

- Biochar application in soils (post water treatment) can improve soil health and fertility. It can act as a carbon sink, helping in carbon sequestration.

Challenges and Considerations

- Consistency and Quality Control: The properties of biochar can vary significantly based on the feedstock and pyrolysis conditions, affecting its performance. Standardization and quality control are necessary to ensure consistent performance in water treatment applications.
- Regeneration and Disposal: The regeneration of biochar after saturation with contaminants needs to be efficient and cost-effective. Safe disposal or reuse of spent biochar, particularly if it contains hazardous materials, must be managed properly.
- Integration with Existing Systems: Designing biochar-based filters that can be easily integrated with existing water treatment infrastructure can be challenging. Pilot-scale studies and real-world applications are needed to validate performance and scalability.

Future Prospects

The future of biochar-based filtering systems for process water treatment looks promising, with ongoing research focusing on:

Enhancing the adsorption properties of biochar through chemical activation and surface modifications.

Developing hybrid systems that combine biochar with other treatment technologies (e.g., membrane filtration, advanced oxidation processes).

Scaling up production and application to meet industrial demands.

In summary, biochar-based filtering systems represent a versatile and sustainable approach to improving process water quality. Their development and optimization could play a significant role in addressing water pollution challenges across various sectors.

2. Materials and methods

Chemical-physical characterization of vine biomass.

For the analysis of moisture content, reference was made to the UNI EN ISO 18134-1:2015 standard (replaces UNI EN 14774:2010) Solid biofuels - Determination of moisture content.

For the analyzes of the ash content, reference was made to the UNI EN ISO 18122:2016 standard (replaces UNI EN 14775:2010): Solid biofuels - Determination of the ash content.

For the analyzes of the calorific value, reference was made to the UNI EN ISO 18125:2018 standard (replaces UNI EN 14918:2010).

In the first experimental plan, 30 kg of biochar was produced from vine residues using the pyrolytic boiler made available to SEA Tuscia S.r.l.

Pyrolysis process consists of the thermochemical decomposition of biomass obtained through the administration of heat at temperatures that can vary from 400 to 800°C, in the total absence of oxidizing agents.

From the reaction we obtain: o Solid fraction: constitutes 20-30% by weight of the initial biomass, is carbonaceous based due to the high carbon content and has a good calorific value (8000 kcal/kg), which is why it can be used as fuel; o Liquid fraction: constitutes 50-60% by weight, can be considered as a bio-oil; o Gaseous fraction: constitutes 15-30% by weight, is called syngas and is composed of hydrogen, carbon dioxide, carbon monoxide and light hydrocarbons. It generally has an average high calorific value of 15-22 MJ/kg and can be used for initial drying, electrical power generation, for storage or can be sold to third parties.

The chemical-physical characterization of the biochar did not show a significant difference in the characteristics, except in the increase in ash content and a reduction in hydrogen (Table 1). In Table 1 shows the metals present in biochar. Compared with the regulatory values of Legislative Decree 75/2010, only 2 pollutants lead and cadmium were found with values of 14.56 and 0.59 mg/kg respectively, which are well within the regulatory limits of 140 and 1.5 mg/ kg.

Parameters	Values
Ashes	2,03
PCS	22,36
PCI	21,73
C%	51,32
H%	3,09
N%	2,97

Table 1: Chemical characterization analysis

Figure 1: Biochar production by vine biomass

Once the biochar was produced, the prototype was created to evaluate the degree of filtering and the effectiveness of the biofilter as shown in figure 2.

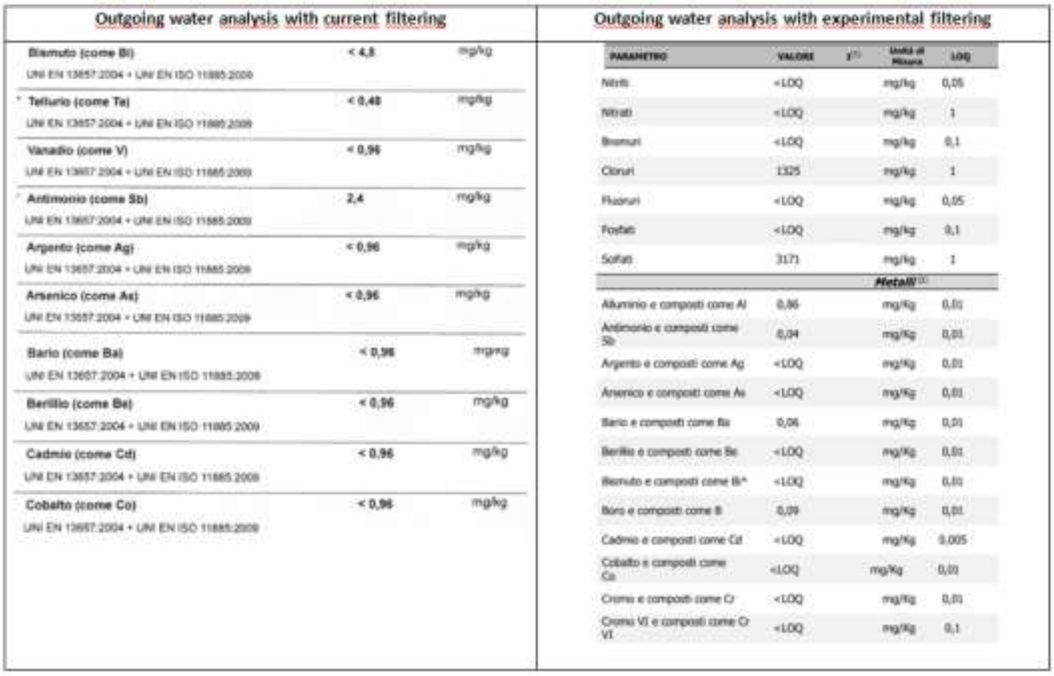
Figure 2: Creation of the prototype and acquisition of post-filtered water

3. Conclusion

After filtering, the research in its final phase involved the comparison between:

- the analysis of post-filtering water with the current filtration system:
- the analysis of post-filtering water with the filtration system based on the use of vine biochar.

The aforementioned analyzes are represented and compared below:



Outgoing water analysis with current filtering

Bismuto (come Bi) UNI EN 13657:2004 + UNI EN ISO 11885:2009	< 4,8	mg/kg
Tellurio (come Te) UNI EN 13657:2004 + UNI EN ISO 11885:2009	< 0,48	mg/kg
Vanadio (come V) UNI EN 13657:2004 + UNI EN ISO 11885:2009	< 0,96	mg/kg
Antimonio (come Sb) UNI EN 13657:2004 + UNI EN ISO 11885:2009	2,4	mg/kg
Argento (come Ag) UNI EN 13657:2004 + UNI EN ISO 11885:2009	< 0,96	mg/kg
Arsenico (come As) UNI EN 13657:2004 + UNI EN ISO 11885:2009	< 0,96	mg/kg
Bario (come Ba) UNI EN 13657:2004 + UNI EN ISO 11885:2009	< 0,96	mg/kg
Berillio (come Be) UNI EN 13657:2004 + UNI EN ISO 11885:2009	< 0,96	mg/kg
Cadmio (come Cd) UNI EN 13657:2004 + UNI EN ISO 11885:2009	< 0,96	mg/kg
Cobalto (come Co) UNI EN 13657:2004 + UNI EN ISO 11885:2009	< 0,96	mg/kg

Outgoing water analysis with experimental filtering

PARAMETRO	VALORE	I(1)	Unità di Misura	LOQ
Nitriti	<LOQ		mg/kg	0,05
Nitrati	<LOQ		mg/kg	1
Bromuri	<LOQ		mg/kg	0,1
Cloruri	1325		mg/kg	1
Fluoruri	<LOQ		mg/kg	0,05
Fosfati	<LOQ		mg/kg	0,1
Solfati	3171		mg/kg	1
			Metalli (1)	
Alluminio e composti come Al	0,86		mg/Kg	0,01
Antimonio e composti come Sb	0,04		mg/Kg	0,01
Argento e composti come Ag	<LOQ		mg/Kg	0,01
Arsenico e composti come As	<LOQ		mg/Kg	0,01
Bario e composti come Ba	0,06		mg/Kg	0,01
Berillio e composti come Be	<LOQ		mg/Kg	0,01
Bismuto e composti come Bi*	<LOQ		mg/Kg	0,01
Boro e composti come B	0,09		mg/Kg	0,01
Cadmio e composti come Cd	<LOQ		mg/Kg	0,005
Cobalto e composti come Co	<LOQ		mg/Kg	0,01
Cromo e composti come Cr	<LOQ		mg/Kg	0,01
Cromo VI e composti come Cr VI	<LOQ		mg/Kg	0,1

As can be seen from the comparison, the new filtering system, although being tested and in a controlled environment, produces excellent effects on the reduction of toxic metals such as: Arsenic, Cadmium, Phosphorus, Cobalt, etc.

Vineyard biochar has excellent values in terms of calorific value and a low ash content.

The presence of inorganic micropollutants was not found which would not allow its use both as a fuel and as a soil improver in the event of transformation into biochar.

It was stated that the experimentation gave excellent results and could be exploited in the industrial process, producing economic, technical and environmental benefits.

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