ACADÉMIE
DES SCIENCES
INSTITUT DE FRANCE

Comptes Rendus

Chimie

Salah Jellali and Mejdi Jeguirim

Foreword to Special Issue "Valorization of biomass and waste: the path for sustainability and circular economy promotion"

Volume 27, Special Issue S3 (2024), p. 3-6

Online since: 17 March 2025

Part of Special Issue: Materials and Energy Valorization of Biomass and Waste: The Path for Sustainability and Circular Economy Promotion
Guest editors: Mejdi Jeguirim (Université de Haute-Alsace, Institut de Sciences des Matériaux de Mulhouse, France) and Salah Jellali (Sultan Qaboos University, Oman)

https://doi.org/10.5802/crchim.392

CENTRE MERSENNE

The Comptes Rendus. Chimie *are a member of the Mersenne Center for open scientific publishing*
www.centre-mersenne.org — e-ISSN : 1878-1543

ACADÉMIE DES SCIENCES
INSTITUT DE FRANCE

Comptes Rendus. Chimie
2024, Vol. 27, Special issue S3, p. 3-6
https://doi.org/10.5802/crchim.392

Materials and Energy Valorization of Biomass and Waste: The Path for Sustainability and Circular Economy Promotion

Foreword to Special Issue "Valorization of biomass and waste: the path for sustainability and circular economy promotion"

Salah Jellali [a] **and Mejdi Jeguirim** [*, b]

[a] Centre for Environmental Studies and Research, Sultan Qaboos University, Muscat, Al-Khoud 123, Oman

[b] The Institute of Materials Science of Mulhouse (IS2M), University of Haute Alsace, University of Strasbourg, CNRS, UMR 7361, F-68100 Mulhouse, France

E-mails: s.jelali@squ.edu.om (S. Jellali), mejdi.jeguirim@uha.fr (M. Jeguirim)

Abstract. Biomass and wastes are produced in huge amounts all over the world. Even if they have high potential to be valorized in various sectors including energy, agriculture, and environment, a big fraction continues to be considered as a serious burden. This situation is worsened by the global climate change due to important emission of greenhouse gases (GHGs) generated by the consumption of considerable amounts of fossil fuels and also by the mismanagement of the produced biomass and wastes. The sustainable valorization of these biomass and wastes for energy recovery, synthesis of new materials for use in industry, in agriculture, and in environment, will decrease GHG emission, boost the circular economy, and preserve the environment. The current special issue published in Comptes Rendus Chimie (CRC) reviews recent advancements in biomass and waste valorization for the promotion of circular economy and sustainability concepts.

Keywords. Solid wastes, Management, Biomaterials, Adsorbents, Catalysts, Energy recovery and storage.

Manuscript received and accepted 5 March 2025.

1. Introduction

Consumption of resources and production are continuously increasing in the world. This is mainly caused by the high rate of population growth, urbanization, and industrialization. This has ultimately induced the production of huge amounts of waste. Waste can be liquid or solid. Solid wastes are usually classified according to their source. They include household waste, institutional waste, industrial waste, medical waste, agricultural waste, and municipal waste. Biomass is an important part of this waste. It is defined as renewable organic materials originating from plants and animals and represents an important fraction of municipal solid wastes.

According to the latest report of the United Nations Environment Program (UNEP 2024), municipal solid waste produced globally was evaluated to 2.1 billion tons. This amount will reach more than 3.7 billion tons by 2050. In 2020, only 13% of this amount was valorized for energetic purposes. In developing countries, direct incineration and landfilling are generally used for the management of wastes, which result in negative effects onto the environment and human health. The same report of UNEP indicates

* Corresponding author

that, in comparison with 2020 and for a waste management scenario as usual, by 2050 there will be a 91% increase in GHG emission, a 84% increase in loss of natural species, and a 87% increase in negative impact on human health.

Valorization of waste, and particularly biomass has become a promising alternative option to incineration and landfilling. Waste valorization consists in the application of the 4Rs principle: Reduce, Recycle, Reuse, and Recovery. The last option permits the conversion of wastes into valuable materials that can be used in various sectors such as energy, agriculture, and environment. Indeed, renewable energy can be recovered from this waste through various mastered technologies including anaerobic digestion, gasification, and pyrolysis. This energy can partially replace the one generated from fossil fuel combustion and consequently reduces atmospheric pollution as well as GHG emission. This will in turn facilitate the transition to sustainable energy that is regarded as a focal point in the United Nations Sustainable Development Goals and also the Paris Agreement on climate change. Besides renewable energy production systems, an intensive research work is being deployed for its tailored storage. In this context, the synthesis of specific materials is considered an important challenge to advance the transition to sustainable and renewable energy. Moreover, new valuable materials can be also derived from this waste. For instance, organic wastes may be transformed into an eco-friendly compost (through composting technology) that can be used instead of synthetic fertilizers in agriculture. This operation will boost the circular economy concept and reduces farmers' expenses. Besides that, this waste may be converted into a valuable biochar through the pyrolysis process. This biochar, in raw or modified form, may be used for the treatment of industrial/urban wastewater. Moreover, it can be used for nutrient recovery from actual wastewater for further use in agriculture. These nutrients-loaded biochars, when used to amend agricultural soils, usually allow soils to improve their water holding capacity and microbiological activity. Furthermore, it can act as slow-release fertilizer which offers cultivated plants the required nutrients during a long period and at the same time reduces the pollution risk to the underlying groundwater. Likewise, using biochar instead of activated carbons for the treatment of wastewater and in substitution of synthetic fertilizers promotes the circular economy and sustainability concepts, reduces GHG emission, protects the groundwater against pollution, and offers a high economic added value to farmers.

The present special issue in the journal "Comptes Rendus Chimie", is entitled: "Valorization of biomass and waste: the path for sustainability and circular economy promotion". It provides an interesting update on the conversion of wastes, in general and biomass in particular into high added-value by-products by using advanced and eco-friendly technologies. These by-products are intended to contribute to the promotion of circular economy and sustainability. Moreover, this special issue aims to fulfill national and international requirements regarding sustainable development and climate change adaptation and mitigation.

2. Outcomes

The current special issue contains 12 papers that have undergone a peer review process by at least two skilled reviewers. Published papers address several subtopics, including: (i) direct valorization of waste in several domains including concrete, cellulose and biomaterials extraction, (ii) biomass turned into adsorbents for removal of pollutants from wastewater, (iii) use of catalysts to improve the quality of biomass conversion by-products, (iv) application of hydrothermal carbonization as an innovative option for waste management, and (v) test of new materials for solar energy storage.

The first part of this special issue addresses the challenges of waste management, direct reuse, and the extraction of valuable biomaterials [1–5]. For instance, Chaouch et al. [1] investigated the use of recycled Polyvinyl chloride (PVC) powder as a substitute for conventional PVC resin in the expanded layer of floorcoverings. They showed that mixing recycled PVC with PVC resin up to 33% did not affect its mechanical characteristics (i.e., break strength, elongation at rupture, and tear resistance). Moreover, with finer recycled PVC particles (size lower than 200 μm), this percentage can be pushed further to 86%. In another study, in order to reduce the cost of air condition in arid areas, Siddique et al. [2] tested the use of four types of recycled plastics: low-density polyethylene (LDPE), polypropylene (PP), polyester, and high-density polyethylene (HDPE), as partial sand substitutes in concrete for roofing applications. Their results show that LDPE exhibited the most significant economic and environmental benefits. In the case of New Delhi, a LDPE percentage of 30% leads to an annual saving of around 1 $\$/m^2$ and a reduction in carbon emissions of 18 kg/kWh. The third study, by Ben Ali et al. [3], showed that cellulose can be extracted in an eco-friendly way from prickly pear seeds. The cellulose extraction yield was 39.3% by maceration and 23.2% when using the Soxhlet extraction method. Moreover, characterization of the extracted cellulose showed that it was exceptionally strong and light, allowing its possible use for the production of carbon fibers for reinforcing composite materials used in the aerospace, automotive, shipbuilding, and other industries. In the fourth study, Mestour et al. [4] examined the optimization of using supercritical CO_2 for the extraction of bioactive substances from onion waste. They reported that the optimal oil extraction yield (24.4%) was achieved for a pressure, temperature, particle size, and CO_2 mass flowrate of 250 bar, 57 °C, 0.25 mm, and 50 g CO_2/min, respectively. The analysis of the oil produced by gas chromatography showed that it contained the four following fatty acids: 9,12-octadecadienoic acid, methyl ester; 9,12-octadecadienoic acid (Z,Z)-, methyl ester; 9-octadecadienoic acid (Z)-, methyl ester; and hexadecanoic acid, methyl ester. Finally, Deffar et al. [5] studied the extraction of bioethanol from a pre-treated water hyacinth biomass, a free-floating perennial plant. Bioethanol extraction was carried out through a fermentation process by using a locally isolated thermophilic consortium in a partially consolidated bioprocessing process. They showed that the maximum experimental yield (7.7 g/L) was achieved at 50 °C, 72 h of fermentation time, and an inoculum dose of 6.64% (v/v).

The second part of this special issue is about biomass transformation into valuable by-products including biochar, bio-oil and biogas [6–12]. In this context, Jellali et al. [6] synthesized three Mg-, Al-, and Mg/Al-modified biochars from date palm wastes and valorized them for the recovery of phosphorus from aqueous solutions under a wide range of experimental conditions. Their ultimate aim is to use the phosphorus-loaded biochar in agriculture as a slow-release fertilizer. They showed that the biochar modified using a Mg/Al mixture solution exhibited the best physico-chemical properties and consequently the highest P recovery efficiency (14.1 mg/g). Moreover, the P recovery process involved both physical and chemical mechanisms. They conclude that the P-loaded Mg/Al-modified biochar has a good potential to be used as an attractive slow-release fertilizer instead of the costly commercial ones. In another study, Alfares et al. [7] examined the valorization of an abundant plant waste in Iraq: pinecones. They pyrolyzed different particle sizes (0.26–0.841 mm) of this waste at numerous temperatures (400–600 °C) for diverse residence times (30–120 min) and various heating rates (10–50 °C/min). They showed that the highest pyrolytic oil yield production (42.1%) was obtained for a particle size of 0.4 mm, a pyrolysis temperature of 500 °C, a residence time of 1 h, and a heating rate of 30 °C/min. The bio-oil characterization indicated that it can be considered as a high energy fuel since its higher calorific value was evaluated to be around 27.0 MJ/kg. Moreover, the activation of the corresponding biochar with K_2CO_3 at 750 °C led to the formation of a highly porous material. This activated biochar exhibited a large Cr(VI) removal capacity under a wide range of experimental conditions. For their part, Audu et al. [8] studied the effect of a new catalyst, synthesized by incorporating mesoporous iron oxide (FeO) into alumina (Al_2O_3), on the quality of the biogas formed from the pyrolysis of polyethylene terephthalate (PET). They showed that, in comparison with a blank test, use of this catalyst at a 5% load decreases oxygen content in the biogas from 23.3% to 5.3%. Moreover, the presence of this catalyst significantly improved the contents in H_2 and CH_4 gases. The highest H_2 and CH_4 contents were evaluated to 17.1%, and 16.2%, respectively. These yields were obtained for catalyst doses of 5 and 3%, respectively. In another study, Zheng et al. [9] synthesized a novel hierarchical calcium-based catalyst CaO(S) through sol–gel-biotemplate method using calcium nitrate-ethanol-citric acid as precursor and rape pollen as biotemplate. Then, they used it to catalyze oil/methyl acetate/methanol for no-glycerol biodiesel production. They showed a relatively high yield of no-glycerol biodiesel (96.6%) for the following optimal parameters: a temperature of 65 °C, a catalyst dosage of 10%, and an oil/methyl acetate/methanol ratio of 1/1/8. Furthermore, the regeneration study showed a significant catalytic stability with a yield of 91.4% after three cycles. Besides that, hydrothermal carbonization (HTC) of biomass was studied in this special issue [10,11]. In this context, Zhang et al. [10] studied the effect of the HTC experimental conditions on the yield and quality of the hydrochars produced from sludge. They showed that the organic matter and ash content in the sludge as well as the HTC temperature highly affect the fuel properties of hydrochars. However, the solid loading had no significant effect on hydrochar quality but did affect energy consumption by the HTC process itself. The former lack of effect was confirmed by Bedoui et al. [11] when studying the HTC of date pits and pine nut shells at 250 °C for 1 h. These authors also showed that the hydrochar with the largest higher heating value (29.7 MJ/kg) was observed for date pits and a solid/water ratio of 1:48. Moreover, steam activation of the hydrochar for 1 h at 850 °C highly improved its physicochemical properties, especially its porosity and surface area.

In a last but not least contribution, Sharma et al. [12], studied the effect on freshwater production of incorporating sensible heat storage materials (i.e., bricks, paper napkins wrapped around the brick, sand bed) in a triangular solar still. They showed that adding a sand bed reduced the cost of freshwater generation by around 43%, and the payback period by 44%.

Declaration of interests

The authors do not work for, advise, own shares in, or receive funds from any organization that could benefit from this article, and have declared no affiliations other than their research organizations.

References

[1] W. Chaouch and S. Msahli, “Recycled PVC content and particle size distribution effects on morphological and mechanical properties of expanded PVC layer for floorcoverings”, *C. R. Chim.* **27** (2024), pp. 1–21.

[2] M. J. Siddique and P. K. Akhas, “Advancing energy efficiency: thermomechanical characterization of plastic-infused concrete for sustainable building solutions”, *C. R. Chim.* **27** (2024), pp. 1–15.

[3] N. Ben Ali, A. Abdedayem, H. Nouri and S. Ben Ali, “Cellulose extraction by biomass valorization of prickly pear seed waste”, *C. R. Chim.* **27** (2024), pp. 1–9.

[4] S. Mestour, A. H. Menai, S. Melloul and M. Louaer, “Sustainability by extraction of bioactive compounds from onion seeds”, *C. R. Chim.* **27** (2024), pp. 1–13.

[5] S. S. Deffar, A. Kumar, A. Muliw, N. N. Pili and T. Omara, “Bioethanol production from water hyacinth with isolated thermophilic microbial consortium from Kenya”, *C. R. Chim.* **27** (2024), pp. 1–12.

[6] S. Jellali, S. Hadroug, M. Al-Wardy, et al., “Synthesis of Mg-, Al- and Mg/Al-date palm fronds modified biochars: characterization and investigations on phosphorus adsorption characteristics”, *C. R. Chim.* **27** (2024), pp. 1–14.

[7] A. Alfares, A. M. Younis, L. A. Rasheed and A. B. Fadhil, “Valorization of pinecone as a pyrolysis feedstock: identification of bio-oil and synthesis of activated biochar for Cr(VI) elimination from wastewater”, *C. R. Chim.* **27** (2024), pp. 1–19.

[8] E. A. Audu, A. F. Ade-Ajayi, A. A. Osigbesan, Z. S. Gano and J. T. Barminas, “FeO–alumina catalyst for reforming waste polyethylene terephthalate (PET) pyrolyzed products: synthesis, characterization, and performance evaluation”, *C. R. Chim.* **27** (2024), pp. 1–12.

[9] J. Zheng, S. Tao, Y. Yang and Y. Tang, “Gel–sol synthesis of hierarchical CaO using pollen as biotemplate for biodiesel production”, *C. R. Chim.* **27** (2024), pp. 1–14.

[10] C. Zhang, B. Wang, J. Wang, S. Rong, H. Xie, H. Qu and Y. Feng, “Assessment of the applied potential of sludge-derived hydrochar in terms of process parameters and product properties”, *C. R. Chim.* **27** (2024), pp. 1–18.

[11] A. Bedoui, H. Nouri, M. Boutaieb, R. Ghouil, B. Ledesma, M. Alonso, S. Roman and M. Guiza, “Hydrothermal carbonization of date palm pits and pine nut shells: fuel characteristics of hydrochar, and surface characteristics and adsorption application of activated hydrochar”, *C. R. Chim.* **27** (2024), pp. 1–13.

[12] N. Sharma, A. Patel, R. Deep and S. Gautam, “Performance augmentation of triangular solar still using sensible energy storage materials: thermo-exergo-economic and sustainability analyses”, *C. R. Chim.* **27** (2024), pp. 1–15.