Sustainable Materials and Technologies 9 (2016) 10–40

Contents lists available at ScienceDirect

Sustainable Materials and Technologies

journal homepage: www.elsevier.com/locate/susmat

Characteristics and adsorption capacities of low-cost sorbents for wastewater treatment: A review

Sabino De Gisi [a,*], Giusy Lofrano [a,b], Mariangela Grassi [b], Michele Notarnicola [a]

[a] Department of Civil, Environmental, Land, Building Engineering and Chemistry (DICATECh), Technical University of Bari, Via E. Orabona n. 4, 70125 Bari (BA), Italy
[b] Department of Chemistry and Biology, University of Salerno, via Giovanni Paolo II, 132 84084 Fisciano, (Salerno), Italy

ARTICLE INFO

Article history:
Received 16 December 2015
Accepted 21 June 2016
Available online 25 June 2016

Keywords:
Adsorbent-pollutant matrix
Adsorption
Low-cost sorbents
Wastewater treatment
Sustainable technologies

ABSTRACT

Low-cost by-products from agricultural, household and industrial sectors have been recognized as a sustainable solution for wastewater treatment. They allow achieving the removal of pollutants from wastewater and at same time to contribute to the waste minimization, recovery and reuse. Despite numerous reviews have been published in the last few years, a direct comparison of data obtained using different sorbents is difficult nowadays because of inconsistencies in the data presentation. In this context, the aim of the study was to revise the current literature concerning the application of low-cost adsorbents for wastewater treatment highlighting, systematically, both adsorbents characteristics and adsorption capacities. For this scope, low-cost sorbents have been divided into the following five groups: (i) Agricultural and household wastes, (ii) industrial by-products, (iii) sludge, (iv) sea materials, (v) soil and ore materials and (vi) novel low-cost adsorbents. The affinity of sorbents in removing various pollutants, their applications on real wastewater, costs and considerations on their reuse after adsorption processes, has been discussed. Finally, in order to better highlights the affinity of sorbents for more pollutants (dyes, heavy metals, biorecalcitrant compounds, nitrogen and phosphate compounds), simple methodological tools such as "adsorbents-pollutants" matrices have been proposed and applied. In this manner, the adsorbent candidates for replacing commercial activated carbons have been identified.

Contents

1. Introduction and scope

Over the years, the quality of water is deteriorating mainly due to the anthropogenic activities, population growth, unplanned urbanization, rapid industrialization and unskilled utilization of natural water

* Corresponding author.
E-mail address: sabino.degisi@poliba.it (S. De Gisi).

http://dx.doi.org/10.1016/j.susmat.2016.06.002
2214-9937/

resources. Furthermore, the increased awareness of the importance of providing impacts due to the current environmental strategies has pushed the research community towards the development of robust, economically feasible and environmentally friendly processes capable of removing pollutants from water and at same time to safeguard the health of affected populations [1].

A variety of treatment technologies are available with different degree of success to control and minimize water pollution [2]. However, the shortcomings of most of these methods are high operational and maintenance costs, generation of toxic sludge and complicated procedure involved in the treatment [3]. Comparatively, adsorption process is considered a better alternative in water and wastewater treatment because of convenience, ease of operation and simplicity of design [3,4,5]. In wastewater treatment plants (WWTPs), adsorption processes are applied for the removal of dissolved pollutants that remain from the subsequent biological phases or after chemical oxidation treatments. Today, the most commonly adopted adsorbent is the activated carbon. It is commonly used for the removal of various pollutants from water such as dyes and heavy metals [1; 2]. However, its widespread use in wastewater treatment is sometimes restricted due to its higher cost [4] besides other issues such as the adsorbent regeneration capacity or the disposal of the end-of-life sorbent following different strategies than disposal [6].

A large variety of low-cost adsorbents have been examined for their ability to remove various types of pollutants from water and wastewater. Generally, the goal is to replace activated carbons – representing the state-of-the-art – by means of a by-products coming from various activities such as agriculture and industry. These by-products currently pose a variety of disposal problems due to their bulk volume, toxicity or physical nature (i.e., petroleum wastes, scrap tyres, rice hulls). If these wastes could be used as low-cost adsorbents, it will provide a two-fold advantage to environmental pollution. Firstly, the volume of by-products (or wastes) could be partly reduced and secondly the low-cost adsorbent, if developed, can reduce the pollution of wastewaters at reasonable cost [1].

Over the last few decades, several literature reviews concerning the use of low-cost adsorbents for wastewater treatment have been published as shown in Table 1.

Table 1
Review articles concerning low-cost adsorbents in the field of separation science published in the years 2009–2016.

N.	References	Goal	Type of adsorbent[(a)]	Pollutants being investigated
1	Ungureanu et al. [7]	The review presented a state of the art of adsorption techniques for arsenic and antimony removals from water and wastewater.	Agricultural and household wastes; Industrial wastes; Sea materials; soil and ore materials; metal oxides and hydroxides	Arsenic and antimony
2	Çifçi and Meriç [8]	The study aimed to review the scientific literature of pumice stone with the particular focus on its use for the treatment of water and wastewater.	Soil and ore materials	Various pollutants
3	Bhatnagar et al. [3]	The review compiles the work conducted by various researchers over the last few decades on the use of various agricultural waste peels as adsorbents for the water and wastewater treatment. In this review, adsorption capacities for organic and inorganic pollutants by different peel-based adsorbents are summarized.	Agricultural and household waste	Dyes; heavy metals
4	Gautam et al. [4]	The review provided a comprehensive appraisal of the equilibrium modeling of a number of biosorption processes as well as the structural, chemical and morphological modifications and activation of biosorbents.	Agricultural and household wastes; sea materials	Heavy metals
5	Abdolali et al. [9]	The review deals with utilization of typical low cost wastes and by products produced in different food agricultural and agro-industries as biosorbent and reviews the current state of studies on a wide variety of cheap biosorbents in natural and modified forms.	Agricultural and household	Heavy metals
6	Yagub et al. [10]	The review article provides extensive literature information about dyes, its classification and toxicity, various treatment methods, and dye adsorption characteristics by various adsorbents.	Agricultural and household wastes; industrial wastes; soil and ore materials	Dyes
7	Anastopoulos and Kyzas [11]	The review summarizes the recently published literature (after 2010) regarding the use of agricultural peels for dye adsorption.	Agricultural and household	Dyes
8	Rangabhashiyam et al. [12]	The review article focuses on the various sources of the agricultural waste products and its adsorption capacity of the different dyes.	Agricultural and household	Dyes
9	Nguyen et al. [13]	The review discusses the potential use of agricultural waste based biosorbents (AWBs) for sequestering heavy metals in terms of their adsorption capacities, binding mechanisms, operating factors and pretreatment methods.	Agricultural and household	Heavy metals
10	Bilal et al. [14]	The review is dedicated to presenting state of the art knowledge on various bioadsorbents and physico-chemical conditions used to remediate Cu2 + from waste streams.	Agricultural and household	Copper
11	Ali et al. [5]	The review described the conversion of waste products into effective adsorbents and their application for water treatment	Agricultural and household wastes; industrial waste; sea materials; soil and ore materials; metal oxides and hydroxides	Organic pollutants
12	Bhatnagar and Sillanpää [15]	In this review, an extensive list of low-cost adsorbents (prepared by utilizing different types of waste materials) from vast literature has been compiled and their adsorption capacities for various aquatic pollutants as available in the literature are presented.	Activated carbon; agricultural and household wastes; Industrial wastes; Sludge;	Various pollutants (Dyes; heavy metals; PAHS)
13	Foo and Hameed [16]	The paper presented a state of the art review of the rice milling industry, its background studies, fundamental properties and industrial applications. Moreover, the key advance on the preparation of novel adsorbents, its major challenges together with the future expectation has been highlighted and discussed.	Agricultural and household waste; industrial waste (agro food industry).	Various pollutants
14	Gupta and Suhas [17]	This review highlights and provides an overview of these low cost adsorbents (LCAs) comprising natural, industrial as well as synthetic materials/wastes and their application for dyes removal.	Activated carbon; agricultural and household wastes; sludge; sea materials; soil and ore materials.	Dyes