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Low-cost materials to face soil and water pollution

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Abstract

In this mini-review, the authors comment on selected papers focused on the use of low-cost materials to prevent/remediate environmental pollution (specifically, soil and water pollution). The authors have selected publications corresponding to the years 2021 and 2022, using the searching tools Scopus, Web of Sciences, and Google Scholar to find basic data about the papers, the countries where the researches were carried out, number of citations, and other details indicative of the relevance of the works. Overall, the field of research is receiving growing attention and efforts, providing useful data on classical and new low-cost materials, both raw and modified by means of low-cost procedures, which constitute a clearly interesting alternative to face environmental pollution currently and for the future.

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Keywords

Environmental pollution, Low-cost treatment, Soil remediation, Water treatment.

Introduction

The use of low-cost materials to control environmental pollution has been studied for years, and it is currently on the focus of a variety of researchers.

To have a rapid view, Figure 1 shows a picture, by countries, with results corresponding to the scientific searching tool Web of Sciences (WOS) for the string "Low cost materials environmental remediation," limited to the years 2021 and 2022. In addition, the global numbers provided are as follows: 381 publications for 2021 and 224 publications for 2022.

Figure 1 indicates that China is the country on the top in the last two years, with 430 publications, followed by India (109), USA (51), and then other 21 countries with less than 30 publications.

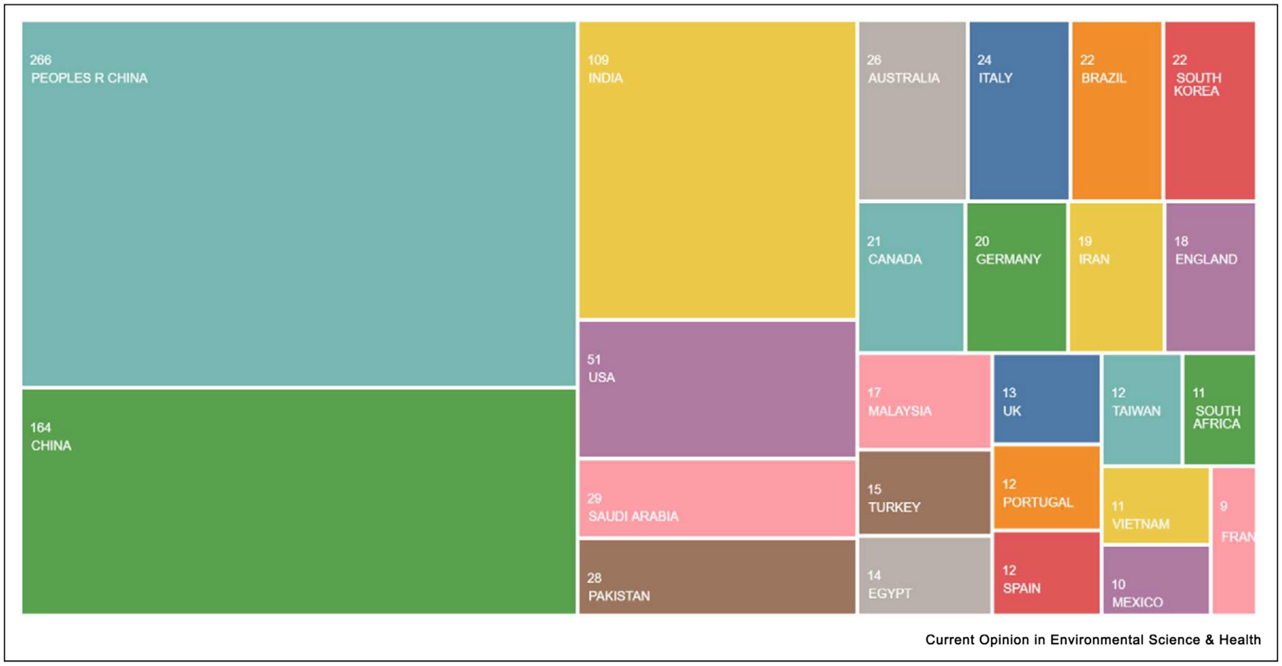
In this mini-review, the authors have considered data available on three different scientific databases: WOS, Scopus, and Google Scholar (GS). These sources were used to get an overall view on the number of publications and to find those papers receiving the highest citations, as well as others representative of significant works in the area.

Comments on selected publications focused on the use of low-cost materials to prevent/remediate environmental pollution

As per Scopus and WOS, searching for the string "Low cost materials environmental remediation," the number of papers found by the end of October 2022, for the period 2021–2022, was as follows: 324 for Scopus and 607 for WOS.

For both tools, the paper receiving the highest number of citations was the one by Liang et al. [1], where the authors

Figure 1



Graphic results for number of publications by country corresponding to “Low cost materials environmental remediation,” limited to the years 2021 and 2022. Source: WOS.

indicate that biochar-based composites have demonstrated good performance in the removal of both organic and inorganic contaminants, but some aspects related to eventual toxicity and stability need additional research.

In addition, both searching tools found other two publications that had more than 100 citations at the date. Nasrollahzadeh et al. [2] focused on assessing the sustainable applications of specific nanomaterials, with “superior surface area, mechanical properties, significant chemical reactivity, and cost-effectiveness with low energy consumption,” for removing pollutants from water. Alka et al. [3] concluded that some novel functional materials (carbon nanotubes, metal–organic frameworks, graphite oxides, and others) can be seen as promising alternatives for arsenic removal.

Another highly cited paper on the topic was the one by Riaz et al. [4], as reported by WOS, where the authors pay special attention to mycorrhizal fungi-assisted remediation of heavy metals and to mycorrhizal fungi strategies to cope with environmental pollution. Also, highly cited is the paper by Pal et al. [5], which is focused on reviewing the use of chitosan and some derivate products to remove biological contaminants, antibiotics, pesticides, dyes, or heavy metals from aqueous media and for soil remediation.

The results provided by GS were clearly above than those from WOS and Scopus when searching for the string “Low cost materials environmental remediation,” with a total number of 16,900 references for the years 2021–2022, although reduced to 515 results when searching for “Low-cost-materials environmental remediation” for the same period.

The authors of this mini-review carried out additional searches using GS for a variety of searching strings, such as “Low-cost-sorbents”, “Low-cost-sorbents soil”, “Low-cost-sorbents soil-pollution”, “Low-cost water-pollution”, or “Low-cost environmental-pollution-remediation”. Among the whole set of results, different publications were selected based on the number of citations received and/or on other aspects, such as relevance or originality within the field of research, thus meriting special attention. These selected papers are indicated below.

Firstly, it should be noted that the authors of the mini-review have been working for years in the field of recycling low-cost materials to fight soil and water pollution. Some of their publications on the topic, in the period 2021–2022, were the following.

Ahmed et al. [6] studied low-cost raw and modified biochar as an efficient and promising approach for Pb(II) removal from polluted waters, while also promoting the recycling of by-products, whereas Ahmed et al. [7] studied another kind of low-cost biochar as an effective means for removing uranium (VI) from liquid environments.

Other papers published by the authors during this biannual period [8–11] were focused on the use of low-cost bioadsorbents to retain/remove different antibiotics from environmental compartments, while the research by Cela-Dablanca et al. [12] dealt with the efficacy of low-cost bioadsorbents in the removal of Cu and As(V), reaching overall good results, but showing that some of the bioadsorbents performed better for some of the pollutants.

García-Reyes et al. [13] found positive results as regard the removal of different pharmaceuticals from liquid media, by means of lignocellulose-derived granular activated carbon, while Ramos et al. [14] reported interesting findings about the use of marble sludge particles as efficient nanomaterials for Cu(II) adsorption from water, and Mateus et al. [15] showed promising data on the catalytic activity of calcined $MnFe_2O_4$ solid nanospheres to oxidize para-nitrophenol with peroxymonosulfate and n-C7 asphaltenes with air.

Regarding the other papers selected on GS for this review, it is noteworthy that some of them deal with means to face soil pollution, while others are mainly focused on water pollution, and, in addition, some of the publications are limited to raw materials (natural or waste products), whereas other works are related to the use of modified (although low-cost) materials. Within these different groups, the papers selected for this review, ordered by number of citations received (from the highest to the lowest numbers), were the following.

Seven of the papers selected from those reported by GS have received more than 100 citations to date. Among them, the one by Liu et al. [16], which received 230 citations, focused on the use of doped graphitic carbon nitride photocatalysts for the degradation of organic pollutants, with special attention to the fact that element doping may be considered an efficient and simple strategy for improving photocatalytic performance. Cheng et al. [17] reviewed the high potential of modified biochar used for the adsorption of emerging pollutants from water, receiving 220 citations to date. Chakraborty et al. [18] reviewed the relevant efficacy of raw and modified low-cost materials in the adsorption of heavy metals, with 191 citations to date. Yu et al. [19] have received 158 citations to their review on MXenes nanomaterials (as emerging transition metal nitrides, carbides, or carbonitrides) showing its high importance when used in environmental remediation. The work by Rafiq et al. [20] reviewed the marked efficacy of using photocatalysts to remove dyes from water, receiving 139 citations to date, whereas the publication by Long et al. [21], which has received 126 citations, studied the use of carbon dots to fight environmental pollution, showing the high performance of these nanomaterials. Nasrollahzadeh et al. [22] published a review on the good perspectives for using carbon-based sustainable nanomaterials in water treatment, which has received 111 citations.

With less than 100 citations to date, but still ordered by decreasing number of citations, the remaining papers selected for this review are commented below.

Rathi and Kumar [23] reviewed the use of adsorption to effectively remove emerging pollutants from water, while Bilal et al. [24] found overall good results regarding heavy metals elimination from water by means of biosorbents. In turn, Sajjadi et al. [25] reported on the successful and promising use of lignin-derived materials and nanomaterials to face environmental pollution, and Bushra et al. [26] reviewed the feasibility of effectively using raw and modified agricultural waste materials for removing dyes from water. In addition, Mondol and Jhung [27] showed their positive view on the use of metal–organic framework-based materials to eliminate pesticides from water, whereas Feng et al. [28] reviewed and recommended as feasible and effective the use of invasive plants as potential sustainable feedstocks for biochar production.

Other interesting studies were those carried out by Esfandiar et al. [29] on the effective removal of heavy metals from storm runoff using different low-cost sorbent materials, the one by Liu et al. [30] dealing with the successful use of modified biochar to retain/remove heavy metals, the work performed by Wu et al. [31] about the use of genetically engineered microorganisms to remediate soils co-contaminated by heavy metals and polycyclic aromatic hydrocarbons, and the one by Pourali et al. [32] on the removal of dye pollution from water using activated carbon coated with AC-ZnO composite. Velusamy et al. [33] also studied the efficient use of biochar to remove emerging pollutants from water, while Tony [34] made a review on low-cost adsorbents used in pollution treatment, and Esfandiar et al. [35] showed the positive results obtained using low-cost agricultural/industrial by-products for removing polycyclic aromatic hydrocarbons from urban stormwater.

Garg et al. [36] reported the successful removal of fluoride from water by means of a biosorbent obtained from agricultural and fruit waste, whereas Lashen et al. [37] used nanomaterials derived from sugar beet processing- and clay brick factory-solid wastes to remove Cd and Cu from soil and water. Dong et al. [38] presented a review dealing with the use of radiation techniques to functionalize adsorbent materials, while Madhubashani et al. [39] reviewed biochar performance in the removal of oil spills, and Elamin et al. [40] showed promising results regarding the elimination of paracetamol and metformin from water using acid-treated clay. Vishnu et al. [41] compared different sorbents, including various being low-cost, finding adsorption capacities up to five times higher for hybridized nanosorbents than for single materials, whereas Xiong et al. [42] reported on the efficient Pb(II) removal achieved after the modification of a low-cost bioadsorbent, and Gupta et al. [43] showed the efficacy of low-cost adsorbents for metal removal from water. In turn, Américo-Pinheiro et al. [44] reported the successful elimination of naproxen from water by means of a hybrid material functionalized with iron oxide, while Yu et al. [45] commented on the positive results regarding herbicide removal from soil using esterase-embedded zeolitic imidazolate frameworks, and Singh et al. [46] showed good results in the elimination of the pesticide

Table 1

Selected data on different low-cost materials used to face environmental pollution.

Material	Pollutants to face	Efficacy/Cost	Reference
Biochar	Organic and inorganic	Good/Low	[1]
Green nanomaterials	Water pollutants	Good/Low	[2]
Novel functional materials	Arsenic	Good/Low	[3]
Mycorrhizal fungi	Heavy metals in soil	Good/Low	[4]
Chitosan	Water and soil pollutants	Good/Low	[5]
Biochar.	Pb(II) in water	Good/Low	[6]
Biochar	Uranium(VI)	Good/Low	[7]
Bioadsorbents	Antibiotics	Good/Low	[8]
Bioadsorbents	Antibiotics	Good/Low	[9]
Bioadsorbents	Antibiotics	Good/Low	[10]
Bioadsorbents	Antibiotics	Good/Low	[11]
Bioadsorbents	Cu and As(V)	Good/Low	[12]
Lignocellulosic carbon	Pharmaceuticals	Good/Low	[13]
Marble sludge nanomats	Cu(II) in water	Good/Low	[14]
$MnFe_2O_4$ nanospheres	p-nitrophenol/asphaltenes	Good/Low	[15]
Doped g-C_3N_4	Organic pollutants	Good/Low	[16]
Modified biochar	Emerging pollutants	Good/Low	[17]
Various bioadsorbents	Heavy metals	Good/Low	[18]
MXenes nanomats	Environmental pollutants	Good/Low	[19]
Semiconductor photocatalyst	Dyes in water	Good/Low	[20]
Carbon dots	Environmental pollutants	Good/Low	[21]
Carbon-based nanomats	Water pollutants	Good/Low	[22]
Bioadsorbents	Emerging pollutants in water	Good/Low	[23]
Low-cost adsorbents	Heavy metals in water	Good/Low	[24]
Lignin-derived materials	Environmental pollutants	Good/Low	[25]
Agricultural wastes	Dyes	Good/Low	[26]
Metal–organic frameworks	Pesticides in water	Good/Low	[27]
Invasive plants biochar	Environmental pollutants	Good/Low	[28]
Low-cost sorbents	Heavy metals in runoff	Good/Low	[29]
Modified biochar	Heavy metals	Good/Low	[30]
Gen-modified microbes	Heavy metals/PHAs in soils	Good/Low	[31]
Low-cost adsorbent	Dye in water	Good/Low	[32]
Biochar	Emerging pollutant in water	Good/Low	[33]
Low-cost adsorbents	Environmental pollutants	Good/Low	[34]
Agricultural by-products	PHAs in urban stormwater	Good/Low	[35]
Agricultural and fruit waste	Environmental pollutants	Good/Low	[36]
Nanomats from wastes	Cd and Cu in water and soil	Good/Low	[37]
Radiation-prepared sorbent	Environmental pollutants	Good/Low	[38]
Biochar	Oil spill pollutants	Good/Low	[39]
Acid-treated clay	Pharmaceuticals	Good/Low	[40]
Low-cost nanosorbents	Environmental pollutants	Good/Low	[41]
Modified low-cost sorbent	Pb(II)	Good/Low	[42]
Low-cost adsorbents	Metals in water	Good/Low	[43]
Hybrid material/iron oxide	Naproxen in water	Good/Low	[44]
Zeolitic frameworks	Herbicide in soil	Good/Low	[45]
Potato peel biochar	The pesticide chlorpyrifos	Good/Low	[46]
Materials from biowaste	Environmental pollutants	Good/Low	[47]
Nanomaterials	Mercury	Good/Low	[48]
Bauxite residue	Organic pollutants in water	Good/Low	[49]
Low-cost materials	Pesticides in groundwater	Good/Low	[50]
Green biomass materials	Oil spill pollutant	Good/Low	[51]

chlorpyrifos with potato peel biochar. Finally, Ashrafi et al. [47] reviewed about the use of materials and nanomaterials derived from biowaste or natural products in the removal of environmental pollutants, while Liu et al. [48] showed the positive results found as regard the remediation of mercury pollution using nanotechnology, and Zhang et al. [49] informed on the high potential of a bauxite residue for the removal of organic pollutants from wastewater due to its adsorption and photocatalysis characteristics, whereas Abbas et al. [50] showed the positive outcome of using low-cost materials as reactive barrier against pesticides in groundwater, ending with Yue et al. [51], who gave details on the efficacy of green biomass-derived materials used to face oil spill pollution.

The whole set of papers selected for this mini-review is briefly summarized in Table 1.

In addition, Ahmed et al. [52] made a review on the removal of hazardous contaminants from wastewater and water, where some comments focus on the need of further treatment for pollutants after being removed through a different process.

Conclusions and prospects

The use of low-cost materials to face environmental pollution is receiving a growing interest, with a high number of interesting works published in the last two years. Among the different alternatives with potential to be efficiently used, some classic raw and waste materials continue to be investigated, while other more innovative (although low-cost) products and procedures (such as some based on nanotechnology) are increasingly on the focus. In fact, different procedures used to enhance the efficacy of raw materials and wastes in removing different pollutants from the environment may be seen as a promising way of future development in this field of research, which could continue to give positive results, and could be even more effective and cheap in the coming years.

CRediT author statement

Avelino Núñez-Delgado: conceptualization, methodology, software, data curation, writing – original draft, visualization, investigation, supervision, validation, writing – review & editing; Esperanza Álvarez-Rodríguez: conceptualization, data curation, visualization, supervision, validation; María J. Fernández-Sanjurjo: conceptualization, data curation, visualization, supervision, validation; Manuel Arias-Estévez: conceptualization, data curation, visualization, supervision, validation; David Fernández-Calviño: conceptualization, data curation, visualization, supervision, validation; M. Victoria López-Ramón: conceptualization, data curation, visualization, supervision, validation; Manuel Sánchez-Polo: conceptualization, data curation, visualization, supervision, validation.

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Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data were used for the research described in the article.

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* of special interest

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This paper is a recent but basic reference regarding the use of raw and modified biochar in the removal of organic and inorganic pollutants.

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This is a recent and at the same time basic reference as regards the use of green-synthesized nanomaterials in water treatment.

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