sustainability

MDPI

Phytoremediation of Mercury Contamination: Bibliometric Analysis

Lina M. Mosquera [1], Diego Paredes Cuervo [2*], Ana M. López [3], Carlos A. Arias [4*], Pedro N. Carvalho [5]

[1] Faculty of Engineering, Environmental Engineering, Universidad Tecnológica del Chocó, Quibdó 270002, Chocó and Colombia; d-lina.mosquera@utch.edu.co
[2] Faculty of Basic Environmental Sciences, Universidad Tecnológica de Pereira, Pereira 660003, Risaralda, Colombia
[3] Faculty of Agricultural Sciences and Agroindustry, Universidad Tecnológica de Pereira, Pereira 660003, Risaralda, Colombia; alopez@utp.edu.co
[4] Department of Biology-Aquatic Biology, Aarhus University, Ole Worms Allé 1, Building 1135, 8000 Århus, Denmark
[5] WATEC—Centre for Water Technology, Aarhus University, Ny Munkegade 120, 8000 Aarhus, Denmark; pedro.carvalho@envs.au.dk
[6] Department of Environmental Science, Aarhus University, Frederiksborgvej 399, 4000 Roskilde, Denmark
* Correspondence: diparede@utp.edu.co (D.P.C.); carlos.arias@bio.au.dk (C.A.A.)

Citation: Mosquera Chaverra, L.; Paredes Cuervo, D.; López Gutiérrez, A.; Arias, C.A.; Carvalho, P.N. Phytoremediation of Mercury Contamination: Bibliometric Analysis. *Sustainability* **2024**, *16*, 9408. https://doi.org/10.3390/su16219408

Academic Editors: Panayiotis G. Dimitrakopoulos, Miklas Scholz, Mario A. Pagnotta and Arshiya Noorani

Received: 25 July 2024
Revised: 5 October 2024
Accepted: 12 October 2024
Published: 30 October 2024



Copyright: © 2024 by the authors. Submitted for possible open access publication under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

Table S1. Top 10 authors with the highest number of articles in WoS and Scopus on the phytoremediation of mercury contamination.

Rank	WoS				Scopus			
	Author	Country	Documents	Citations	Author	Country	Documents	Citations
1	Feng, Xinbin	China	10	251	Wang, Jianxu	China	16	816
2	Liu, Zhongchuang	China	10	190	Feng, Xinbin	China	14	753
3	Wang, Li-Ao	China	9	140	Kumar, Amit	Canada	11	544
4	Wang, Jianxu	China	8	218	Liu, Zhongchuang	China	10	151
5	Anderson, Christopher W. N.	New Zealand	8	205	Meagher, Richard Brian	United States	9	821
6	Marrugo Negrete, Jose	Colombia	7	287	Kiyono, Masako	Japan	8	171
7	Smolinska, Beata	Poland	7	110	Wang, Li-Ao	China	8	148
8	Kiyono, Masako	Japan	6	71	Chen, Jian	China	8	410
9	Nakamura, Ryosuke	Japan	6	71	Anderson, Christopher W. N.	New Zealand	8	798
10	Pereira, Eduarda	Portugal	6	95	Wang, H	China	8	232

Table S2. Journals with the greatest scientific production in WoS.

Rank	Source	Documents	Percentage of publications	Citations	H	Q (2022)	Country	Subject area
1	Environmental Science and Pollution Research	26	5.7	564	154	Q2	Germany	Environmental Science; Medicine
2	International Journal of Phytoremediation	26	5.7	479	98	Q2	United Kingdom	Environmental Science; Agricultural and Biological Sciences

3	Chemosphere	23	5.0	875	98	Q2	United Kingdom	Environmental Science; Medicine; Chemistry
4	Science of the Total Environment	19	4.2	1551	317	Q1	Netherlands	Environmental Science
5	Journal of Hazardous Materials	17	3.7	546	329	Q1	Germany	Environmental Science
6	Ecotoxicology and Environmental Safety	14	3.1	785	161	Q1	United States	Environmental Science; Medicine
7	Water Air and Soil Pollution	13	2.8	239	127	Q2	Netherlands	Environmental Science
8	Environmental Monitoring and Assessment	10	2.2	238	132	Q2	Netherlands	Environmental Science; Medicine
9	Ecological Engineering	7	1.5	180	150	Q1	Netherlands	Environmental Science
10	Environmental Pollution	7	1.5	364	275	Q1	United Kingdom	Environmental Science; Medicine; Pharmacology, Toxicology and Pharmaceutics

Table S3. Journals with the greatest scientific production in Scopus.

Rank	Source	Documents	Percentage of publications	Citations	H	Q (2022)	Country	Subject area
1	Chemosphere	26	3.7	2031	288	Q1	United Kingdom	Environmental Science; Medicine; Chemistry

2	Environmental Science and Pollution Research	26	3.7	704	154	Q2	Germany	Environmental Science; Medicine
3	International Journal of Phytoremediation	26	3.7	963	98	Q2	United Kingdom	Environmental Science; Agricultural and Biological Sciences
4	Ecotoxicology And Environmental Safety	19	2.7	1500	161	Q1	United States	Environmental Science; Medicine
5	Journal Of Hazardous Materials	19	2.7	1235	329	Q1	Germany	Environmental Science
6	Water, Air, And Soil Pollution	19	2.7	826	127	Q2	Netherlands	Environmental Science
7	Science Of the Total Environment	16	2.3	1582	317	Q1	Netherlands	Environmental Science
8	Environmental Pollution	14	2.0	1297	275	Q1	United Kingdom	Environmental Science; Medicine; Pharmacology, Toxicology and Pharmaceutics
9	Environmental Monitoring and Assessment	13	1.9	1004	132	Q2	Netherlands	Environmental Science; Medicine
10	Ecological Engineering	8	1.2	222	150	Q1	Netherlands	Environmental Science

Table S4. Most cited papers on the phytoremediation of mercury pollution in WoS.

No.	First author/ Corresponding author	Institution and Country of origin (based on first author's affiliation)	Journal	Tittle	Publication Year	Citations	Document type	References
1	Liu, L/Guo, M	Delaware State University (USA)	Science of the Total Environment	Remediation techniques for heavy metal-contaminated soils: Principles and applicability	2018	814	Review	[69]
2	Park, J/Lee, Y, Martinoia, E	University of Zurich (Zurich) and Pohang University of Science and Technology (Korea)	The Plant Journal	The phytochelatin transporters AtABCC1 and AtABCC2 mediate tolerance to cadmium and mercury.	2012	382	Article	[70]
3	Li, C/Yan, X	Academy of Agricultural Sciences (China)	Soil and Sediment Contamination	A review on heavy metals contamination in soil: Effects, sources, and remediation techniques	2019	277	Review	[71]
4	Marchand, L	Université Bordeaux 1 (France)	Environmental pollution	Metal and metalloid removal in constructed wetlands, with emphasis on the importance of plants and standardized measurements: A review	2010	262	Review	[132]
5	Xiao, R	Northwest A&F University (China)	Ecotoxicology and environmental safety	Soil heavy metal contamination and health risks associated with artisanal gold mining in Tongguan, Shaanxi, China	2017	246	Article	[133]

6	Rahman, M	Kanazawa University (Japan)	Chemosphere	Aquatic arsenic: Phytoremediation using floating macrophytes	2011	230	Review	[134]
7	Khanam, R/Nayak, A	ICAR – National Rice Research Institute (India)	Science of the Total Environment	Metal (loid) s (As, Hg, Se, Pb and Cd) in paddy soil: Bioavailability and potential risk to human health	2019	178	Review	[135]
8	Hernández, L	Universidad Autónoma de Madrid (Spain)	Journal of Experimental Botany	Contribution of glutathione to the control of cellular redox homeostasis under toxic metal and metalloid stress	2015	174	Review	[136]
9	Wang, L/Hou, D	Tsinghua University (China)	Environment international	Remediation of mercury contaminated soil, water, and air: A review of emerging materials and innovative technologies	2020	164	Review	[137]
10	OB, O	Tshwane University of Technology (South Africa)	International Journal of Physical Sciences	Remediation of heavy metals in drinking water and wastewater treatment systems: processes and applications	2010	158	Review	138
11	Arao, T	National Institute for Agro-Environmental Sciences (Japan)	Paddy and water Environment	Heavy metal contamination of agricultural soil and countermeasures in Japan	2010	158	Review	[139]
12	Gaur, N	School of Biotechnology, Rajiv Gandhi Proudyogiki Vishwavidyalaya (India)	Environmental Science: Processes & Impacts	A review with recent advancements on bioremediation-based abolition of heavy metals	2014	139	Review	[140]

13	Singh, J	BB Ambedkar (Central) University (India)	Gene	Genetically engineered bacteria: an emerging tool for environmental remediation and future research perspectives	2011	138	Review	[141]
14	Bonanno, G	University of Catania (Italy)	Ecotoxicology and Environmental Safety	Comparative performance of trace element bioaccumulation and biomonitoring in the plant species *Typha domingensis*, *Phragmites australis,* and *Arundo donax*	2013	125	Article	[142]
15	Marrugo-Negrete, J/Díez, S	University of Córdoba (Colombia)/ Institute of Environmental Assessment and Water Research (Spain)	Chemosphere	Phytoremediation of mercury-contaminated soils by *Jatropha curcas*	2015	122	Article	[24]
16	Li, K/Ramakrishna, W	Michigan Technological University (USA)	Journal of hazardous materials	Effect of multiple metal resistant bacteria from contaminated lake sediments on metal accumulation and plant growth	2011	106	Article	[143]
17	Monterroso, C	Universidade de Santiago de Compostela (Spain)	Applied Geochemistry	Heavy metal distribution in mine-soils and plants growing in a Pb/Zn-mining area in NW Spain	2014	96	Article	[144]
18	Mleczek, M/Rutkowski, P	University of Life Sciences in Poznan (Poland)	Biomass and Bioenergy	Biomass productivity and phytoremediation potential of *Salix alba* and *Salix viminalis*	2010	90	Article	[145]

19	Bonanno, G	University of Catania (Italy)	Ecotoxicology and Environmental Safety	Comparative analysis of element concentrations and translocation in three wetland congener plants: *Typha domingensis*, *Typha latifolia,* and *Typha angustifolia*	2017	88	Article	[146]
20	Li, W	The Hong Kong Institute of Education (Hong Kong)	Environmental Science and Pollution Research	Health risk and significance of mercury in the environment	2015	87	Review	[147]

Table S5. Most cited papers on the phytoremediation of mercury pollution in Scopus.

No.	**First author/ Corresponding author**	**Institution and Country of origin (based on first author's affiliation)**	**Journal**	**Tittle**	**Publication Year**	**Citations**	**Document type**	**References**
1	Schützendübel, A	Georg-August-University Göttingen (Germany)	Journal of experimental botany	Plant responses to abiotic stresses: heavy metal-induced oxidative stress and protection	2002	1766	Review	[72]

				by mycorrhization				
2	Mulligan, C	Concordia University (Canada)	Engineering geology	Remediation technologies for metal-contaminated soils and groundwater: An evaluation	2001	1235	Review	[73]
3	He, J	Zhejiang University (China) and University of Florida (USA)	Journal of Trace Elements in Medicine and Biology	Trace elements in agroecosystems and impacts on the environment	2005	1171	Review	[74]

4	Tangahu, B	Universiti Kebangsaan (Malaysia)	International Journal of Chemical Engineering	A review on heavy metals (As, Pb, and Hg) uptake by plants through phytoremediation	2011	1099	Review	[148]
5	Liu, L/Guo, M	Delaware State University (USA)	Science of The Total Environment	Remediation techniques for heavy metal-contaminated soils: Principles and applicability	2018	954	Review	[69]
6	McGrath, S	Rothamsted Research	Current Opinion in Biotechnology	Phytoextraction of metals	2003	902	Review	[149]

		(United Kingdom)		and metalloids from contaminated soils				
7	Wong, M	Hong Kong Baptist University (Hong Kong)	Chemosphere	Ecological restoration of mine degraded soils, with emphasis on metal contaminated soils	2003	861	Review	[150]
8	Weis, J	Rutgers University (USA)	Environment International	Metal uptake, transport, and release by wetland plants: Implications for	2004	776	Review	[151]

				phytoremediation and restoration			
9	Ojuederie, O/Babalola, O	North-West University (South Africa)	International journal of environmental research and public health	Microbial and plant-assisted bioremediation of heavy metal polluted environments: A review	2017	587	Review [152]
10	Gall, J/Rajakaruna, N	College of the Atlantic (USA) And North-West University (South Africa)	Environmental monitoring and assessment	Transfer of heavy metals through terrestrial food webs: A review	2015	519	Review [3]
11	Ashraf, S	University of Agriculture (Pakistan)	Ecotoxicology and Environmental Safety	Phytoremediation:	2019	483	Review [14]

12	Wang, J/Feng, X	Institute of Geochemistry, Chinese Academy of Sciences (China)	Journal of Hazardous Materials	Environmentally sustainable way for reclamation of heavy metal polluted soils Remediation of mercury contaminated sites: A review	2012	472	Review	[22]
13	Park, J/Lee, Y, Martinoia, E	University of Zurich (Zurich) and Pohang University of Science and Technology (Korea)	The Plant Journal	The phytochelatin transporters AtABCC1 and AtABCC2 mediate tolerance to	2012	444	Article	[70]

				cadmium and mercury				
14	Patra, M.	University of Calcutta (India)	The Botanical Review	Mercury toxicity in plants	2000	442	Review	[153]
15	McGrath, S	Agriculture and the Environment Division IACR-Rothamsted (United Kingdom)	Advances in Agronomy	Phytoremediation of metals, metalloids, and radionuclides	2002	419	Review	[154]
16	Krämer, U	Max Planck Institute of Molecular Plant Physiology (Germany)	Current opinion in Biotechnology	Phytoremediation: novel approaches to cleaning up polluted soils	2005	380	Review	[155]
17	Doty, S	University of Washington (USA)	New Phytologist	Enhancing	2008	371	Review	[156]

				phytoremediation through the use of transgenics and endophytes				
18	Eapen, S	Bhabha Atomic Research Centre (India)	Biotechnology Advances	Prospects of genetic engineering of plants for phytoremediation of toxic metals	2005	348	Review	[157]
19	Li, C/Yan, X	Academy of Agricultural Sciences (China)	Soil and Sediment Contamination	A review on heavy metals contamination in soil: Effects, sources,	2019	340	Review	[71]

				and remediation techniques Performance of bioaugmentation-assisted phytoextraction applied to metal contaminated soils: A review				
20	Lebeau, T	University of Haute-Alsace (France)	Environmental Pollution		2008	301	Review	[158]

Table S6. Top 28 keywords with the strongest citation bursts in WoS.

Keywords	Frequently	Year_q1	Year_med	Year_q3
Diversity	12	2020	2022	2023
Soils	44	2015	2020	2022
Remediation	43	2018	2020	2022
Lead	40	2018	2020	2022
Plant-Growth	16	2019	2021	2022
Stress	16	2017	2021	2022
***Oryza-Sativa* L.**	6	2020	2022	2022
Escherichia-coli	9	2010	2013	2021
Cadmium	88	2014	2018	2021
Mercury	48	2015	2018	2021
Phytoremediation	184	2015	2019	2021
Heavy-Metals	155	2016	2019	2021
Accumulation	152	2015	2019	2021
Aquatic macrophytes	10	2014	2016	2020
Phytoextraction	51	2014	2017	2020
Resistance	16	2014	2017	2020
Plants	84	2015	2018	2020
Availability	6	2012	2014	2019
Metal	5	2013	2015	2019
Zinc	19	2012	2016	2019
Metals	17	2014	2016	2019
Organic-Acids	6	2012	2014	2018
Glutathione	11	2013	2017	2018
Exposure	9	2014	2015	2017
Thlaspi-caerulescens	8	2012	2015	2017
Areas	7	2012	2013	2016
Volatilization	7	2010	2010	2014
Nickel	5	2012	2013	2013

Table S7. Top 18 keywords with the strongest citation bursts in Scopus.

Keywords	Frequently	Year_q1	Year_med	Year_q3
Plant root	99	2012	2016	2019
Phytoremediation	593	2012	2017	2020
Mercury	504	2012	2017	2020
Bioremediation	411	2014	2017	2020
Soil pollution	357	2014	2018	2021
Heavy metal	260	2015	2018	2021
Arsenic	137	2014	2018	2021
Soil	177	2017	2020	2022
China	60	2017	2020	2022
Phytostabilization	32	2015	2020	2022
Human	49	2016	2021	2022
Ecosystem	36	2017	2021	2022
Risk Assessment	38	2020	2022	2022
Siderophore	13	2021	2022	2022
Inductively coupled plasma mass spectrometry	13	2019	2022	2023
Agricultural land	8	2022	2023	2023
Mycorrhizae	7	2016	2023	2023
Brassicaceae	5	2017	2023	2023

Table S8. Plants used in mercury phytoremediation.

No	Plant	Country	Test conditions	Hg Concentration	Author	References
1	*Ipomoea aquatica*	Indonesia	Field trial	85.36 mg/kg	Muryani et al., 2023	[28]
2	*Syngonium podophyllum*			74.13 mg/kg		
3	*Imperata cylindrica*			73.57 mg/kg		
4	*Solanum nigrum L.*	China	Pot experiment	0.51–3.95 mg/kg	Zhao et al., 2023	[159]
5	*Cardamine violifolia*	China	Pot experiment	6000 μg/g	Cui et al., 2023	[32]
6	*Jatropha curcas*	Colombia (Córdoba)	Pot experiment	1, 5, and 10 μg/g Hg.	Marrugo – Negrete et al., 2015.	[160]
				5, 10, 20, 40, and 80 $\mu g \cdot ml^{-1}$	Marrugo – Negrete et al., 2016.	[161]
7	*Clidemia sericea* D. Don	Colombia	Pot experiment	3.11 (mg kg^{-1}).	Durante-Yánez, 2022.	[162]
8	*Opuntia stricta* *Aloe vera* *Setcreasea purpurea* *Chlorophytum comosum*	China	Pot experiment	2, 10, 50, 100, 200, 500, and 800 $\mu g \cdot L^{-1}$	Liu et al., 2017	[163]
9	*Oxalis corniculata* *Paspalum distichum*	China	Pot experiment	233 μg/g	Ding et al., 2019	[164]

10	*Juncus maritimus*	Spain	Pot experiment	Hg: 0.380–6.650 μg g^{-}	García-Ordiales et al., 2020	[165]
11	*Arthraxon hispidus*	China (Wanshan)	Field trial	140 μg g^{-}	Qian et al., 2018	[26]
12	*Eremochloa ciliaris*			125 μg g^{-}		
13	*Brassica juncea* L	United States	Pot experiment	0, 5, 10, 25, 50, and 100 μM	Shiyab et al., 2009	[166]
14	*Jatropha curcas*	Colombia	Field trial	127–184 μg kg^{-1}	Marrugo-Madrid et al., 2020	[101]
15	P*opulus tomentosa* (álamo)	China	Pot experiment	10–20 μM $HgCl_2$	Sun et al, 2018	[35]
16	*Arabidopsis*	China	Pot experiment	10–20 μM $HgCl_2$		
17	*Cyrtomium macrohyllum*	China	Pot experiment	5, 10, 20, 50, 100, 200, 500, and 1000 mg kg^{-1} $HgCl_2$.		
18	*Woodwardia unigemmata*	China	Field trial	Hg: 69.1 mg kg^{-1}	Xun et al., 2017	[25]
19	*Ixeris denticulata*	China				
20	*Xanthium sibiricum patrin ex wider a*	China				
21	*Lupinis albus* L	Spain	Pot experiment	HgCl2: 5 and 10 μM	Esteban et al., 2008	[123]
22	*Suaeda vermiculata*	Saudi Arabia	Pot experiment	Hg: 1.367 mg kg^{-1}	Ibraheem et al., 2022	[124]
23	*Suaeda schimperi*			Hg: 1.456 mg kg^{-1}		
24	*Inga edulis* *Jatropha curcas*	Colombia	Field trial	230–6320 ng g^{-1}	Marrugo-Negrete et al., 2016	[24]

25	*Clidemia sp.*
27	*Plectramthus sp.*

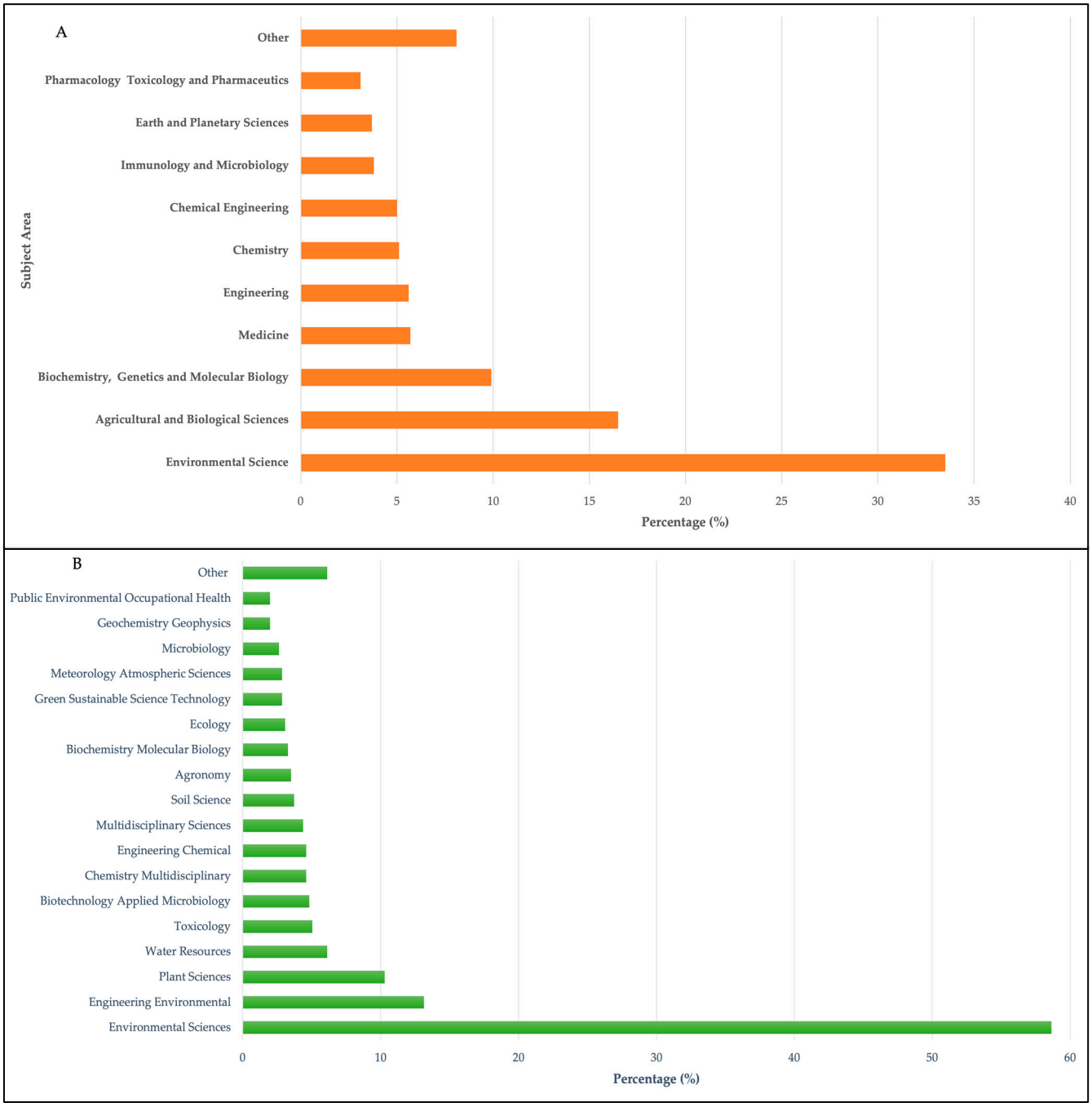
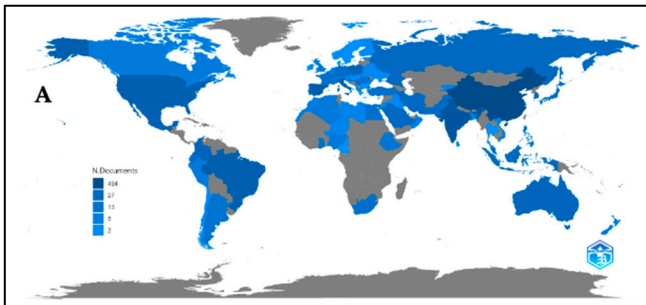
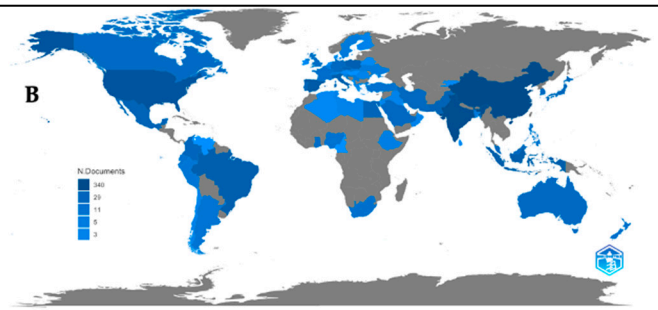


Figure S1. Documents by subject area: (**A**) Scopus and (**B**) WoS.



Rank	Country	N (%)	Citations
1	China	(115, 25.2%)	2784
2	India	(58, 12.7%)	1551
3	Spain	(40, 8.8%)	867



Rank	Country	N (%)	Citations
1	India	(145, 20.8%)	1551
2	China	(131, 17.9%)	2784
3	USA	(86, 12.3%)	1222

Figure S2. Countries' scientific production: (**A**) WoS and (**B**) Scopus.

The intensity of the blue color is related to the countries with the highest number of published papers. In contrast, the gray color is related to the countries where no papers related to this topic have been published.

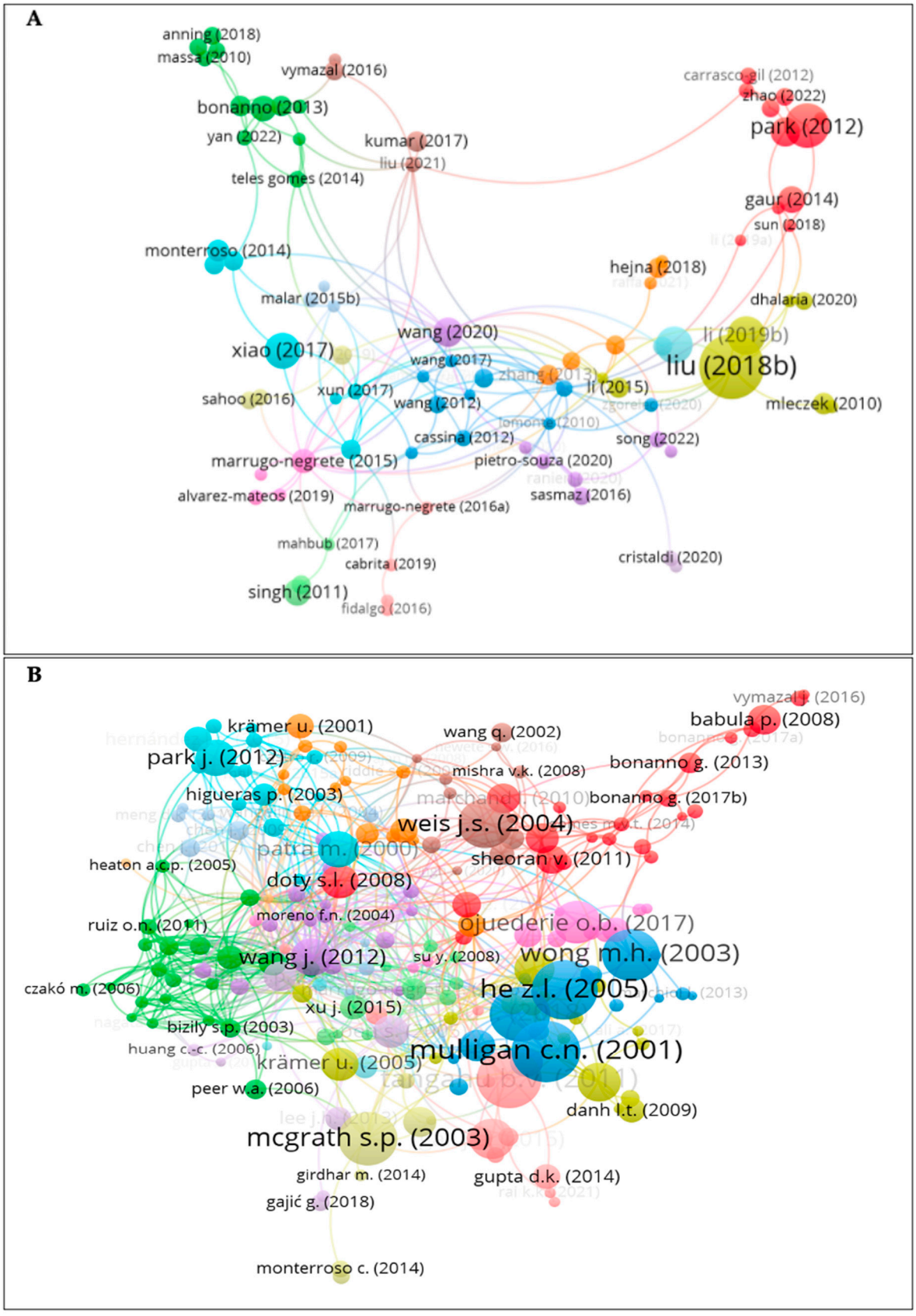


Figure S3. Highly cited articles: (**A**) WoS and (**B**) Scopus.

References

3. Gall, J.E.; Boyd, R.S.; Rajakaruna, N. Transfer of heavy metals through terrestrial food webs: a review. *J. Environ Monit Asses.* **2015**, 187, 201. https://doi.org/10.1007/s10661-015-4436-3

14. Ashraf, S.; Ali, Q.; Zahir, Z.A.; Ashraf, H.N.; Ashraf, S. Phytoremediation: Environmentally sustainable way for reclamation of heavy metal polluted soils. *J. Ecotoxicol. Environ. Saf.* **2019**, 174, 714-727. https://doi.org/10.1016/j.ecoenv.2019.02.068

22. Wang, J.; Feng, X.; Anderson, C. W.; Xing, Y.; Shang, L Remediation of mercury contaminated sites – A review. *J. Hazard. Mater*. **2012**, 221–222, 1–18.: https://doi.org/10.1016/j.jhazmat.2012.04.035.

24. Marrugo-Negrete, J.; Marrugo-Madrid, S.; Pinedo-Hernández, J.; Durango-Hernández, J.; Díez, S. Screening of native plant species for phytoremediation potential at a Hg-contaminated mining site. *J. Sci.Total Environ*. 2016, 542, 809–816. https://doi.org/10.1016/j.scitotenv.2015.10.117.

25. Xun, Y.; Feng, L.; Li, Y.; Dong, H. Mercury accumulation plant Cyrtomium macrophyllum and its potential for phytoremediation of mercury polluted sites. *J. Chemosphere*. **2017**, 189, 161–170. https://doi.org/10.1016/j.chemosphere.2017.09.055.

26. Qian, X.; Wu, Y.; Zhou, H.; Xu, X.; Xu, Z.; Shang, L.; Qiu, G. Total mercury and methylmercury accumulation in wild plants grown at wastelands composed of mine tailings: Insights into potential candidates for phytoremediation. *J. Environ. Pollut.* **2018**, 239, 757–767. https://doi.org/10.1016/j.envpol.2018.04.105.

28. Muryani, E.; Sajidan, S.; Budiastuti, M. T. S.; Pranoto, P. Diversity and potential of herbaceous plants as mercury (Hg) hyperaccumulators in small-scale gold mining sites in Pancurendang, Banyumas, Indonesia. *J. Biodiversitas*. **2023**, 24, 3364–3372. https://doi.org/10.13057/biodiv/d240632

32. Cui, L.; Tian, X.; Xie, H.; Cong, X.; Cui, L.; Wu, H.; Wang, J.; Li, B.; Zhao, J.; Cui, Y.; Feng, X.; Li, Y.-F. Cardamine violifolia as a potential Hg hyperaccumulator and the cellular responses. *J. Sci. Total Environ.* **2023**, 863, 160940. https://doi.org/10.1016/j.scitotenv.2022.160940.

35. Sun, L.; Ma, Y.; Wang, H.; Huang, W.; Wang, X.; Han, L.; Sun, W.; Han, E.; Wang, B. Overexpression of PtABCC1 contributes to mercury tolerance and accumulation in Arabidopsis and poplar. *J. Biochem. Biophys Res Commun*. **2018,** 497, 997–1002. https://doi.org/10.1016/j.bbrc.2018.02.133.

69. Liu, L.; Li, W.; Song, W.; Guo, M. Remediation techniques for heavy metal-contaminated soils: Principles and applicability. *J. Environ Sci Technol.* **2018,** 633, 206-219. https://doi.org/10.1016/j.scitotenv.2018.03.161

70. Park, J.; Song, W. Y.; Ko, D.; Eom, Y.; Hansen, T. H.; Schiller, M.; Lee, Y. The phytochelatin transporters AtABCC1 and AtABCC2 mediate tolerance to cadmium and mercury. *J. Plant Journal*. **2012**, 69, 278–288. https://doi.org/10.1111/j.1365-313X.2011.04789.x

71. Li, C., Zhou, K., Qin, W., Tian, C., Qi, M., Yan, X., & Han, W. (2019). A review on heavy metals contamination in soil: effects, sources, and remediation techniques. *Soil and Sediment Contamination: An International Journal*. **2019**, *28*(4), 380-394. https://doi.org/10.1080/15320383.2019.1592108

72. Schutzendubel, A.; Polle, A. Plant responses to abiotic stresses: heavy metal-induced oxidative stress and protection by mycorrhization. *J. Exp Bot*. 2002, 53, 1351–1365. https://doi.org/10.1093/jexbot/53.372.1351.

73. Mulligan, C. N.; Yong, R. N.; Gibbs, B. F. Remediation technologies for metal-contaminated soils and groundwater: an evaluation. *J. Eng Geol*. **2001**, 60, 193–207. https://doi.org/10.1016/S0013-7952(00)00101-0.

74. He, Z. L.; Yang, X. E.; Stoffella, P. J. Trace elements in agroecosystems and impacts on the environment. *J. Trace Elem Med Bio*. **2005**, 19, 125 – 140. https://doi.org/10.1016/j.jtemb.2005.02.010

101. Marrugo–Madrid, S.; Turull, M.; Montes, G.E.; Pico, M.V.; Marrugo–Negrete, J.L.; Díez, S. Phytoremediation of mercury in soils impacted by gold mining: A case study of Colombia. *Bioremediation for Environmental Sustainability: Toxicity, Mechanisms of Contaminants Degradation, Detoxification and Challenges*. **2021**, 145 – 160. https://doi.org/10.1016/B978-0-12-820524-2.00007-9

123. Esteban, E.; Moreno, E.; Penalosa, J.; Cabrero, J. I.; Millán, R.; Zornoza, P. Short and long-term uptake of Hg in white lupin plants: Kinetics and stress indicators. *J. Environ. Exp. Bot*. **2008**, 62, 316 – 322. https://doi.org/10.1016/j.envexpbot.2007.10.006.

124. Ibraheem, F.; Al-Hazmi, N.; El-Morsy, M.; Mosa, A. Ecological risk assessment of potential toxic elements in salt marshes on the east coast of the red sea: Differential physiological responses and adaptation capacities of dominant halophytes. *J. Sustainability.* **2021**, 13, 11282. https://doi.org/10.3390/su132011282

132. Marchand, L.; Mench, M.; Jacob, D. L.; Otte, M. L. Metal and metalloid removal in constructed wetlands, with emphasis on the importance of plants and standardized measurements: A review. *J. Environ Pollut.* **2010**, 158, 3447 – 3461**.** https://doi.org/10.1016/j.envpol.2010.08.018.

133. Xiao, R.; Wang, S.; Li, R.; Wang, J. J.; Zhang, Z. Soil heavy metal contamination and health risks associated with artisanal gold mining in Tongguan, Shaanxi, China. *J.Ecotoxicol Environ Saf*. **2017**, 141, 17–24, 201. https://doi.org/10.1016/j.ecoenv.2017.03.002.

134. Rahman, M. A.; Hasegawa, H. Aquatic arsenic: Phytoremediation using floating macrophytes," *J. Chemosphere*. **2011**, 83, 633–646. https://doi.org/10.1016/j.chemosphere.2011.02.045.

135. Khanam, R.; Kumar, A.; Nayak, A. K.; Shahid, M.; Tripathi, R.; Vijayakumar, S.; Pathak, H. Metal(loid)s (As, Hg, Se, Pb and Cd) in paddy soil: Bioavailability and potential risk to human health. *J. Sci.Total Environ.* **2020**, 699, 134330, 2020. https://doi.org/10.1016/j.scitotenv.2019.134330.

136. Hernández, L. E., Sobrino-Plata, J., Montero-Palmero, M. B., Carrasco-Gil, S., Flores-Cáceres, M. L., Ortega-Villasante, C., & Escobar, C. Contribution of glutathione to the control of cellular redox homeostasis under toxic metal and metalloid stress. *J. Exp. Bot*. **2015**, 66, 2901 – 2911. https://doi.org/10.1093/jxb/erv063.

137. Wang, L.; Hou, D.; Cao, Y.; Ok, Y. S.; Tack, F. M.; Rinklebe, J.; O'Connor, D. Remediation of mercury contaminated soil, water, and air: A review of emerging materials and innovative technologies. *J. Environ Int.* **2020**, 134, p. 10528. https://doi.org/10.1016/j.envint.2019.105281.

138. OB, A.; Muchie, M. Remediation of heavy metals in drinking water and wastewater treatment systems: processes and applications. *Int. J. Phys. Sci*. **2010**, 5, 1807–1817.

139. Arao, T.; Ishikawa, S.; Murakami, M.; Abe, K.; Maejima, Y.; Makino, T. Heavy metal contamination of agricultural soil and countermeasures in Japan. *Paddy and Water Environ.* **2010**, 8, 247 – 257. https://doi.org/10.1007/s10333-010-0205-7.

140. Gaur, N.; Flora, G.; Yadav, M.; Tiwari, A. A review with recent advancements on bioremediation-based abolition of heavy metals. *J. Environ. Sci.: Processes Impacts*. **2014**, 16, 180–193, 2014, https://doi-org/10.1039/C3EM00491K.

141. Singh, J. S.; Abhilash, P. C.; Singh, H. B.; Singh, R. P.; Singh, D. P. Genetically engineered bacteria: An emerging tool for environmental remediation and future research perspectives. *J. Gene*. **2011**, 480, 1–9. https://doi.org/10.1016/j.gene.2011.03.001.

142. Bonanno, G. "Comparative performance of trace element bioaccumulation and biomonitoring in the plant species Typha domingensis, Phragmites australis and Arundo donax. *J. Ecotoxicol Environ Saf*. **2013**, 97, 124 – 130. https://doi.org/10.1016/j.ecoenv.2013.07.017.

143. Li, K.; Ramakrishna, W. Effect of multiple metal resistant bacteria from contaminated lake sediments on metal accumulation and plant growth. *J. Hazard Mater*. **2011**, 189, 531–539. https://doi.org/10.1016/j.jhazmat.2011.02.075.

144. Monterroso, C.; Rodríguez, F.; Chaves, R.; Diez, J.; Becerra-Castro, C.; Kidd, P. S.; Macías, F. Heavy metal distribution in mine-soils and plants growing in a Pb/Zn-mining area in NW Spain. *J. Appl Geochem*. **2014**, 44, 3 – 11. https://doi.org/10.1016/j.apgeochem.2013.09.001.

145. Mleczek, M.; Rutkowski, P.; Rissmann, I.; Kaczmarek, Z.; Golinski, P.; Szentner, K.; Stachowiak, A. Biomass productivity and phytoremediation potential of Salix alba and Salix viminalis.. *J. Biomass Bioenergy.* **2010**, 34, 1410 – 1418. https://doi.org/10.1016/j.biombioe.2010.04.012.

146. Bonanno, G.; Cirelli, G.L. Comparative analysis of element concentrations and translocation in three wetland congener plants: Typha domingensis, Typha latifolia and Typha angustifolia. *J. Ecotoxicol Environ Saf*. 2017, 143, 92. https://doi.org/10.1016/j.ecoenv.2017.05.021.

147. Li, W.C., Tse, H.F. Health risk and significance of mercury in the environment. *J. Environ Sci Pollut Res*. **2015**, **22**, 192–201. https://doi.org/10.1007/s11356-014-3544-x

148. Tangahu, B. V., Sheikh Abdullah, S. R.; Basri, H., Idris, M.; Anuar, N.; Mukhlisin, M. A review on heavy metals (As, Pb, and Hg) uptake by plants through phytoremediation. *Int. J. Chem. Eng*. **2011**, 1, 939161. https://doi.org/10.1155/2011/93916

149. McGrath, S. P.; Zhao, F. J. Phytoextraction of metals and metalloids from contaminated soils. *J. Curr. Opin. Biotechnol*, **2003,** 14, 277–282. https://doi.org/10.1016/S0958-1669(03)00060-0.

150. Wong, M. H. Ecological restoration of mine degraded soils, with emphasis on metal contaminated soils. *J. Chemosphere.* **2003**, 14, 277–281. https://doi.org/10.1016/S0045-6535(02)00232-1.

151. Weis, J. S.; Weis, P. Metal uptake, transport and release by wetland plants: implications for phytoremediation and restoration. J. *Environ. Int*. **2004**, 30, 685–700. https://doi.org/10.1016/j.envint.2003.11.002.

152. Ojuederie, O. B.; Babalola, O. O. Microbial and plant-assisted bioremediation of heavy metal polluted environments: A review. *Int J Environ Res Public Health*. **2017,** 14, 1504. https://doi-org/10.1007/s10661-015-4436-3

153. Patra, M.; Sharma, A. Mercury toxicity in plants. *The Botanical Review*. **2000,** 66, 379–422. https://doi.org/10.1007/BF02868923

154. McGrath, S. P.; Zhao, J.; Lombi, E. Phytoremediation of metals, metalloids, and radionuclides. *J. Adv. Agro*. **2002**, 75, 1–56. https://doi.org/10.1016/S0065-2113(02)75002-5.

155. Krämer, U. Phytoremediation: novel approaches to cleaning up polluted soils. *J. Curr. Opin. Biotechnol*. **2005,** 16, 133–141. https://doi.org/10.1016/j.copbio.2005.02.006.

156. Doty, S. L. Enhancing phytoremediation through the use of transgenics and endophytes. *J. New Phytologist*. **2008,** 179, 318 -333. https://doi.org/10.1111/j.1469-8137.2008.02446.x

157. Eapen, S.; D'souza, S. F. Prospects of genetic engineering of plants for phytoremediation of toxic metals. *J. Biotechnol Adv*. **2005**, 23, 97–114.: https://doi.org/10.1016/j.biotechadv.2004.10.001.

158. Lebeau, T., Braud, A., & Jézéquel, K. (2008). Performance of bioaugmentation-assisted phytoextraction applied to metal contaminated soils: a review. *J. Environ Pollut*. **2008**, 153, 497 – 522. https://doi.org/10.1016/j.envpol.2007.09.015.

159. Zhao, R.; Cao, X.; Li, X.; Li, T.; Zhang, H.; Cui, X.; Cui, Z. Ecological toxicity of Cd, Pb, Zn, Hg and regulation mechanism in Solanum nigrum L. *J. Chemosphere*. **2023**, 313, 137447. https://doi.org/10.1016/j.chemosphere.2022.137447.

160. Marrugo-Negrete, J.; Durango-Hernández, J.; Pinedo-Hernández, J.; Olivero-Verbel, J.; Díez, S. Phytoremediation of mercury-contaminated soils by Jatropha curcas. *J. Chemosphere*. **2015**, 127, 58 – 63. https://doi.org/10.1016/j.chemosphere.2014.12.073.

161. Marrugo-Negrete, J.; Durango-Hernández, J.; Pinedo-Hernández, J.; Enamorado-Montes, G.; Díez, S. Mercury uptake and effects on growth in Jatropha curcas. *J. Environ Sci*. **2016**, *48*, 120-125. https://doi.org/10.1016/j.jes.2015.10.036

162. Durante-Yánez, E. V.; Martínez-Macea, M. A.; Enamorado-Montes, G.; Combatt Caballero, E.; Marrugo-Negrete. Phytoremediation of Soils Contaminated with Heavy Metals from Gold Mining Activities Using Clidemia sericea D. Don. *J. Plants*. **2022,** 11. https://doi.org/10.3390/plants11050597.

163. Liu, Z.; Wang, L. A.; Xu, J.; Ding, S.; Feng, X.; Xiao, H. Effects of different concentrations of mercury on accumulation of mercury by five plant species. *J. Ecol Eng*. **2017**, 106, 273 – 278. https://doi.org/10.1016/j.ecoleng.2017.05.051.

164. Ding, W.; Zhang, J.; Wu, S. C.; Zhang, S.; Christie, P.; Liang, P. Responses of the grass Paspalum distichum L. to Hg stress: A proteomic study. *J. Ecotoxicol Environ Saf*. **2019**, 183, 109549. https://doi.org/10.1016/j.ecoenv.2019.109549.

165. Garcia-Ordiales, E.; Roqueñí, N.; Loredo, J. Mercury bioaccumulation by Juncus maritimus grown in a Hg contaminated salt marsh (northern Spain). *J. Mar Chem.* **2020**, 226, 103859. https://doi.org/10.1016/j.marchem.2020.103859.

166. Shiyab, S., Chen, J.; Han, F. X.; Monts, D. L.; Matta, F. B.; Gu, M.; Su, Y. (2009). Phytotoxicity of mercury in Indian mustard (Brassica juncea L.). *J. Ecotoxicol Environ Saf*. **2009**, 72, 619 – 625. https://doi.org/10.1016/j.ecoenv.2008.06.002