Bibliometric Analysis of Articles Published in The Scopus Database In 2019-2021 Pertaining to The Problem of Heavy Metals

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Abstract
Soil and nature contamination by heavy metals resulting from increased anthropogenic pressure associated with industry and agriculture poses a severe threat to environmental ecosystems and human populations. This study aims to assess and analyze the problem of heavy metal contamination using bibliometric methods to contribute to the evolution of knowledge about the ecological, economic, and social impacts of heavy metals. The methodical process included: (I) selection and analysis of search topics in Scopus and databases; (II) application of Bibliometric and Visualization of Similarity Viewer (VOSviewer) programs to the data collected; (III) consideration of the scientific structure of the relationship between the topics of heavy metals, their sub-themes, and program areas; (IV) Literature review on author keywords. 817 articles were selected, and the most cited country, institution, and authors analyzed articles and journals. At the country level, China had the highest number of contributions from authors. The most popular research topic keywords were "heavy metals" and "soil pollution," with cadmium being the most highly researched heavy metal. This study provides further understanding of heavy metal pollution trends, and the analyzed data can guide future research directions.
Keywords: soil pollution; keywords; authors; citations; VOSviewer; treatment technologies

1. INTRODUCTION

One of the most significant challenges facing society today is the contamination of heavy metals (HM) resulting from urbanization and industrialization (Hu et al., 2021; Li et al., 2021; Lv & Liu, 2019). Metal pollution in agricultural fields and soil has led to the contamination of food sources and poses a threat to human health (Jia et al., 2020; Singh et al., 2020). HM and metalloids such as Cr, Co, Cu, Zn, Hg, Mn, Pb, Ni, Cd, Sn have a significant toxic effect. The use of fertilizers, increasing cropping intensity, and the development of farming practices with advanced technology have led to HM contamination of agricultural fields, resulting in a rapid increase in concentrations of metals or metalloids in agricultural soils that affects plant growth, food security, and soil microflora (Thakur et al., 2021; Zhao et al., 2021; Abeysingha et al., 2020; Nagarajan et al., 2022). HMs that are toxic to the environment can directly affect the essential metabolic processes of plants (Elango et al., 2022; Liu et al., 2021). While some HMs such as Mn, Cu, Co, Cr, and Zn are necessary for metabolic activities in small amounts, their overabundance can be harmful. HM pollution is a significant problem that affects not only human health but also other organisms living in contaminated areas (Manzoor et al., 2018; Zhang et al., 2020). The primary components of pollutants are anthropogenic sources, although various pollutants can occur naturally in soil as mineral components and can be highly toxic (Gao et al., 2021). Soil pollution is often a hidden problem that is not easily measured or visible, making it difficult and costly to determine the true extent of pollutant exposure. Quantifying the risks of exposure to HMs from various sources can help prioritize sources and reduce risks (Xu et al., 2021). The Contaminated Land Exposure Assessment (CLEA) model can be used in China to manage non-volatile contaminated sites such as HMs and assess risk, and calculate site-specific soil screening values (SSVs) (Sun et al., 2020). Developing accurate models for predicting HM accumulation in plants will facilitate soil quality assessment and potential risk from metals. However, establishing such models on a large regional scale is challenging due to soil heterogeneity (Qu et al., 2020). While soil pollution is the third most important soil function in Europe and Eurasia, it is fourth in North Africa, fifth in Asia, seventh in the Pacific Northwest, eighth in North America, and ninth in sub-Saharan Africa and Latin America (Valdiviezo Gonzales et al., 2023). HMs and metalloids are bio-accumulators and gradually enter plants, animals, and humans through the food chain, water, and air (Jayakumar et al., 2021; Lv & Liu, 2019). However, some microorganisms with strong biodegradability of HMs can reduce their toxicity and create a suitable soil environment for growing food crops (Jiang et al., 2021; Khalid et al., 2021).

Bibliometrics is a valuable tool for analyzing the distribution patterns and quantitative shifts in a body of literature by combining mathematical, statistical, and bibliographic techniques (Gong et al., 2022). It is commonly used by academic institutions, scientists, and scientific periodicals to evaluate the state of advancement of a particular subject of study (F.-H. Liu et al., 2022; L.-C. Yang et al., 2022). Through quantitative analysis of the evolution of a study field, including its leading authors, publishing houses, annual publication numbers, hot research topics, and major research nations, researchers can gain a better understanding of various characteristics of the field. Bibliometrics can also be used to quantitatively analyze the evolution of disciplines and map their body of knowledge (L. Yang et al., 2022).

Over the years, dozens of studies have been conducted and published on HM (Abeysingha et al., 2020; Alam et al., 2020; Manzoor et al., 2018; Usmonkulova et al., 2022; Yao et al., 2021; Yu et al., 2022). The importance of bioremediation in reducing HM has increased (Shahid et al., 2021; Song et al., 2021). The growth and internal mechanisms of plants for phytoremediation of heavy metal-contaminated environments have been discovered (C. Li et al., 2020; X. Liu et al., 2020). Researchers have identified the involvement of metallothioneins and phytochelatins in plants' resistance to heavy metal stress conditions (Luo et al., 2020; Yao et al., 2021). Additionally, the application of electric fields can effectively control the absorption of HM (Cd, Cu, and Zn) in the soil by hybrid Pennisetum (Yuan et al., 2021).

In this study, we investigated three main areas: 1) the scientific fields that have been researching HM contamination the most; 2) the reasons behind the high citation rates of certain publications and the subject areas in which they are cited; and 3) how different countries approach their research and cooperate with each other. To guide future research, we conducted a literature review to gain a comprehensive understanding of the current state of HM-contaminated environments.

2. MATERIALS AND METHODS

In this study, we conducted a bibliometric analysis of research and published articles to explore the issue of heavy metal (HM) contamination. On September 16th, 2022, we collected publications from Scopus and exported them to a CSV file. Our search strategy included the search parameter "ALL" in Scopus, which includes all search fields, such as title, abstract, keywords, affiliation, funding information, country, and subject. To ensure the comprehensiveness of our search, we searched for articles published by Indian and Chinese scientists during 2019–2021, using the keyword "heavy metal". We downloaded a total of 817 articles and categorized them by the number of papers on the HM issue by the year of publication in China and India.

Next, we compiled a list of the top journals in China and India that published the most articles, the number of articles published in the past three years, the surnames of the top authors who published the most articles, the top institutions and sponsors, the number of citations for each article, a list of the number of citations per journal, and the share of publications by topic. We then converted the data into CSV and RIS files for analysis.

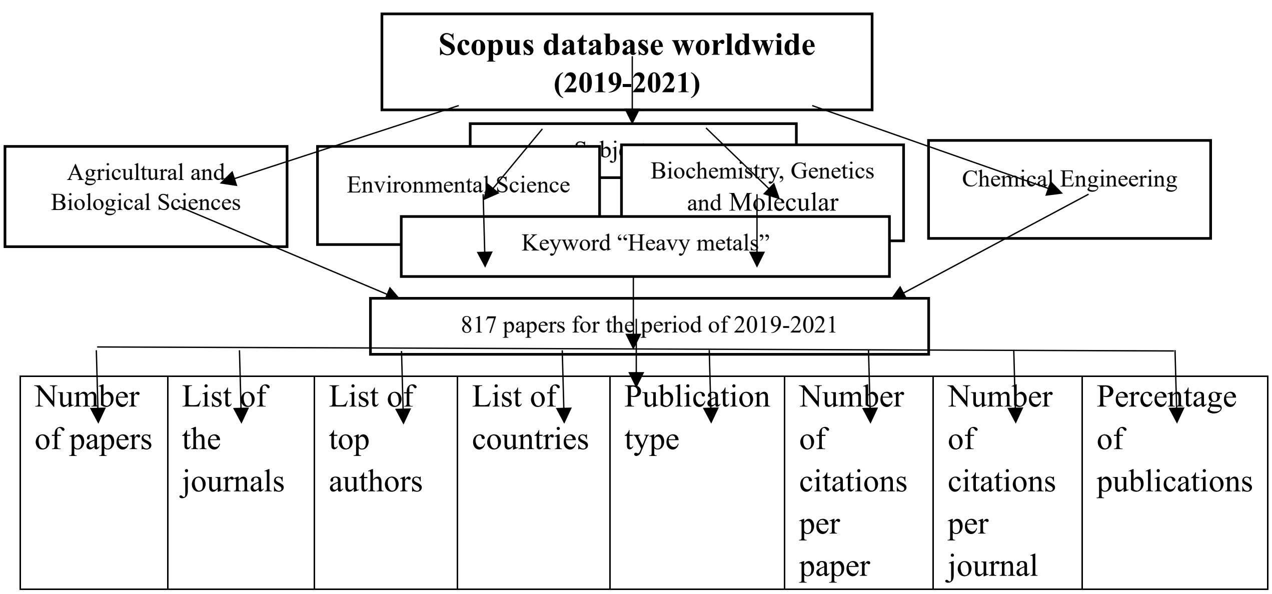

Figure 1. Flowchart of the methodology

We used Microsoft Excel 2021 to analyze the CSV files and VOSviewer software version 1.6.18 to analyze the RIS files. Figure 1 illustrates the methodological direction chosen for our research.

3. RESULTS AND DISCUSSION

3.1 Temporal Trend of Published Articles

We conducted a bibliometric analysis of 817 papers on the problem of heavy metals published between 2019 and 2021 (Fig. 2). The data showed that the number of publications increased from 195 in 2019 to 291 in 2020, and further to 331 in 2021. The majority of these articles focused on finding solutions to the problem of heavy metal contamination in different fields of research, such as Agricultural and Biological Sciences, Environmental Science, Biochemistry, Genetics, and Molecular Biology.

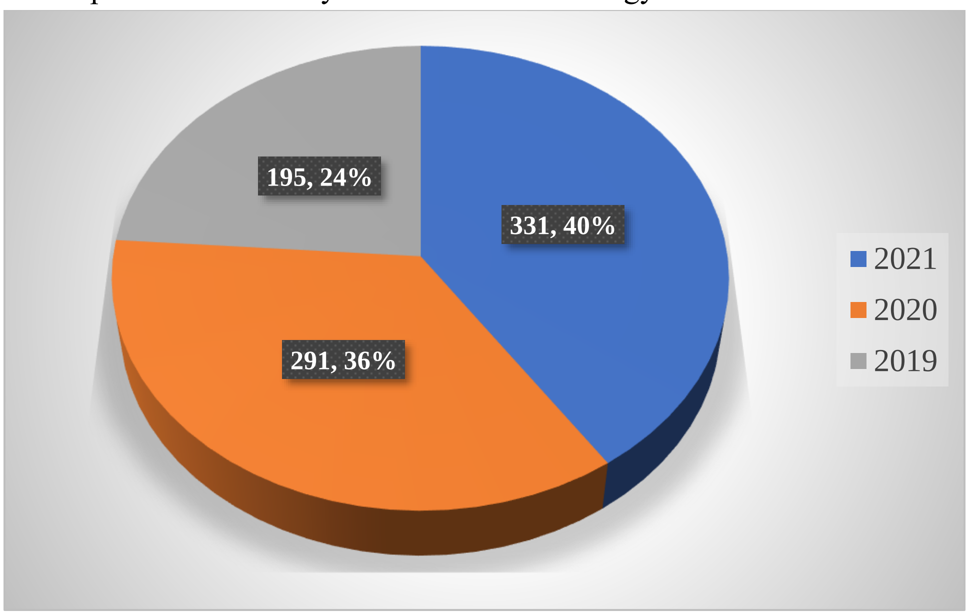

Figure 2. Number of papers on HM issue by the year of publication in China and India

We also identified the top Scopus-based journals that published articles related to heavy metal issues over three years (Table 1).

Table 1. List of the top journals on HM problems in the world

Scopus Source title	Number	Scopus Source title	Number
Polish Journal Of Environmental Studies	32	Frontiers In Plant Science	6
International Journal Of Phytoremediation	23	International Journal Of Environmental Research And Public Health	6
Chemosphere	22	Land	6
Sustainability Switzerland	21	Agriculture Switzerland	5

Journal Of Cleaner Production	20	Ecological Indicators	5
Applied Ecology And Environmental Research	19	Ekologi	5
Bulletin Of Environmental Contamination And Toxicology	19	Geoderma	5
Journal Of Hazardous Materials	19	Indian Journal Of Agricultural Sciences	5
Human And Ecological Risk Assessment	16	Journal Of Environmental Management	5
Science Of The Total Environment	16	Nature Environment And Pollution Technology	5
Environmental Pollution	13	Physiology And Molecular Biology Of Plants	5
Fresenius Environmental Bulletin	13	Plant Archives	5
Chemical Engineering Journal	10	Plant Soil And Environment	5
Environmental Technology And Innovation	10	Process Safety And Environmental Protection	5
Journal Of Environmental Chemical Engineering	10	Agronomy	4
Applied Soil Ecology	9	Archives Of Agronomy And Soil Science	4
Arabian Journal Of Geosciences	9	Ecological Engineering	4
Ecotoxicology And Environmental Safety	9	Environmental Monitoring And Assessment	4
Indian Journal Of Environmental Protection	9	Frontiers In Environmental Science	4
Plants	9	Frontiers In Microbiology	4
Soil And Sediment Contamination	9	Journal Of Applied Biology And Biotechnology	4
Pedosphere	8	Journal Of Soil Science And Plant Nutrition	4
Biocatalysis And Agricultural Biotechnology	7	Plant Cell Biotechnology And Molecular Biology	4
Environmental Geochemistry And Health	7	SN Applied Sciences	4
Environmental Pollutants And Bioavailability	7	Agronomy Journal	3

		Asian Journal Of Water Environment And Pollution	3
Plant And Soil	7		
Chemistry And Ecology	6	Atmospheric Pollution Research	3

Among them, Polish Journal of Environmental Studies, International Journal of Phytoremediation, Chemosphere, Sustainability Switzerland, Journal of Cleaner Production, and Applied Ecology and Environmental Research accounted for 16.7% of all articles published. Bulletin of Environmental Contamination and Toxicology, Journal of Hazardous Materials, Human and Ecological Risk Assessment, and Science of the Total Environment were also among the top ten journals, accounting for 8.5% of all published articles. We further analyzed the impact factors and publishing countries of the top 10 journals (Table 2).

Table 2. Distribution of research output in prolific journals

Scopus Source title	**Number of papers**	**Impact factor**	**Publishing Country**
Polish Journal Of Environmental Studies	32	1,66	Poland
International Journal Of Phytoremediation	23	3.65	United Kingdom
Chemosphere	22	7,086	United Kingdom
Sustainability	21	4.7	Switzerland
Journal Of Cleaner Production	20	9,2	United Kingdom
Applied Ecology And Environmental Research	19	0,86	Hungary
Bulletin Of Environmental Contamination And Toxicology	19	2,65	United States
Journal Of Hazardous Materials	19	14,2	Netherlands
Human And Ecological Risk Assessment	16	4,9	United kingdom
Science Of The Total Environment	16	7,9	Netherlands
Total (%)	**207 (20,7%)**		

The journals with the highest impact factors were Journal of Hazardous Materials (14.2) and Chemosphere (8.6), while the impact factor of Applied Ecology and Environmental Research was 0.86. Four of the top 10 journals were published in the United Kingdom, two in the Netherlands, and the remaining journals were published in Poland, Switzerland, Hungary, and the United States. These findings suggest that journals in the United Kingdom publish more articles on the problem of heavy metal contamination.

3.2 Authors analysis

Our analysis of authors who published on the problem of HM between 2019 and 2021 in China and India revealed that 161 authors were involved in such research(Figure 3). We identified the top 16 authors based on the number of published articles. Li Y published 39 articles and had a total link strength of 32, followed closely by Liu Y who published 38 articles and had a total link strength of 30. Yang Y and Zhang X completed the list of top authors with 19 articles each.

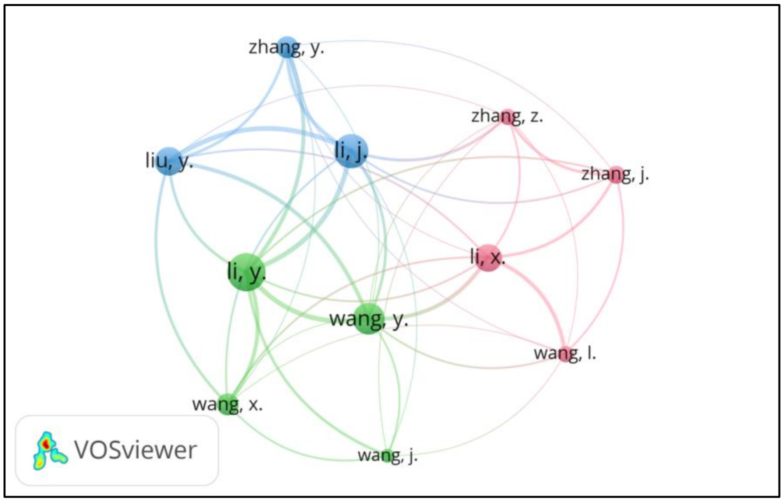

Figure 3. Co-authorship analysis using VOSviewer.

Further analysis showed that Li X, who published 35 articles, had the most links (13) and a total link strength of 29. We divided the top 16 authors into three groups based on their research direction, with six authors in the first and second groups, and four in the third group. The total number of links and total link strengths for all three clusters were the same, 77 and 159, respectively.

The first group included Li J, Li Y, Liu Y, Wang X, Wang Y, and Zhang Y, while the second group included Li X, Wang H, Wang I, Zhang Z, Zhang J, and Zhang H. The third group included Zhang X, Zhang C, Wang J, and Yang Y. These authors collaborate frequently in their scientific research and activities.

We found that most of the top authors had an h-index greater than 12 and worked at the Chinese Academy of Sciences. Additionally, our analysis revealed a reciprocal relationship between these scientists.

3.3 Keywords co-occurrence

The use of different keywords to describe the problem of heavy metal (HM) pollution depends on the field of research. Keywords that have similar meanings tend to appear together. In this study, we analyzed the 5924 keywords mentioned in 817 articles related to HM pollution. We found that 25 keywords were used at least 44 times, and these were divided into three groups: the first group had 12 keywords, the second group had 9 keywords, and the third group had 4 keywords (Figure 4).

The most frequently used keywords were "heavy metals" (351 times), "heavy metal" (322 times), "soil pollution" (295 times), "soil pollutant" (182 times), "China" (150 times), and "soil pollutants" (180 times). The keywords "HM" (1855), "soil pollution" (1682), "soil pollutants" (1590), and "soil pollutants" (1581) had the highest total link strength.

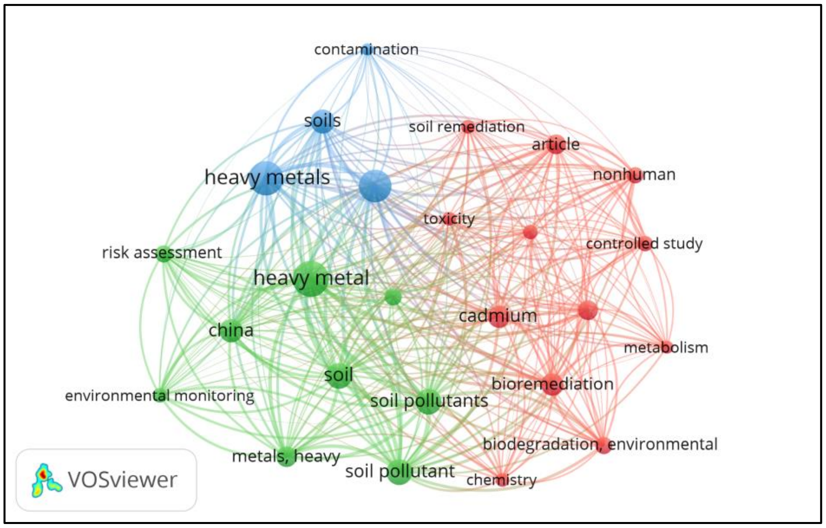

Figure 4. Network map of keyword co-occurrence

Based on the analysis of these keywords, we can assume that the problem of HM pollution is predominantly studied in the context of soil pollution, and that the Chinese government and scientists have a high level of involvement in this research area.

3.4 . Publication Institutions and funding sponsor

We formed and analyzed a list of top institutions based on collected materials and published articles (Figure 5). Thirteen institutes and organizations were selected based on the number of articles they published, with the Chinese Academy of Sciences taking the highest place by publishing 93 articles from 2019 to 2021.

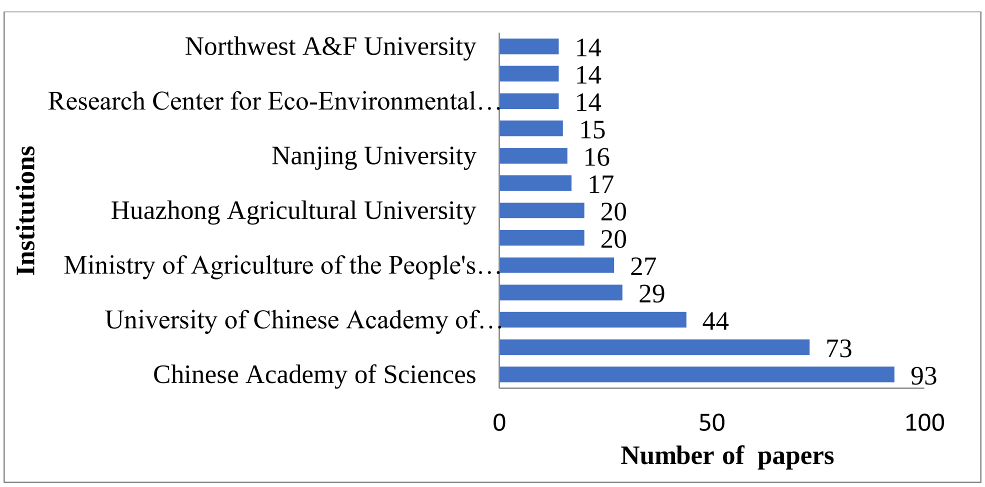

Figure 5. List of top institutions on HM issue in China and India

The Ministry of Education China followed with 73 articles, and the University of Chinese Academy of Sciences completed the top 3 list with 44 articles. It is evident that Chinese state institutions and organizations are actively publishing articles to raise awareness of the problem of HM. Chinese scientists show a greater concern for this issue, and the state's interest in the matter is high. The publication of the most articles in the Chinese Academy of Sciences indicates that the study of the problem of HM is a relevant and comprehensive field in the academy.

In addition to top institutions, founding sponsors also support the publication of research on the problem of HM. A top 10 list of these sponsors was formed and analyzed in Figure 6.

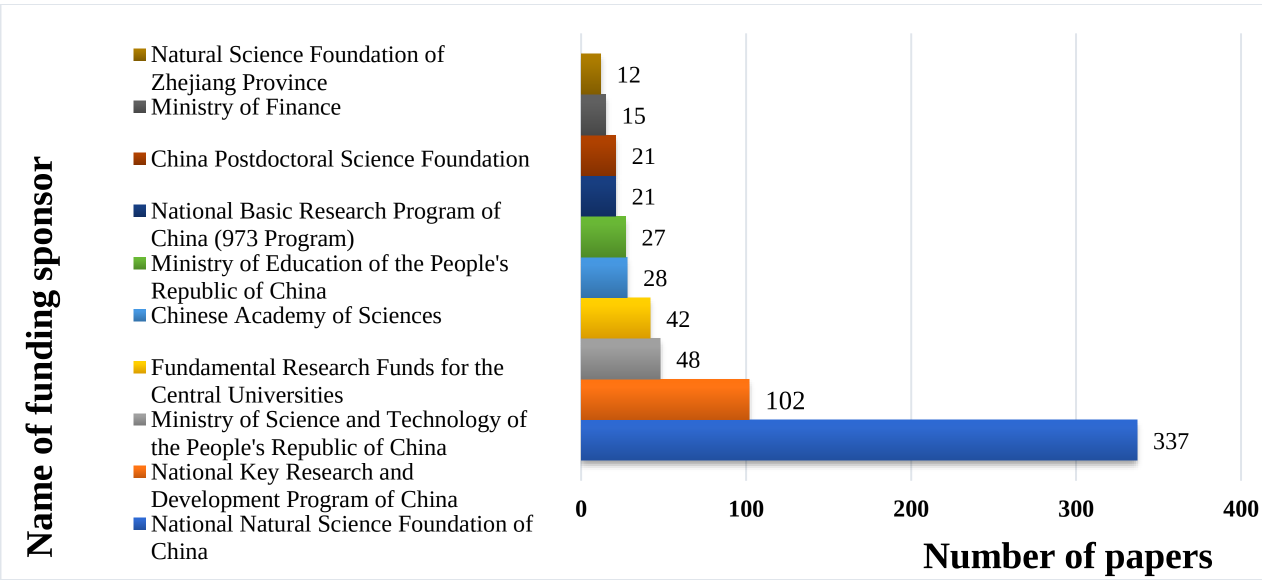

Figure 6. List of top funding sponsor on HM issue in China and India

The Natural Science Foundation of China supported the publication of the highest number of articles, with a total of 337 over 3 years, accounting for 41% of the total published articles. However, a sharp decline in the number of articles published with the help of subsequent sponsors was observed. For instance, the number of articles published with the financial support of National Key Research and Developed China, Ministry of Science and Technology of the People's Republic of China, and Fundamental Research Funds for the Central Universities were 102, 48, and 42, respectively.

3.5 Top cited papers on HM issue

The number of citations a research paper receives is a measure of its quality and novelty. Table 3 presents the fifteen most cited papers on HM issues. For the given period, a total of 7195 citations were given to 694 publications in 817 articles on HM issues. Of these citations, almost 13.3% (957) were given to the fifteen papers listed in Table 3.

Table 3. List of top cited publications on HM issues

№	Title	Journal	Corresponding author	Country	PY	TC	TP
1.	Understanding the molecular mechanisms for the enhanced phytoremediation of HM through plant growth promoting rhizobacteria: A review	Journal of Environmental Management	Karthik C	India	2020	123	Review
2.	Risk assessment, spatial patterns and source apportionment of soil HM in a typical Chinese hickory plantation region of southeastern China	Geoderma	Fu W.	China	2020	86	Article
3.	Do polystyrene nanoplastics affect the toxicity of cadmium to wheat (Triticum aestivum L.)?	Environmental Pollution	Liu W.	China	2020	67	Article
4.	Source quantification and potential risk of mercury, cadmium, arsenic, lead, and chromium in farmland soils of Yellow River Delta	Journal of Cleaner Production	Dai J.	China	2019	66	Article
5.	Global soil pollution by toxic elements: Current status and future perspectives on the risk assessment and	Journal of Hazardous Materials	Khan S.	China	2021	65	Review

	remediation strategies – A review						
6.	Effects of exposure of polyethylene microplastics to air, water and soil on their adsorption behaviors for copper and tetracycline	Chemical Engineering Journal	Wang X.	China	2021	62	Article
7.	Morpho-physiological traits, gaseous exchange attributes, and phytoremediation potential of jute (Corchorus capsularis L.) grown in different concentrations of copper-contaminated soil	Ecotoxicology and Environmental Safety	Liu L.	China	2020	59	Article
8.	Assessment of soil heavy metal pollution using stochastic site indicators	Geoderma	Yang Y.	China	2019	58	Article
9.	Unique root exudate tartaric acid enhanced cadmium mobilization and uptake in Cd-hyperaccumulator Sedum alfredii	Journal of Hazardous Materials	Li T.	China	2020	58	Article
10.	Bio-remediation approaches for alleviation of cadmium contamination in natural resources	Chemosphere	Kumar A.	India	2021	56	Article

11.	Bacterial community response to cadmium contamination of agricultural paddy soil	Applied Soil Ecology	Xie L.L.	China	2019	55	Article
12.	Soil contamination in China: Current priorities, defining background levels and standards for HM	Journal of Environmental Management	Jones K.C.	United Kingdom	2019	52	Article
13.	An integrated approach to identify quantitative sources and hazardous areas of HM in soils	Science of the Total Environment	Lv J.	China	2019	50	Article
14.	Effects of soil environmental factors and UV aging on Cu2+ adsorption on microplastics	Environmental Science and Pollution Research	Cang L.	China	2019	50	Article
15.	Serratia marcescens BM1 enhances cadmium stress tolerance and phytoremediation potential of soybean through modulation of osmolytes, leaf gas exchange, antioxidant machinery, and stress-responsive genes expression	Antioxidants	El-Esawi M.A.	Egypt	2020	50	Article

Notes: "TC"- total citation "PY"- published year; "TP"- type of papers.

The first fifteen top-cited papers consist of two reviews and thirteen research articles. China is represented in eleven of the top fifteen papers, while India is represented in two, and Egypt and the United Kingdom each have one representative.

3.6 Top cited journals on HM issue

In this section, we analyzed the most frequently cited journals for their published articles on HM. Since most scientific journals publish a majority of scientific articles and receive the most citations, we decided to study the most popular journals in this area. We sorted the source names alphabetically of an Excel file containing 817 documents and then summarized the total number of citations received by each journal. This approach resulted in an updated list of potential journal names, and we selected the initial 8 journals for analysis (Figure 7).

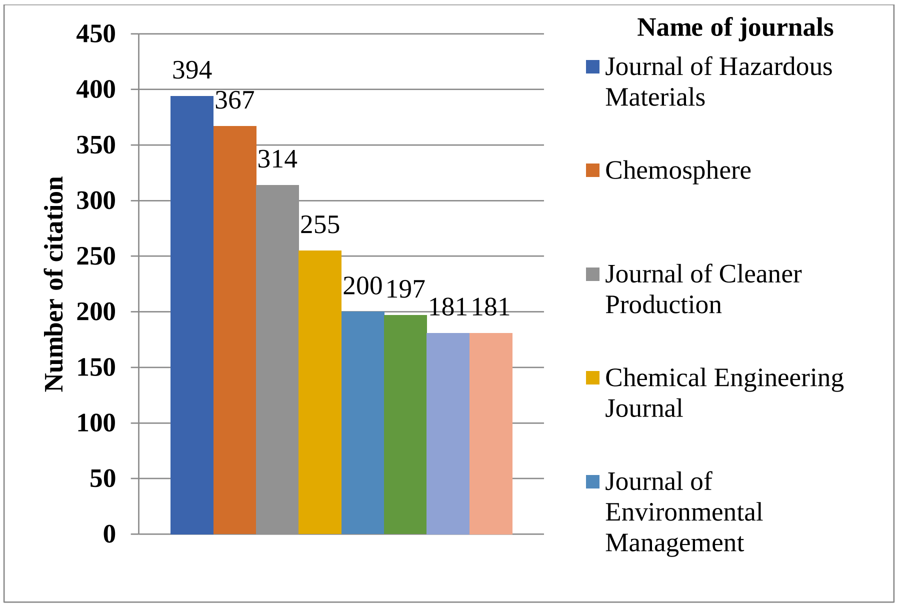

Figure 7. Top cited journals on HM issues in China and India

Interestingly, nearly 29.03% (2089 citations) of total citations were given to papers published in these 8 journals. Among these, the Journal of Hazardous Materials received the most citations (394 citations) and was recognized as the best journal (Tables 1 and 2). Three journals, including the Journal of Hazardous Materials, Chemosphere, and Journal of Cleaner Production, were ranked as the most frequently cited journals (Table 2). Additionally, five journals, including Chemical Engineering Journal, Journal of Environmental Management, Environmental Pollution, Ecotoxicology and Environmental Safety, and Geoderma, received more citations, even though they had fewer articles on HM issues worldwide.

4. DISCUSSION

We found that a variety of approaches have been employed in bibliometric studies by other researchers to explore solutions to the issue of HM. For example, Yu et al. (2022) conducted a bibliometric analysis on HM and metalloids, specifically focusing on studies that investigated the use of constructed wetlands for reducing HM. They analyzed term usage, literature, and recent research trends. Yang et al. (2022) established the global status and research areas for phytoremediation of heavy metal pollution, and conducted separate analyses of the most prolific publications by literary types, research fields, nation, institution, and author. Ho and Fu (2016) examined research on worldwide metal-organic frameworks from 1995 to 2014, highlighting document types, languages, performance of publications, yearly outputs, journals, Web of Science categories, countries, and institutions. They also assessed six publishing indicators for countries' publications, including total, independent, collaborative, first author, corresponding author, and single author publications. Hu et al. (2010) conducted a bibliometric study based on the Science Citation Index published by the Institute of Scientific Information (ISI) to better understand research trends from 1991 to 2007 and to identify the global research relevant to lead in drinking water. Liao et al. (2021) analyzed 7,400 papers on current developments in arsenic-contaminated soil remediation techniques and provided suggestions for future research. They also critically assessed the literature of various methodologies. Ruru Han et al. (2020) conducted a bibliometric analysis on the health risk levels, sources, and control methods of HM in various parts of the world between 1989 and 2018. Their findings demonstrated that over the past decade, there has been a significant increase in concern about the risks and consequences of HM, particularly in China and other emerging nations. China surpassed the US as the most productive nation in 2010, and contributed about half of global growth due to growing concerns about heavy metal pollution (Liu et al., 2014; Olmedo et al., 2013).

Similarly, we used 817 articles to analyze the top scientists, institutes, top periodicals, and the most cited articles and journals related to the issue of HM. Our analysis revealed that the Chinese state and scientists are dealing with the problem of pollution the most, which is consistent with the research of others. The increase in this indicator from year to year in China indicates that the problem of HM is also growing.

5. CONCLUSION

Scientists' interest in reducing heavy metal (HM) levels in the environment has increased in response to the growing presence of HM in the environment. To gain insight into this issue, we analyzed papers published between 2010 and 2021 that addressed HM in China and India. Our analysis covered 817 publications, with the majority co-authored by scientists from China, India, the United Kingdom, and Egypt. The fact that the number of publications has increased each year—195 in 2019, 291 in 2020, and 331 in 2021—suggests that the issue of HM is becoming an increasingly pressing concern.

We found that China is particularly invested in addressing the issue of HM pollution, as evidenced by the fact that the top 10 institutions and sponsors of articles addressing the issue of HM are located in China. These include the Chinese Academy of Sciences, which published 93 articles, and the Natural Science Foundation of China, which published 337 articles. Chinese scientists also had the highest number of publications and citations received. Ten of the top authors, who have produced 19-39 pieces in the last three years, are from China. Notably, Fu W. et al. published a study in the

Chinese journal "Geoderma" in 2020 titled "Risk assessment, spatial patterns, and source apportionment of soil HM in a typical Chinese hickory plantation region of southeastern China," which received 86 citations. Eight papers written by Chinese scientists rank in the top 10 most cited papers. Our analysis of keywords used in all articles revealed that heavy metal, heavy metals, soil pollution, and China were frequently used. This indicates that the Chinese government and scientists are particularly concerned about the issue of HM pollution of soil. The field of environmental science accounted for the most publications, followed by agriculture and biology. This suggests that HM pollution has significant ecological and agricultural impacts and affects living organisms in general.

In conclusion, our analysis of publications related to HM pollution in China and India underscores the growing concern among scientists about this issue. Our findings suggest that HM pollution poses a significant threat to the environment, agriculture, and living organisms in general.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

REFERENCES

Abeysingha, N. S., Maduranga, K. H. R. S., Singh, S., & Duminda, D. M. S. (2020). Phytoextraction of nutrients and heavy metals by two monocot plants in thaulla area of small reservoir in Anuradhapura, Sri Lanka. *J. Agricul.Scien. - Sri Lanka*. https://doi.org/10.4038/jas.v15i3.9026

Alam, N., Anis, M., Javed, S. B., & Alatar, A. A. (2020). Stimulatory effect of copper and zinc sulphate on plant regeneration, glutathione-S-transferase analysis and assessment of antioxidant activities in Mucuna pruriens L. (DC). *Plant Cell, Tissue and Organ Culture*. Scopus. https://doi.org/10.1007/s11240-020-01776-8

Chen, L., Wang, G., Wu, S., Xia, Z., Cui, Z., Wang, C., & Zhou, S. (2019). Heavy Metals in Agricultural Soils of the Lihe River Watershed, East China: Spatial Distribution, Ecological Risk, and Pollution Source. *Inter. J. Environ. Research and Public Health*. https://doi.org/10.3390/ijerph16122094

Elango, D., Devi, K. D., Jeyabalakrishnan, H. K., Rajendran, K., Thoomatti Haridass, V. K., Dharmaraj, D., Charuchandran, C. V., Wang, W., Fakude, M., Mishra, R., Vembu, K., & Wang, X. (2022). Agronomic, breeding, and biotechnological interventions to mitigate heavy metal toxicity problems in agriculture. *Journal of Agriculture and Food Research*, *10*, 100374. https://doi.org/10.1016/j.jafr.2022.100374

Elgarahy, A. M., Elwakeel, K. Z., Mohammad, S. H., & Elshoubaky, G. A. (2021). A critical review of biosorption of dyes, heavy metals and metalloids from wastewater as an efficient and green process. *Cleaner Engineering and Technology*, *4*, 100209. https://doi.org/10.1016/j.clet.2021.100209

Gao, Z., Dong, H., Wang, S., Zhang, Y., Zhang, H., Jiang, B., & Liu, Y. (2021). Geochemical characteristics and ecological risk assessment of heavy metals in surface soil of gaomi city. *Inter.J.Environ. Research and Public Health*. https://doi.org/10.3390/ijerph18168329

Gong, S., Gong, F., & Kabarriti, A. (2022). Top 50 Most Cited Articles About OAB: A

Bibliometric Analysis. *Urology*. https://doi.org/10.1016/j.urology.2022.09.038

Han, R., Zhou, B., Huang, Y., Lu, X., Li, S., & Li, N. (2020). Bibliometric overview of research trends on heavy metal health risks and impacts in 1989–2018. *J. Clear. Produc. 276*, 123249. https://doi.org/10.1016/j.jclepro.2020.123249

Ho, Y.-S., & Fu, H.-Z. (2016). Mapping of metal-organic frameworks publications: A bibliometric analysis. *Inorganic Chemistry Communications*, *73*, 174–182. https://doi.org/10.1016/j.inoche.2016.10.023

Hu, J., Ma, Y., Zhang, L., Gan, F., & Ho, Y.-S. (2010). A historical review and bibliometric analysis of research on lead in drinking water field from 1991 to 2007. *Scien. Total Environ. 408*(7), 1738–1744. https://doi.org/10.1016/j.scitotenv.2009.12.038

Hu, S., Chen, X., Jing, F., Liu, W., & Wen, X. (2021). An assessment of spatial distribution and source identification of five toxic heavy metals in Nanjing, China. *Environmental Engineering Research*. Scopus. https://doi.org/10.4491/eer.2020.135

Jayakumar, M., Surendran, U., Raja, P., Kumar, A., & Senapathi, V. (2021). A review of heavy metals accumulation pathways, sources and management in soils. *Arabian Journal of Geosciences*. Scopus. https://doi.org/10.1007/s12517-021-08543-9

Jia, Z., Wang, J., Li, B., Li, Y., Zhou, Y., Tong, G., Yan, D., & Zhou, S. (2020). An integrated methodology for improving heavy metal risk management in soil-rice system. *J.Clean. Produc.*. Scopus. https://doi.org/10.1016/j.jclepro.2020.122797

Jiang, Y., Huang, R., Jiang, L., Chen, K., & Zhu, W. (2021). Alleviation of cadmium toxicity to medicago truncatula by AMF involves the changes of cd speciation in rhizosphere soil and subcellular distribution. *Phyton*. Scopus. https://doi.org/10.32604/phyton.2021.014376

KHALID, M., UR-RAHMAN, S., HASSANI, D., HAYAT, K., ZHOU, P., & HUI, N. (2021). Advances in fungal-assisted phytoremediation of heavy metals: A review. *Pedosphere*. Scopus. https://doi.org/10.1016/S1002-0160(20)60091-1

Li, C., Wang, H., Liao, X., Xiao, R., Liu, K., Bai, J., Li, B., & He, Q. (2022). Heavy metal pollution in coastal wetlands: A systematic review of studies globally over the past three decades. *J.Hazar. Mater. 424*, 127312. https://doi.org/10.1016/j.jhazmat.2021.127312

Li, C., Yu, F., Li, Y., Niu, W., Li, J., Yang, J., & Liu, K. (2020). Comparative analysis of the seed germination of pakchoi and its phytoremediation efficacy combined with chemical amendment in four polluted soils. *Inter.J.Phytorem*. Scopus. https://doi.org/10.1080/15226514.2020.1741508

Li, P., Wu, T., Jiang, G., Pu, L., Li, Y., Zhang, J., Xu, F., & Xie, X. (2021). An integrated approach for source apportionment and health risk assessment of heavy metals in subtropical agricultural soils, eastern China. *Land*. Scopus. https://doi.org/10.3390/land10101016

Liu, E., Yan, T., Birch, G., & Zhu, Y. (2014). Pollution and health risk of potentially toxic metals in urban road dust in Nanjing, a mega-city of China. *Scien.Total Environ. 476–477*, 522–531. https://doi.org/10.1016/j.scitotenv.2014.01.055

Liu, F.-H., Yu, C.-H., & Chang, Y.-C. (2022). Bibliometric analysis of articles published in journal of dental sciences from 2009 to 2020. *Journal of Dental Sciences*, *17*(1), 642–646. https://doi.org/10.1016/j.jds.2021.08.002

Liu, X., Shen, S., Zhang, X., Chen, X., Jin, R., & Li, X. (2020). Effect of enhancers on the phytoremediation of soils polluted by pyrene and Ni using Sudan grass (Sorghum sudanense (Piper) Stapf.). *Environ.Scien. Poll.Res*. Scopus. https://doi.org/10.1007/s11356-020-09934-3

Liu, Y., Ma, Z., Liu, G., Jiang, L., Dong, L., He, Y., Shang, Z., & Shi, H. (2021). Accumulation risk and source apportionment of heavy metals in different types of farmland in a typical farming area of northern China. *Environ.Geochem. Health*. Scopus. https://doi.org/10.1007/s10653-021-01002-0

Luo, S., Calderón-Urrea, A., YU, J., Liao, W., Xie, J., Lv, J., Feng, Z., & Tang, Z. (2020). The role of hydrogen sulfide in plant alleviates heavy metal stress. *Plant and Soil*, *449*(1), 1–10. https://doi.org/10.1007/s11104-020-04471-x

Lv, J., & Liu, Y. (2019). An integrated approach to identify quantitative sources and hazardous areas of heavy metals in soils. *Scien.Total Environ*. Scopus. https://doi.org/10.1016/j.scitotenv.2018.07.257

Manzoor, D., Sharma, M., & Khursheed, W. (2018). Heavy metals in vegetables and their impact on the nutrient quality of vegetables: A review. *Journal of Plant Nutrition*, *41*, 1–20. https://doi.org/10.1080/01904167.2018.1462382

Nagarajan, D., Lee, D.-J., Varjani, S., Lam, S. S., Allakhverdiev, S. I., & Chang, J.-S. (2022). Microalgae-based wastewater treatment – Microalgae-bacteria consortia, multi-omics approaches and algal stress response. *Scien.Total Environ. 845*, 157110. https://doi.org/10.1016/j.scitotenv.2022.157110

Olmedo, P., Pla, A., Hernández, A. F., Barbier, F., Ayouni, L., & Gil, F. (2013). Determination of toxic elements (mercury, cadmium, lead, tin and arsenic) in fish and shellfish samples. Risk assessment for the consumers. *Environ. Inter. 59*, 63–72. https://doi.org/10.1016/j.envint.2013.05.005

Qu, X., Xu, W., Ren, J., Zhao, X., Li, Y., & Gu, X. (2020). A field study to predict Cd bioaccumulation in a soil-wheat system: Application of a geochemical model. *J. Hazar.Mat*. Scopus. https://doi.org/10.1016/j.jhazmat.2020.123135

Shahid, A., Pandey, C., Ahmad, F., & Kamal, A. (2021). Bacterial bioremediation: Strategies adopted by microbial-community to remediate lead from the environment. *J.Appl. Biol.Biotech*. Scopus. https://doi.org/10.7324/JABB.2021.9602

Singh, M., Singh, P., Singh, R. K., Singh, P. K., Prasad, S. M., & Pandey, A. (2020). An introduction of parthenium hysterophorus to be boon for agricultural land: Under heavy metal contamination. *Plant Archives*. Scopus. https://www.scopus.com/inward/record.uri?eid=2-s2.0-

85086470443&partnerID=40&md5=9c1b592a3d9ac0d73edbe37f4bdc061f

Song, Y., Li, R., Chen, G., Yan, B., Zhong, L., Wang, Y., Li, Y., Li, J., & Zhang, Y. (2021). Bibliometric analysis of current status on bioremediation of petroleum contaminated soils during 2000–2019. *International Journal of Environmental Research and Public Health*. https://doi.org/10.3390/ijerph18168859

Sun, Y., Wang, J., Guo, G., Li, H., & Jones, K. (2020). A comprehensive comparison and analysis of soil screening values derived and used in China and the UK. *Environ. Poll*. Scopus. https://doi.org/10.1016/j.envpol.2019.113404

Thakur, A., Kumar, A., Kumar, C. V., Kiran, B. S., Kumar, S., & Athokpam, V. (2021). A review on vermicomposting: By-products and its importance. *Plant Cell Biotechnology and Molecular Biology*. Scopus. https://www.scopus.com/inward/record.uri?eid=2-s2.0-85101742746&partnerID=40&md5=9c80bd3bb06ce52711848d348bb7187c

Usmonkulova, A., Shonakhunov, T., & Kadirova, G. (2022). ACTIVITY OF NITROGEN-FIXING CYANOBACTERIA UNDER SALINITY AND HEAVY METALS STRESS. *Journal of Pharmaceutical Negative Results*, *13*(3), 355–363. https://doi.org/10.47750/pnr.2022.13.03.055

Valdiviezo Gonzales, L. G., Castañeda-Olivera, C. A., Cabello-Torres, R. J., García Ávila, F. F., Munive Cerrón, R. V., & Alfaro Paredes, E. A. (2023). Scientometric study of treatment technologies of soil pollution: Present and future challenges. *Appl.Soil Ecol. 182*, 104695. https://doi.org/10.1016/j.apsoil.2022.104695

Xu, J., Gui, H., Chen, J., Li, C., Li, Y., Zhao, C., & Guo, Y. (2021). A combined model to quantitatively assess human health risk from different sources of heavy metals in soils around coal waste pile. *Human and Ecological Risk Assessment*. Scopus. https://doi.org/10.1080/10807039.2021.1956299

Yang, L., Wang, J., Yang, Y., Li, S., Wang, T., Oleksak, P., Chrienova, Z., Wu, Q., Nepovimova, E., Zhang, X., & Kuca, K. (2022). Phytoremediation of heavy metal pollution: Hotspots and future prospects. *Ecotox.Environ.Saf. 234*, 113403. https://doi.org/10.1016/j.ecoenv.2022.113403

Yang, L.-C., Liu, F.-H., Liu, C.-M., Yu, C.-H., & Chang, Y.-C. (2022). Bibliometric analysis of top-cited articles in Journal of Dental Sciences. *Journal of Dental Sciences*. https://doi.org/10.1016/j.jds.2022.09.017

Yao, L., Wang, J., Li, B., Meng, Y., Ma, X., Si, E., Yang, K., Shang, X., & Wang, H. (2021). Influences of Heavy Metals and Salt on Seed Germination and Seedling Characteristics of Halophyte Halogeton glomeratus. *Bull.Environ. Contamin. Tox*. Scopus. https://doi.org/10.1007/s00128-021-03130-w

Yu, G., Wang, G., Chi, T., Du, C., Wang, J., Li, P., Zhang, Y., Wang, S., Yang, K., Long, Y., & Chen, H. (2022). Enhanced removal of heavy metals and metalloids by constructed wetlands: A review of approaches and mechanisms. *Scien. Total Environ. 821*, 153516. https://doi.org/10.1016/j.scitotenv.2022.153516

Yuan, L., Guo, P., Guo, S., Wang, J., & Huang, Y. (2021). Influence of electrical fields enhanced phytoremediation of multi-metal contaminated soil on soil parameters and plants uptake in different soil sections. *Environmental Research*, *198*, 111290. https://doi.org/10.1016/j.envres.2021.111290

Zhang, K., Yang, J., Wang, Y., Xia, Y., Liu, S., & Zhang, R. (2020). All-region human health risk assessment of cr(Vi) in a coal chemical plant based on kriging. *Polish Journal of Environmental Studies*. Scopus. https://doi.org/10.15244/pjoes/99226

Zhao, Y., Zhang, Z., Li, B., Zhao, Y., Lu, J., & Tang, X. (2021). Accurate Determination and Comprehensive Evaluation of Heavy Metals in Different Soils from Jilin Province in Northeast China. *Analytical Letters*. Scopus. https://doi.org/10.1080/00032719.2020.1828908