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Advances in Groundwater Pollution by Heavy Metal

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Abstract. Indiscriminate discharge of heavy metals into the environment is of great concern globally, especially in developing countries. The health risk caused by heavy metals pollution due to its toxicity, non-biodegradation, bioaccumulation, and complex operation with different sources and routes has accelerated as some industries expand with little investment plan around treatment. Over the years, research has been carried out on different aspects of heavy metals pollution, including-, emissions, impact on human health and environment, and mitigation processes. In this study, bibliometric and visualization analysis were used to analyze and evaluate the term heavy metal pollution, health risk, and its treatment approach was analyzed to acquire the overview of the heavy metal pollution on groundwater sources, health risk and treatment, and or removal approaches in different countries of the world from the web of science 1995-2020 publication. The outcome showed that China had a major interest in heavy metal pollution and its impact on lives and ecosystems in the past years as the highest publishers relating to heavy metal treatment technology.VOS viewer software and MS Excel were used as bibliometric tools for the examination of the researcher's certification in their research trends, progress, and publication performance. This, in turn, reveals the publication trends, subject categories and influential journals, country performance, most cited keyword and co-occurrence, author, and co-authorship collaboration network in heavy metals research, which would be of value to new researchers in the field. This paper highlights the trend in heavy metal removal from wastewater.

KEYWORDS: Heavy metal, groundwater pollution, Bibliometric Analysis, Pollution, Environment, Adsorption

INTRODUCTION

Heavy metals pollution on groundwater sources has raised global concerns because of its impact on human health and the environment. Recently the increase in industrialization and urbanization has accelerated the emission and pollution of heavy metal from anthropogenic operations, for example, mining, smelting and metal treatment, oil and gas wastewater, traffic, waste dumping sites and has deteriorated the environment and human health [1].

The exposure and consumption of these metals such as lead, cadmium, mercury, arsenic, chromium, nickel, copper, zinc, iron and cobalt, etc possess a great threat to human health, Interestingly little quantity of these metals are prevalent in our surrounding and dietary, when consumed at low concentration by the living organism are not harmful because some of them are essential for good health such as iron, copper, zinc, and cobalt but at higher amount becomes toxic for ecosystem and human [2].

Pollution of the drinking water sources, either surface or groundwater, with heavy metals and their related effects has been increasing [3, 4]. Its specific significance is due to its non-biodegradability, toxicity, and accumulating capabilities [5]. The deterioration of the environment and threat to human health is on the increase due to the persistent accumulation of heavy metals discharged into the environment. For example, Nickel is one of the carcinogenic

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substances; when it exceeds the acceptable limit, it can lead to severe lung, kidney, gastrointestinal, skin dermatitis, and pulmonary fibrosis problems [6].

The toxicity of lead can harm human beings and animals, leading to brain damage, nephropathy, seizure, kidney disease, coma, and in extreme cases, death [7]. lead poisoning in children[8]. itai-itai disease induced by cadmium pollution [9]. There are various methods to treat and /or to eliminate heavy metal from the effluent before discharge into the environment, such as anaerobic digestion [10], photocatalysis [11], adsorption [12], membrane filtration [13],ozonation [14] is mostly used. Adsorption method is a conventional and productive approach to remove heavy metals from wastewater [15], and the adsorption mechanism, kinetics, and isotherm of many kinds of adsorbents such as activated carbon [16], sediments [17], and activated/sewage sludge [18] have been studied in depth. Membrane filtration methods include nanofiltration, reverse osmosis, and ultrafiltration, mainly applied to treat dye and textile, heavy metal [19].

Biosorption technique, various types of biomass are used as bioremediation means for heavy metal removal from wastewater [20]. Ion-exchange techniques have been applied in the industries to remove heavy metals from wastewater because of their various benefit, including the maximum treatment capability, rapid kinetics, and removal productivity [21]. The chemical precipitation technique is cheap and simple to operate but generates huge sludge, which leads to additional discharging costs [22].

The monitoring of heavy metals is rapidly becoming a significant feature of pollution study [23]. The pollution of the environment with poisonous metals can take place worldwide due to industrial activities, military weapons, agricultural operations, and wastewater discharge.[24]. Industries such as those that deal in energy and fuel discharge approximately 2.4 million tons of Pb, Cu, Cd, As, Hg, Se, Zn, and V yearly.

While the metallic industry generates 0.39 million tons per year, agriculture inputs 1.4 million tons per year, wastewater/waste discharge 0.72 million tons per year, and manufacturing supplies 0.24 million tons per year of the same metal. The release of these metal ions into the surrounding environment can lead to the accumulation of toxic metals, thereby posing a risk to the economy, public health, and the environment.[25-27].

This study aims to apply a detailed bibliometric analysis in tracing global trends in heavy metal removal from 1995 to 2020. For proper examination of publication trends and to analyze the most effective countries with their research following indicators were used: contributions, authors and organization, collaboration, research patterns, and h-index analysis.

DATA COLLECTING AND METHODOLOGY

Web of Science (WOS) gives orderly, systematize records, and is mostly used in core collection databases in bibliometric analyses [28].

The WOS was used to search for the term "heavy metal pollution" or "heavy metals treatment" with titles, abstracts, and keywords from 1995-2020 publications, which were retrieved and filtered in the English language. The search for 'heavy metals pollution' was applied for the identification of various problems and contamination, while 'heavy metals treatment' was used to consider the research focal point on mechanics and solutions to tackle heavy metals contamination issues. The application of bibliometric analysis is a vital tool in analyzing and predicting research trends [29]. Bibliometric analysis is a trendy and productive technique applied in the identification of research trends in many disciplines of science, social science, and engineering, etc [30].

Publications about the author's information, keywords, institutional links, and journals were extracted, which enabled the determination of the impact key issues and solutions in the field of heavy metal removal from wastewater with various treatment methods like adsorption, Hydroxide precipitation, chemical precipitation, membrane filtration, Electrodialysis, and ion-exchange techniques as the main focus of the application. Index records were used in comparing and analyzing country efficiency and academic performance.

Figure 1 shows the trend of the literature search. Microsoft Excel was used to analyze document type, output, journal, country, source title, abstract keyword, and subject category. VOS viewer was used for data analysis such as co-authors citations, the co-occurrence of author's keywords, a bibliographic coupling of Organizations, and Bibliographic coupling countries with each total link strength calculated.

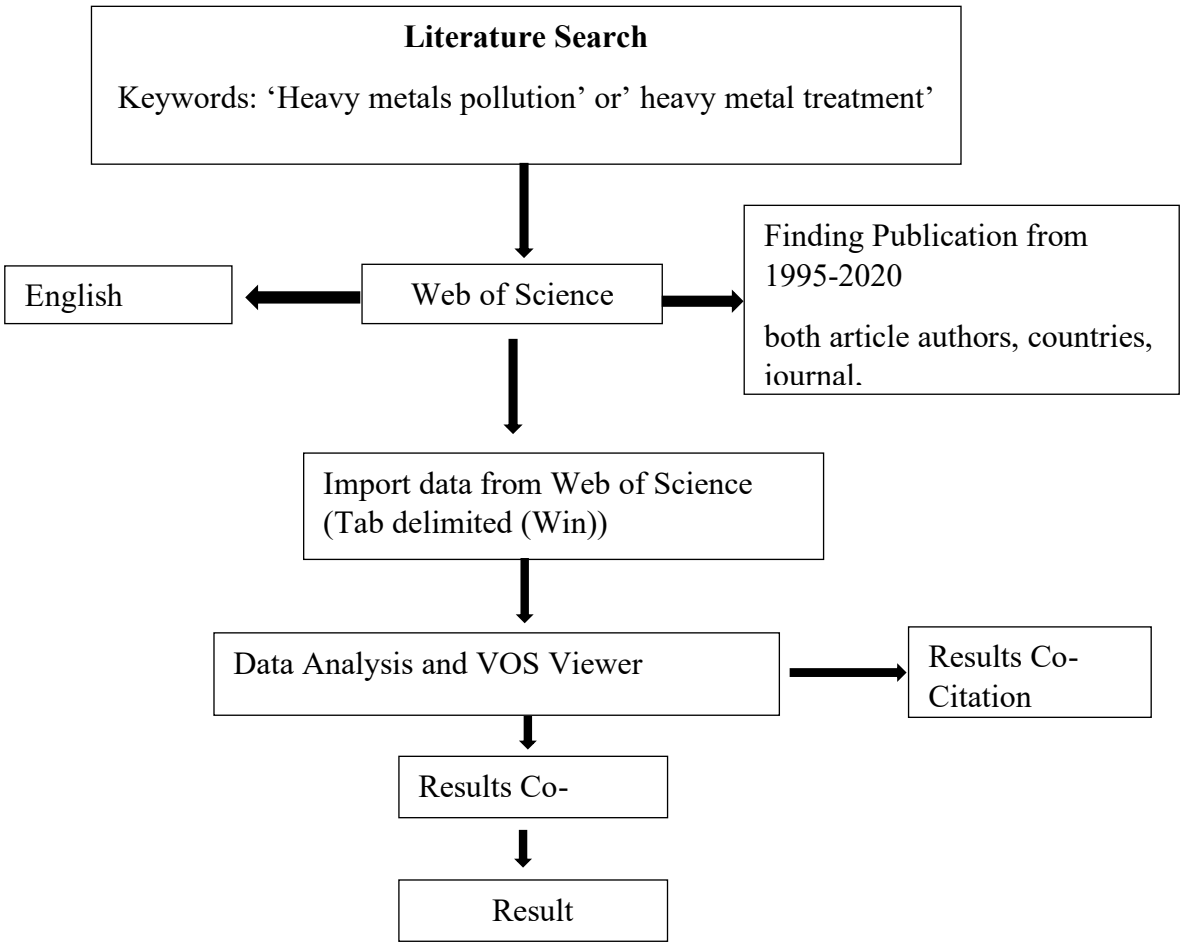

FIGURE1. Bibliometric methodology flowchart

BIBLIOMETRIC ANALYSIS AND RESULTS

The general trends of publication

The data retrieved showed an outcome of research about heavy metal removal and or treatment mechanics over the years. Figure 2 displayed the increase in research publication per year from 1995-2020. The figure revealed the growth trend on heavy metals treatment and or removal technologies from 0.19% in 1995 to 69.68% in 2020 with an article as the most presiding document accounting for 2647 total publications with 86.56% out of 3058 records, h-index of 123, average citation of 29.15, and total no of **77,173** times cited.

The other publications were proceedings papers ranged 2nd with the total publication of 286 and 9.35% out of the total record, h-index of 39, average citation of 16.76, and 4,794 times cited. Review ranked 3rd with 204 records and second with an h-index of 62, an average citation of 116.78, and a total number of **23,824** times cited, book chapter, meeting abstract, early access, editorial material, correction, etc. The increase in published articles about heavy metal removal from industrial wastewater treatment from 1995 to 2020 is because of the fast growth in the world's population, thereby causing an increase in waste generation and pollution of water sources. Most contaminants are chemicals, radioactive materials, pathogenic microbial substances, and heavy metals[31].

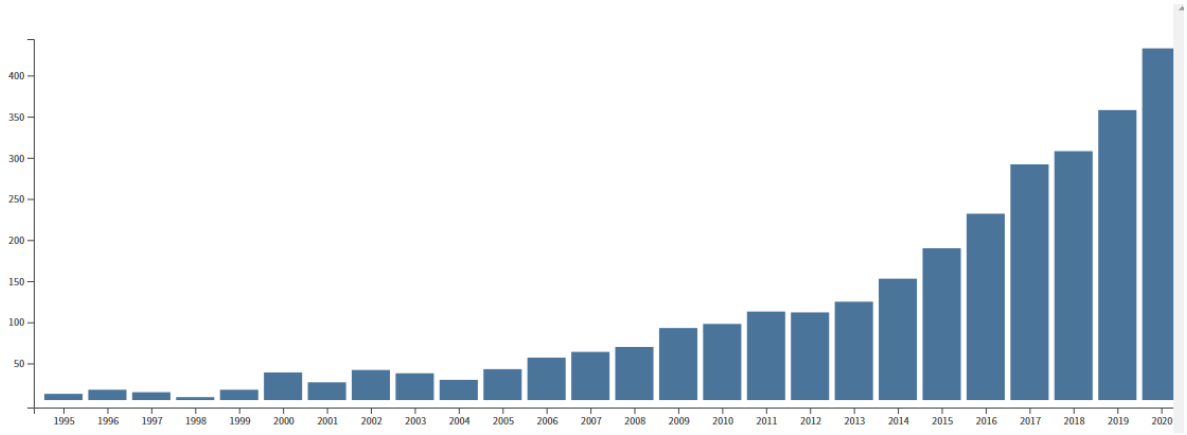

FIGURE 2. The increase in rsearch publication per year from 1995 -2020

Dominant subject categories and influential journals

In total, 3058 articles were analyzed, covering 77 subject categories in the WoS and the categories of environmental science were the dominant categories, accounting for 35 of the total articles, followed by engineering environmental (720), engineering chemical (692), water resources (428), metallurgy metallurgical engineering and atmospheric meteorology sciences accounted for the same result respectively with (45).

The result showed that research on heavy metal pollution and impact mainly focused on environmental issues, engineering, and water resources. The names of the top 10 journals with high publications on heavy metal pollution and treatment approaches are shown in table 1. Journal of hazardous material published the most article of (152 with the highest h-index of 64 and ranked second with 98.24 for average citations per item.

The most average cited article is the bioresource technology (102.44) score. Chemosphere and Environmental Science and Pollution Research recorded the same number of publications of articles, respectively, with a record of 69 and different h-index. Chemical Engineering Journal scored second with an h-index value of 45, while Desalination and water treatment recorded the least with an h-index of 13 and 5.68 average citations per item.

TABLE 1. Showing the top 10 journals that published the most papers on heavy metals pollution and treatment.

Rank	Journal	h-index	Average citaiton	Number of Publication
1	Journal of Hazardous Material	64	98.24	152
2	Desalination and Water Treatment	13	5.68	106
3	Chemical Engineering Journal	45	68.53	99
4	Water Science and Technology	25	28.74	72
5	Chemosphere	31	47.74	69
6	Environmental Science and Pollution Research	15	10.32	69
7	Bioresource Technology	39	102.44	68
8	Separation and Purification Technology	25	54.72	50
9	Water Research	33	93.53	47
10	Science of the Total Environment	22		42

Country Performance

Contribution of different countries

The Contributions of diverse countries were analyzed with the author's information extracted, and it was observed that authors were from 106 countries/regions. Table 2 showing the top 10 with the most efficient countries in terms of total published articles, percentage of articles published as listed, average citation per paper, h-index for each country/region. While figure 3 showed others countries that were involved in the publications.

It's absorbing to observe that China's article output ranked first with a high value of 808 total publications accounting for 26.42% of the total. Still, average citations per paper ranked 3rd with 37.03 points and 1st with an h-index of (75) higher than other countries. China, in the year 2015, generated 73.5 billion tons of wastewater with 79.4 tons of lead, 1.1 tons of mercury, 15.8 tons of cadmium, 105.3 tons of chromium, and 112.1 tons of arsenic. And their main source of control of wastewater was through Wastewater treatment plants [32].

Shanghai was the first city to use an urban drainage system in China. In 1921 the first wastewater treatment plant was constructed, and it increased from 19 in 2000 to 53 in 2015. Currently, before the wastewater is discharged into various beneficiaries, about 92.9% of treatment is achieved [33]. Observing that these countries such as China, India, the USA, Turkey, and Iran are leading in heavy metal pollution and treatment publications. Egypt and Malaysia had the same scores for total publication and average citations per paper, respectively. Egypt is the only African country that made it in the top 10 countries with publications in this area.

TABLE 2. Showing the top 10 countries/region with a total publication with the highest h-index

Country/Region	**total publications**	**Percentage (%)**	**average citations per paper**	**h-index**
China	808	26.42	37.03	75
India	310	10.14	33.28	48
USA	274	8.96	38.48	56
Turkey	202	6.60	32.11	45
Iran	184	6.01	23.27	37
South Korea	133	4.34	35.92	35
Egypt	101	3.30	26.73	25
Malaysia	101	3.30	26.5	23
Australia	81	2.64	35.37	30
Canada	79	2.58	48.65	27

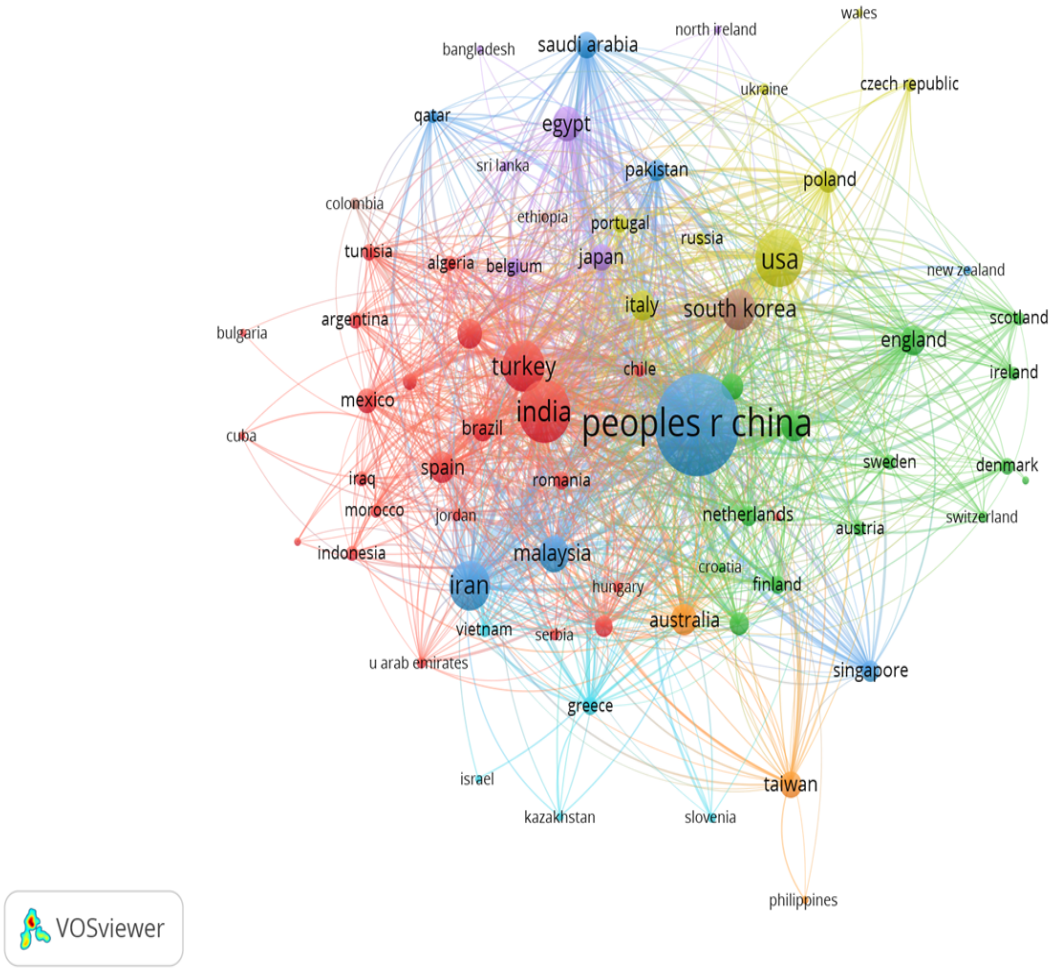

FIGURE 3 Countries involved in the publication of heavy metal (1995-2020)

Co-occurrence and Analysis of keywords

The authors' keywords analysis can give an idea of the primary topics and trends of research in heavy metal pollution[34]. Fig. (4) Below shows the most keyword as heavy metal removal and others. The keyword analysis shows that heavy metal removal is the leading research topic, with 489 occurrences recorded and total link strength of 744. Author keywords were categorized into 16 clusters. The first clusters, including environmental remediation such as ion exchange, electrospinning, electrokinetic remediation, anaerobic digestion, membrane bioreactor, and nanotechnology, are different methods for treating and removing heavy metal from wastewater. The high co-occurrence between adsorption and various heavy metals such as cadmium, chromium, copper, mercury, lead ions, graphene oxide in the second cluster showed that is one of the main methods used for the removal of heavy metal from polluted environment. Adsorption is one of the most efficient and inexpensive approaches to removing heavy metals from dirty water [35].

The fourth cluster concentrated mainly on wastewater sources from various means; examples include industrial wastewater, municipal wastewater, incineration, fertilizer, sewage, activated sludge, acid mine drainage, wastewater sludge, and sewage sludge ash. All these contributed to the pollution of the groundwater and, when consumed, resulted in health challenges. Lead intake can damage the central nervous system in humans and cause kidney, liver, reproductive systems, basic cellular processes, and brain dysfunctions. The toxicity signs are anaemia, insomnia,

headache, dizziness, irritability, weakness of muscles, hallucination, and renal damage (Naseem & Tahir, 2001); cadmium can cause human carcinogens U.S.Environmental Protection Agency categorized. Excess exposure of humans to cadmium can cause kidney failure and extreme death, exposing human health to severe risks. Mercury is a neurotoxin that is harmful to the central nervous system. And causes impairment of pulmonary and kidney dysfunction, chest pain, and dyspnoea [36].

The Minamata Bay is an example of mercury poisoning [37]. Heavy metal pollution was reported in Minamata Bay, Japan, in 1963. The people who lived near Minamata Bay consumed shellfish with high mercury levels. Chemicals released and discharged without a controller by a chemical industry near the bay were the source of these pollutants. A high mercury concentration dumped into the sea as wastewater impacted marine food chains such as shellfish and other seafood, accumulating a large amount of mercury that became toxic to people who consumed it [37].

Babies with mental disorders and physical deformities were born to mothers exposed to poisonous mercury through the consumption of mercury-contaminated fish [38]. A high nickel concentration can cause severe lung and kidney challenge aside from gastrointestinal distress, pulmonary fibrosis, and skin dermatitis [41]. Copper is an essential metal that aid metabolism in animal but excess intake can result to vomiting, cramps, convulsions, or even death [39].

Zinc is a trace element that is essential for human health. It is crucial for the physiological functions of living tissue and regulates many biochemical processes. However, too much zinc can cause eminent health problems, such as stomach cramps, skin irritations, vomiting, nausea, and anaemia [40].

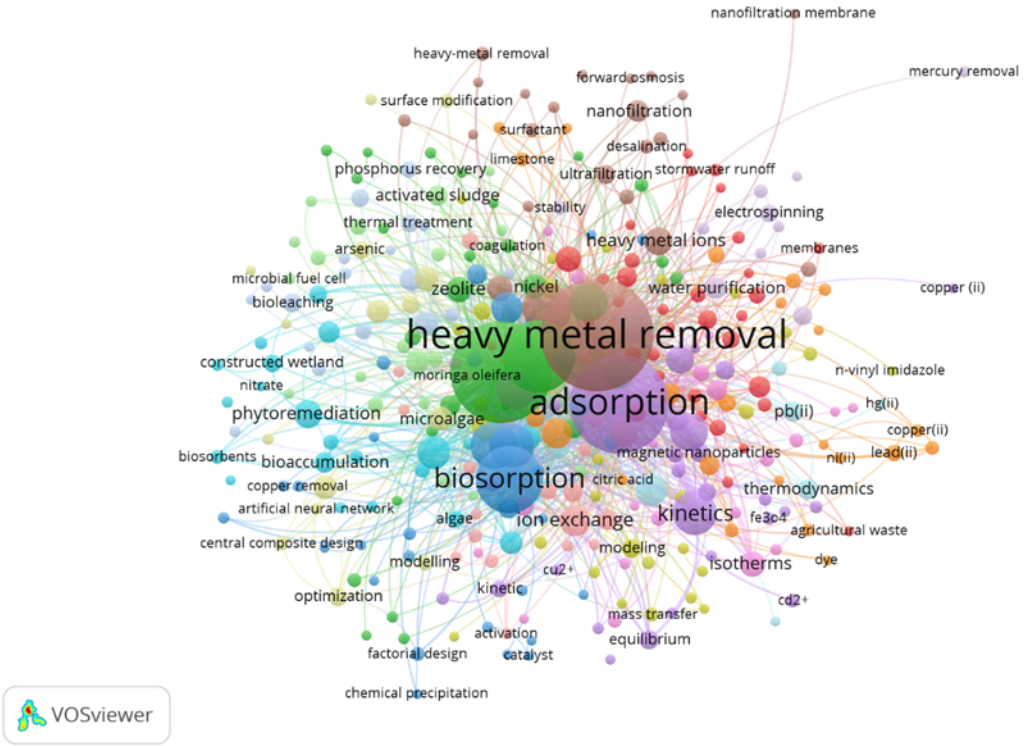

FIGURE. 4. Co-occurrence of author keywords.

AUTHORS AND COLLABORATIONS

In 1995-2000, two or more authors published around 92.4% of articles, and many published more than one article. Table 3 shows the collaborations among authors and their active participation in the academic contribution of heavy metals treatment from industrial wastewater. Denizli, A was the most productive writer, with 23 articles and ranked highest in total link strength of 45, followed by Arica, M. Y with ten points.

They are all from Hacettepe University Ankara, Turkey, and worked together in publishing "Novel dye-attached macroporous films for cadmium, zinc and lead sorption: Alkali Blue 6B-attached macroporous poly (2-hydroxyethyl methacrylate) while their main focus was on the removal of metals using a microporous membrane (film). Chung, Tai-Shung from the National University of Singapore, another creative author with 14 articles and the highest in citation record (1135), had close collaboration with Gao Jie, Sun, Shi- Peng, and Zhang, publishing a (Novel Nanofiltration Membranes Consisting of a Sulfonated Pentablock Copolymer Rejection Layer for heavy Metal Removal) all contributing in the control of heavy metal pollution from wastewater.

TABLE 3. Details of authors and their active participation in the academic contribution of heavy metals treatment and pollution

Authors	Total publication	Citation	Total link strength
Denizli, A	23	875	45
Patir,S	11	409	31
Say, R	12	361	26
Genc, O	10	317	23
Bektas,S	9	311	22
Arica ,MY	10	389	15
Chen W	9	350	14
Chung,Tai-Shung	14	1135	14
Garipcan,B	5	221	14
Mulchandani, A	9	350	14

CONCLUSION

The bibliometric method was used to examine the heavy metal contamination in drinking water. The numeral increase in the trend of publication on heavy metal removal in the past years has shown a significant number of studies has been done in this area demonstrating a considerable concern for heavy metal removal and or treatment due to its impact on environmental health. Collaboration of country networks and keyword co-occurrence networks were acquired through VOS viewers showing their influential academic status in the area. China had the highest publication with 8.08% and highly cited journals with excellent performance academically. Globally researchers are still coming up with intensifying technologies for heavy metal removal and or treatment. And it has progressively evolved from a primary subject such as Engineering, Environmental science, and other interdisciplinary fields example, physics, material science, chemistry, energy fuels, water resources, polymer science, and biotechnology applied microbiology. Material science, chemistry, energy fuels, water resources, polymer science, and applied biotechnology.

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