

Bibliometric Analysis of Macroinvertebrates as Bioindicators of Freshwater Quality

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Abstract– Currently, one of the water quality assessment techniques that is being considered worldwide is the use of bioindicators, due to their easy application and low cost, benefiting human beings and the ecosystem. The objective of this research was to perform a bibliometric analysis of the use of macroinvertebrates as bioindicators of freshwater quality. For the study, research related to the topic (between January 2010 and August 2021) was selected from the Scopus and Web of Science databases, using a search string comprised of keywords. Excel software was used to record and prepare tables and figures, and VOSviewer was used for data and bibliometric network analysis. The results of the search yielded 567 investigations in the Scopus database and 716 for the Web of Science (WoS) database, identifying that the most studied class of macroinvertebrates as a bioindicator of freshwater quality is the Insecta class. The journal with the highest scientific production on the topic studied was “ecological indicator”, both for the Scopus and WoS databases, and the country with the highest number of publications was the United States. The largest number of publications on macroinvertebrates was found in the thematic area “Environmental science”, and the most used keyword was “macroinvertebrates”. Finally, it is concluded that the orders Ephemeroptera, Plecoptera and Trichoptera of the class Insecta are the most used and with the best results as bioindicators of freshwater quality.

Keywords– bibliometric analysis, macroinvertebrates, bioindicator, fresh water, quality.

I. INTRODUCTION

Globally, there is a water deficit due to the contamination of freshwater sources by the various activities carried out by man for his survival, which is reflected in the need for massive consumption, vital for the life of all living beings. The problems of contamination of soils near watersheds, as well as the different anthropogenic actions cause contamination of these water bodies [1], [2].

Fresh water is present in nature, mainly in rivers, lakes and lagoons, originating in the so-called headwaters or upper watersheds, where high quality water is found because it is located in little disturbed ecosystems [3]. However, the various activities developed by humans in the industrial, agricultural, and petrochemical sectors, as well as the disorderly growth of cities, are causing negative impacts on freshwater bodies [4]. These actions generate serious alterations in the different species of animals and plants present in aquatic ecosystems, in addition to health problems for human beings [5]. The progressive contamination of water bodies causes damage to the physiological and ecological functions of various species, and multiple diseases that

directly affect the population, forcing them to invest large amounts of money in the purification of water for its subsequent consumption [6].

One of the techniques that has been implemented is the use of macroinvertebrates such as Ephemeroptera, Odonata and Trichoptera to assess water quality in headwater regions of rivers in Ethiopia, determining the degree of disturbance through a multimetric analysis in different areas of the basin [7]. Also, using benthic macroinvertebrates, the Poyang Lake and Yangtze River in China were evaluated, determining in 2010 that 86.7% of the sampling points are regular quality waters, and in 2013 it was determined that 62.5% of the sampling points are poor quality waters, evidencing that with the passage of time the water disturbances are increasing [8]. In addition, Ref [9] used biological indicators (macroinvertebrates) to assess water quality in the wetlands of the Sajian Plain, determining that 76.2% of the wetland freshwater is in poor or fair condition, suggesting an emphasis on biomonitoring in order to more efficiently manage these water systems.

The use of macroinvertebrates is a sustainable monitoring technique for the evaluation of aquatic systems, without causing disturbances. On the other hand, an early analysis of the quality and state of the water using macroinvertebrates as bioindicators will make it possible to manage and intervene in the points of contamination, avoiding future expenses in treatment systems. In addition, the aim is to determine and make known the areas of the basin that are in good or bad condition with respect to water quality, so that the population does not come into contact with contaminated water and possible diseases are avoided.

Therefore, the present bibliometric analysis research evaluated the use of macroinvertebrates as bioindicators to determine the quality of freshwater, corresponding to the years 2010 to 2021. For this purpose, the following was done: (a) identify the number of research studies that used macroinvertebrates as bioindicators of freshwater quality, (b) identify the journals with the highest scientific production on macroinvertebrates as bioindicators of freshwater quality, (c) identify the countries that have the most publications on macroinvertebrates as bioindicators of freshwater quality, and (d) identify the classes of macroinvertebrates most used as bioindicators of freshwater quality.

II. METHODOLOGY

A. Approach and type of study

The study had a quantitative approach and was of the applied type. In addition, it had a non-experimental design, with an explanatory level based on direct observation and analysis of the literature. For the bibliometric analysis, original articles and reviews from relevant scientific databases such as Scopus and Web of Science, from January 2010 to August 2021, were used.

B. Sources of information and search strategies

In the present research, documents (articles and reviews) indexed in reliable databases such as Scopus and Web of Science were taken into account. For the bibliometric analysis of macroinvertebrates as bioindicators of freshwater quality, a search of documents related to the topic was carried out using keywords and Boolean connectors such as "AND", "OR" and "NOT". The search was conducted in the English language, using the keywords [(macroinvertebrate OR macroinvertebrate OR invertebrate OR invertebrate) AND (freshwater OR "fresh water") AND (indicator OR bioindicator OR bioindicator) AND NOT seawater].

C. Data analysis

The data were analyzed by VOSviewer software, which facilitates the creation of network maps that allow the analysis of large numbers of articles [10]. Data from both databases were processed in tables and graphs using Microsoft Excel software.

III. RESULTS AND DISCUSSION

A. Number of articles published

Figure 1 shows the number of articles published (between January 2010 and August 2021) in the Scopus and WoS databases, showing a slight difference in the number of publications in both databases. In the Scopus database 903 articles were published and in the WoS database 1052 articles were published, sharing 336 articles between the two databases. For [11], in the engineering field, the Scopus database has more publications than Web of Science. However, in this bibliometric analysis, the database with the highest number of publications on the subject studied is Web of Science [10].

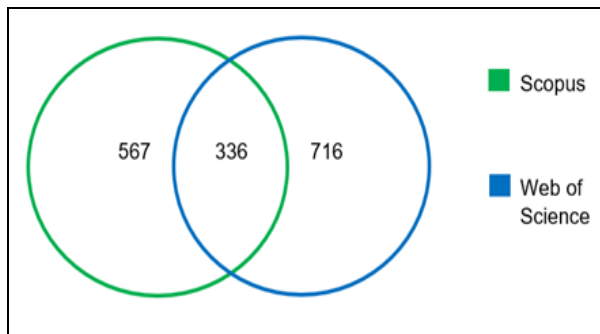


Fig. 1 Venn diagram to identify the amount of research published in Scopus and Web of Science

B. Scientific production: journals with the highest number of publications

For the Scopus database, the scientific journals with the most publications were "ecological indicators", "science of the total environment" and "hydrobiologia", with 72, 52 and 18 publications, respectively. Meanwhile, in the Web of Science database, the scientific journals with the highest number of publications were also "ecological indicators" with 116 published journals, followed by "freshwater biology" with 49 publications and "science of the total environment" with 43 published papers (see Table 1).

The WoS database has more scientific journals containing the topic on macroinvertebrates as bioindicators of freshwater quality. Similarly, [12] performed a bibliometric analysis on the impacts of anthropogenic land use change on aquatic ecosystems, and concluded that the journals oriented to the research topic are "environmental science and water resources", with the most productive journal being "science of the total environment" (7.9%), "environmental monitoring and evaluation" (3.07%) and the journal of "hydrology and environmental science pollution and research" (2.3%). Also, [13] in the bibliometric analysis "global research on riparian zones in the XXI century", indicated that the main journals are "Journal of Hydrology:" with 40 articles, "Forest Ecology and Management" with 30 articles, "Hydrological Processes" with 28 articles, "Journal of the American Water Resources Association" with 28 articles and "Science of the Total Environment" with 26 articles.

TABLE I
JOURNALS WITH THE GREATEST SCIENTIFIC PRODUCTION IN THE SCOPUS AND WEB OF SCIENCE DATABASES

Name of journals	Number of documents	
	Scopus	Web of Science
Ecological Indicators	72	116
Science of the Total Environment	52	43
Hydrobiologia	18	22
Freshwater Science	17	36
Environmental Monitoring and Assessment	12	-
Environmental Science and Pollution Research	12	12
PLoS ONE	12	-
Shengtai Xuebao/ Acta Ecologica Sinica	10	-
Journal of Applied Ecology	9	-
Freshwater Biology	9	49
Marine and freshwater research	-	23
Aquatic conservation-marine and freshwater ecosystems	-	21
Journal of freshwater ecology	-	17
Water	-	10

C. Analysis of Scopus and WoS document types

The most representative document type in the Scopus database (Figure 2a) was articles, representing 92.6% of the 567 studies, and for the Web of Science database (Figure 2b), articles also accounted for 95.5% of the 716 studies. The article is a written report that summarizes the results of a

research, indicating the procedure and type of research with which the studies were conducted [14]. In other bibliometric analyses it is also shown that the article is the most used type of document, for example, in the study of [15] they performed a bibliometric analysis about "global trend of solid waste research from 1997 to 2011". showing that publications correspond to "articles" 94.5% (22712), "procedure

documentation" 10.9% (2629), "reviews" 4.2% (1015), "editorial material" 0.5% (120) and "summaries" 0.4% (102). Additionally, Ref. [16], in the "bibliometric analysis of research on acid rain" showed that the main document consulted was the "article" (76.8%), "procedure documentation" (8.7%) and "reviews" (3.9%).

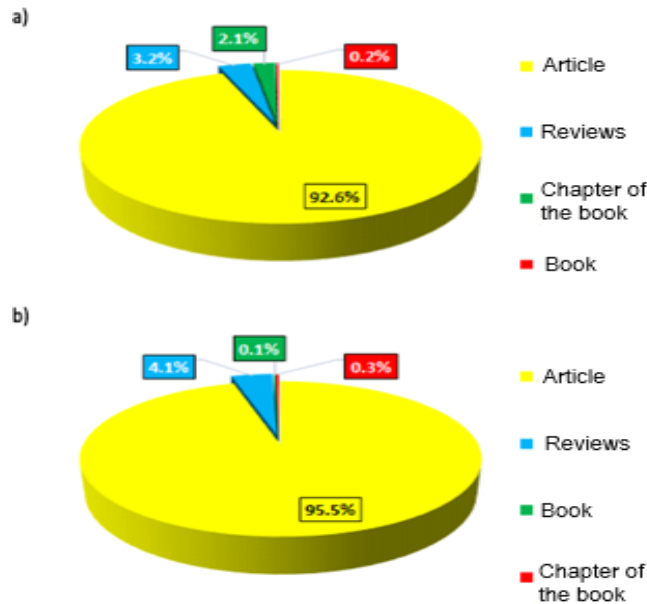


Fig. 2 Database document types (a) Scopus and (b) Web of Science

D. Analysis of the number of publications per year in the Scopus and WoS databases

Figure 3 shows the number of publications per year, showing 567 documents for the Scopus database and 716 documents for the Web of Science database.

Figure 3 shows that for the Scopus database, in 2019, 2020 and 2021 there were more publications with 56, 59 and 69 documents, respectively. While, in the web of science database, in the years 2018, 2019 and 2020 had the highest scientific production with 73, 80 and 78 documents, respectively.

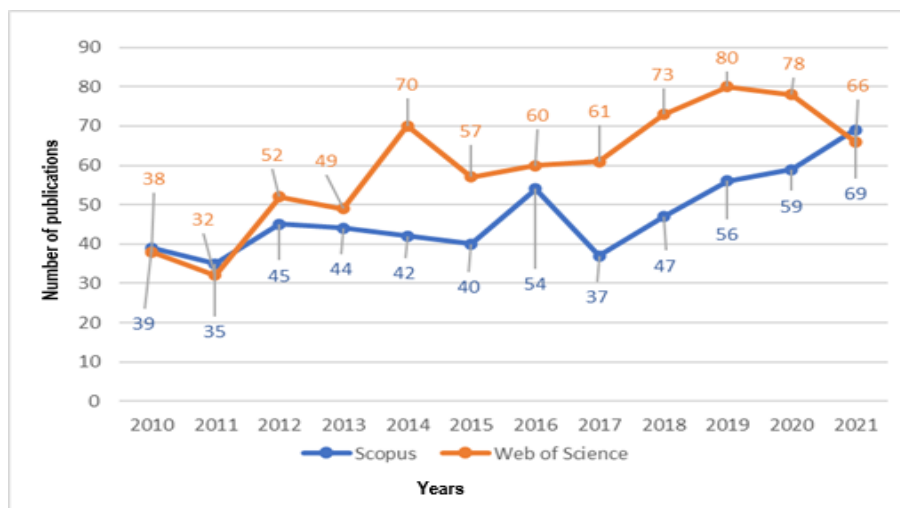


Fig. 3 Number of documents published per year in the Scopus and WoS databases

E. Analysis of the amount of published research by thematic area in Scopus and WoS

Regarding the Scopus database, the thematic area with the most published papers on the use of macroinvertebrates as bioindicators of freshwater quality is "environmental science" with 404 papers, followed by "agricultural and biological sciences" with 337 papers and "decision sciences" with 72 papers (see Table 2). In the Web of Science database, the thematic areas that published the most documents are "environmental science" with 338 documents, followed by "marine freshwater biology" with 230 documents and "ecology" with 199 published documents. In other research such as "A bibliometric analysis on nonpoint source pollution: current stats, development and future", the authors mentioned that the most outstanding thematic areas are "environmental science" with 3081 papers, "water resources" with 2237

papers, "engineering environmental" with 1359 papers, "geosciences" with 883 papers, "ecology" with 490 papers and "civil engineering" with 467 papers [17]. Ref. [18] conducted "A bibliometric analysis of eutrophication literatures: an expanding and shifting focus", indicating that the most used subject areas were "environmental and ecological sciences" with 7190 papers, "marine freshwater biology" with 4950 papers and "engineering" with 1905 papers, respectively. Ref. [19] also conducted a bibliometric analysis "mapping of drinking water research: A bibliometric analysis of research output during 1992-2011", and found that the most representative subject areas were "environmental science" with 8345 papers followed by "water resources" and "engineering environmental", with 4547 and 3867 papers, respectively.

TABLE II
THEMATIC AREA WITH THE GREATEST SCIENTIFIC PRODUCTION IN THE SCOPUS AND WoS DATABASES

Thematic area	Number of documents	
	Scopus	WoS
Environmental Science	404	338
Agricultural and Biological Sciences	337	-
Marine Freshwater Biology	-	230
Ecology	-	199
Biodiversity Conservation	-	146
Limnology	-	82
Decision Sciences	72	-
Water Resources	-	65
Earth and Planetary Sciences	50	-
Fisheries	-	42
Oceanography	-	42
Biochemistry, Genetics and Molecular Biology	35	-
Toxicology	-	22
Medicine	21	-
Pharmacology, Toxicology and Pharmaceutics	20	-
Multidisciplinary	18	-
Social Sciences	18	-
Chemistry	16	-
Engineering Environmental	-	16

F. Class of macroinvertebrates as the most used bioindicators in water quality analysis: Scopus and WoS databases

According to Table 3, the most used class of macroinvertebrate as a bioindicator of freshwater quality is Insecta, with 114 and 143 researches in the Scopus and Web of Science databases, respectively. The second most used class

is Crustacea with 37 and 41 publications in the Scopus and Web of Science databases, respectively.

TABLE III
CLASS OF MACROINVERTEBRATES MOST USED IN WATER QUALITY ANALYSIS
IN SCOPUS AND WoS

Class	Scopus	Web of Science
<i>Insecta</i>	114	143
<i>Crustacea</i>	37	41
<i>Gastropoda</i>	8	15
<i>Oligochaeta</i>	19	14
<i>Bivalvia</i>	3	6
<i>Hirunidea</i>	1	5
<i>Turbelaria</i>	1	3
<i>Demospongiae</i>	1	0
TOTAL	184	227

G. Analysis of the trend in the use of macroinvertebrate classes according to years in the Scopus and WoS databases

In the Scopus database, the trend of macroinvertebrate classes as bioindicators of freshwater quality as a function of years shows that Insecta had a growth from 6 to 16 articles published between the years of 2018 - 2020 (Figure 4a). In comparison to the Web of Science database (Figure 4b), Insecta had a growth of 14 to 20 publications between the years of 2019 - 2021. Other researchers such as [20], [21] and [22] also evaluated water resources in their bibliometric analysis research, but not necessarily using macroinvertebrates.

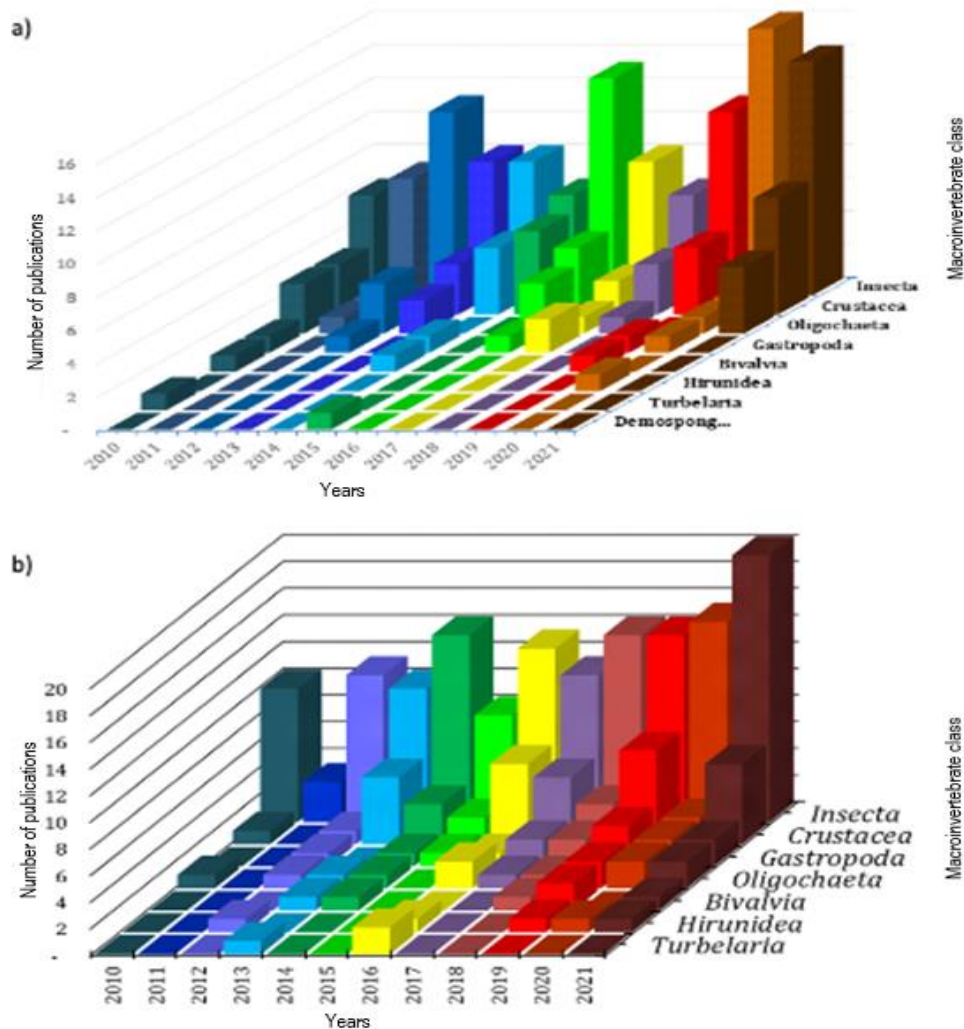


Fig. 4 Trend in the use of macroinvertebrates according to years: a) Scopus and b) WoS

H. Analysis of scientific research according to countries: a) Scopus and b) WoS

The countries with the highest number of publications on macroinvertebrates as bioindicators of freshwater quality in the Scopus database (Figure 5a) were the United States, Germany and the United Kingdom with 98, 64 and 52 documents, respectively, while Ecuador, Ethiopia and Ghana had less than 10 publications. Concerning the Web of Science database (Figure 5b), the countries with the most publications on macroinvertebrates as bioindicators of freshwater quality were the United States, Germany and England with 141, 84 and 67 papers, respectively, while the countries with less than 10 publications were Japan, Russia and India.

Ref [23], in the research "emerging contaminants as global environmental hazards a bibliometric analysis" between

the period from 2000 to 2019, showed that the countries with the most publications in the Scopus database were the United States, China and Spain with 1072, 1025 and 781 publications, respectively. Similarly, Ref [24], in the research "bibliometric analysis for the research on river water quality assessment and simulation" between the period from 2000 to 2014, mentioned that the countries with the largest publications were the United States with 1296, China with 491, United Kingdom with 314, Canada with 221, Australia with 208 and Germany with 191 publications. Similarly, Ref. [25], in the bibliometric analysis on "emerging trend in municipal solid waste incineration ashes research", indicated that the countries contributing the most research were China with 513 publications, Japan with 213 publications and Taiwan with 183 publications.

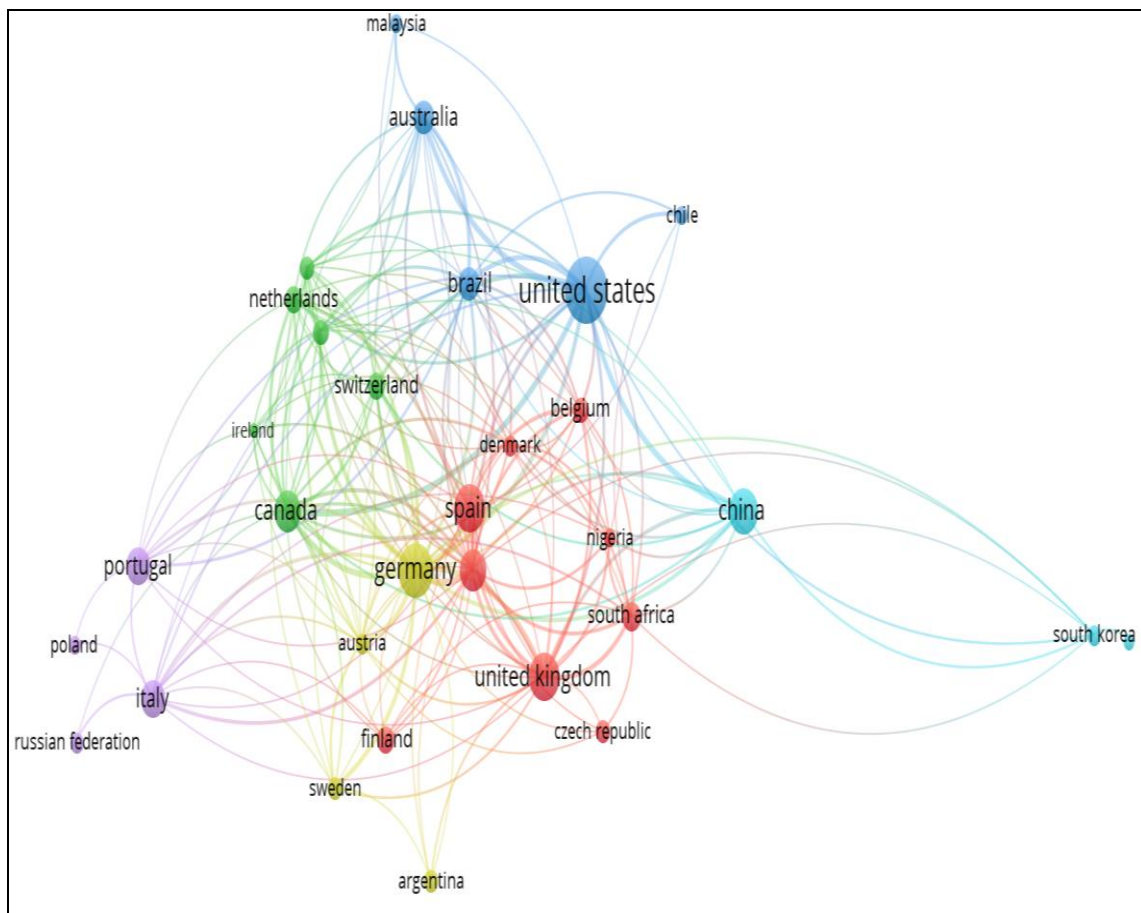


Fig. 5 Analysis of scientific research by country: a) Scopus and b) WoS

IV. CONCLUSIONS

In the bibliometric analysis, the Scopus database showed that the most representative class of macroinvertebrates as a bioindicator of good freshwater quality is insecta and as a bioindicator of poor freshwater quality is Oligochaeta. For the

Web of Science database, it was also found that the insecta class is a good bioindicator of freshwater according to the documents studied. Among other relevant results are:

A total of 1283 documents related to the use of macroinvertebrates as bioindicators of freshwater quality were worked with, corresponding to the period from January 2010

to August 2021, of which 567 correspond to the Scopus database and 716 for Web of Science.

The journal with the highest scientific production on macroinvertebrates as bioindicators of freshwater quality was identified as "Ecological indicators" with 72 publications in the Scopus database and 116 in Web of Science.

The country with the largest number of publications on macroinvertebrates as bioindicators of freshwater quality was the United States, both in the Scopus and Web of Science databases.

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