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An Empirical Study on the Landscape of Mining and Mineral Processing (MMP) With Big Data

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ABSTRACT

Over the last two decades, mining and mineral processing (MMP) has changed dramatically. Little is known about the bibliometric analysis of MMP. To this end, this study used the big data analysis to investigate the quantity and quality of scientific outputs in MMP over the past 21-year timespan. This study used IBM SPSS Statistics 25.0 and VOSviewer software to research on the 20 journals from Science Citation Index Expanded (SCI-Expanded) of Web of Science Core Collection (WOSCC). VOSviewer software was used to identify the visualization contributions of scientific outputs over 21-year timespan. Totally, the big data analysis shows people of China have the highest cumulative IFs, but their mean IFs are relatively low and are ranked in fourth place. Visually, people of Chin ranked the first in total link strength (2967), but not in links (86), which is the third place among Top15 countries. From the perspective of quality, it cannot rank the first. Thus, people of China should put more effort into improving the quality of scientific outputs.

KEYWORDS

Bibliometric Analysis, Mining and Mineral Processing, Multidimensional Data Analysis, Scientific Outputs, VOSviewer

INTRODUCTION

Mining and mineral processing (MMP) have significantly contributed to the advancement of human civilization and national economies, but they also have the potential to cause serious environmental degradation (Adusumilli et al., 2005). Thus, sustainable mining and mineral processing is of paramount importance worldwide. Therefore, the studies of MMP are significantly growing and have made great progress over the last 21 years.

MMP consists of a wide scale of aspects connected with economic development, social needs, ecological balance, and environmental problems, thus the research on MMP involves many aspects. The development of MMP plays a vital role to ensure reliable energy supply, reduce environmental pollution, and mitigate greenhouse gas emissions (Allahabadi et al., 2021).

Over the past 21 years, the study of MMP has made remarkable progress all over the world. However, no literature review in this field has been conducted on the comparison of the quantity and quality of scientific outputs using bibliometric analysis from 2000 to 2020, although Rojas-Sola and

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Aguilera-García (2015) analyzed MMP from a very different perspective (Oelrich et al., 2007). The quantity and quality of the scientific papers can reflect not only the level of individual research, but also the comprehensive national strength of a country (Bhattacharya, M. et al., 2015). For a country, the quantity and quality of publications of that country can reflect its research level in a specific scientific field (Briones-Bitar et al., 2020). Multidimensional data analysis can provide a completely new perspective by and for scholars (Najjar and Dahabiyeh, 2021; Gu et al., 2021; Zhu, 2021).

Bibliometrics is an important tool to analyze the literature of a certain scientific domain and to assess the trends in research activity over time (Brown, 2007). Bibliometric analysis is also a powerful and important tool in evaluating the scientific performance and development of a research field (Cherubini, 2008; Eck & Waltman, 2010; Fu et al., 2011; Fu & Ho, 2010; Journal of Citation Reports, 2022). In view of this situation, this study uses a bibliometric analysis to systematically evaluate the scientific outputs of MMP in the comparison of quantity and quality worldwide and among top ranking countries to provide a new perspective for future research directions. Impact factor (IF) for each journal and each year, total scientific outputs from years 2000-2020, and the numbers of scientific outputs in 20 MMP journals in the studied years were collected from the Science Citation Index Expanded (SCI-Expanded) of the Web of Science Core Collection (WOSCC). Cumulative IFs (CIFs), mean CIFs, citations, and average citations were analyzed in detail and the visualization contribution was investigated in this study. These criteria could be considered as indicators of the quantity and quality of research productivity, although limitations of the criteria, such as the IF or citation analysis should always be taken into account (Garrigos-Simon et al., 2019; Grange, 1999; Herrera-Franco et al., 2021; Huai & Chai, 2016).

For availability and completeness of data, only the 21-year timespan was included for evaluation.

The VOSviewer, developed by the University of Leiden, is visualization software, which was used in this study to construct the bibliographical coupling analysis (Journal Citation Reports, 2022). This software makes it easy to interpret the graphical representation of bibliometric maps (Andersen et al., 2006) and shows the construction and visualization of two-dimensional bibliographic networks (King, 2004). The software has been widely applied in various studies to evaluate different articles and visualize data networks. This study mainly used VOSviewer software to conduct the bibliographical coupling analysis.

To this end, this study used multidimensional data analysis to provide a more accurate landscape of MMP from the perspective of bibliometric analysis within the 21-year timespan.

MATERIALS AND METHODS

Data Collection

This study used the subject category of MMP from the Science Citation Index Expanded (SCI-Expanded) of the Web of Science Core Collection (WOSCC), which is one of the vital sources of scientific information. A total of 20 journals are included in this study according to JCR in 2020, although JCR shows 21 journals included in this category, but Minerals & Metallurgical Processing was changed into Mining Metallurgy & Exploration in 2019. Because of this, scientific outputs from the two journals using the two different names were combined, and the same goes for another two journals. The International Journal of Minerals Metallurgy and Materials changed to the Journal of University of Science and Technology Beijing in 2009, and Coal Preparation was changed into the International Journal of Coal Preparation and Utilization in 2008. These 20 journals come from 11 countries.

The USA ranks first, and four journals (Mineral Processing and Extractive Metallurgy Review, the International Journal of Coal Preparation and Utilization, the Marine Georesources & Geotechnology, and JOM) are involved. This is followed by England (the International Journal of Rock Mechanics and Mining Sciences, the Minerals Engineering, the International Journal of Mining Reclamation and Environment), and Poland (Physicochemical Problems of Mineral Processing, Archives of Mining Sciences, and Gospodarka Surowcami Mineralnymi-Mineral Resources Management), with three journals, respectively. The People of China (only mainland) (the International Journal of Mining Science and Technology, the International Journal of Minerals Metallurgy and Materials). The Netherlands (Ore Geology Reviews and Journal of Applied Geophysics), had two journals, respectively, followed by Germany, South Africa, Russian, the Czech Republic, Switzerland, and Slovakia, with one journal each.

Data Calculation

The methods used to evaluate the quantity and quality of scientific output were as follows:

1. IFs for 20 MMP journals and total scientific outputs distributed in 20 MMP journals were retrieved over the past 21-year timespan.
2. Scientific outputs for the Top 15 countries were exported from WOSCC in the analyzed period.
3. The CIFs and mean CIFs were calculated by JCR.
4. Citation reports for the Top 15 countries were collected through WOSCC.
5. The numbers of scientific outputs published in each one of the 20 MMP journals for the Top 15 countries were counted and the Top 5 high-impact MMP journals were also identified.
6. Visualization contribution of scientific outputs was analyzed by VOSviewer.

The data collected from SCI-Expanded of WOSCC were exported into a Microsoft Excel spreadsheet to carry out the respective treatment and analysis (Man et al., 2014). This Microsoft Excel is also used for some basic calculations. Statistical analysis was performed with IBM SPSS Statistics 25.0. The descriptive statistics (minimum, maximum, mean, median, standard error (SE), and standard deviation (SD)) were used to provide an overall summary of the study indicators. The use of Spearman correlation coefficient (r_s) was to evaluate the correlations between the number of the scientific outputs, CIFs, mean CIFs, total citations, and average citations. The strength of the correlation was indicated by the absolute value of r_s: weak, <0.4; moderate, 0.4 to 0.7; and strong, >0.7 (Falagas et al., 2008). The value of $p<0.05$ was considered significant. A regression analysis was also used to show any significant change in time trend during 2000–2020.

The quality of the scientific output was evaluated by the following two methods: the summed CIFs and mean CIFs were calculated according to Journal of Citation Reports (JCR) published by Clarivate (Oelrich et al., 2007); (2) citation reports from top ranking countries were collected through the Web of Science (Peng et al., 2018).

RESULTS

IFs of 20 Journals in MMP

Table 1 shows the list of 20 MMP journals with their IFs from 2000-2020 and the mean IFs for each year and each journal.

Table 1 presents all IFs of the Top 20 journals in MMP research within the 21-year timespan. As shown in Table 1, the 20 journals of MMP are arranged according to their IFs in 2020. The mean IFs from 2000 to 2020 show the general trend of increase. The arithmetic mean IFs of the 20 evaluated journals were 1.200, with SD 0.892, and a range of 0.011–7.135. Among the 20 journals, 7 journals (Int. J. Rock Mech. Min. Sci., Miner. Eng., Ore Geol. Rev., Mar. Geores. Geotechnol., Int. J. Miner. Metall. Mater., J. S. Afr. Inst. Min. Metall., and J. Min. Sci.) had 21-year-long IFs, with mean IFs as 1.744, 1.579, 2.333, 0.634, 1.01, 0.232 and 0.25, respectively. Of the 7 journals, it is notable that the mean IF of Ore Geol. Rev. ranks first with 2.333, followed by Int. J. Rock Mech. Min. Sci., and Miner. Eng.

Table 1. List of 20 journals in MMP with their impact factors used in this study

Journal name	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Mean IF
Int. J. Rock Mech. Min. Sci.	0.731	0.547	0.884	0.649	0.799	0.338	0.624	0.735	1.031	1.142	1.390	1.272	1.200	1.424	1.686	2.010	2.268	2.836	3.769	4.151	7.135	1.744
Miner. Process Extr. Metall. Rev.													0.647	0.690	0.891	1.560	1.219	2.117	1.615	2.785	5.284	1.868
Miner. Eng.	0.517	0.430	0.564	0.438	0.492	0.678	0.942	0.939	1.022	1.333	1.244	1.352	1.207	1.714	1.597	1.813	2.286	2.707	3.315	3.795	4.765	1.579
Int. J. Min. Sci. Technol.																				3.903	4.084	3.994
Ore Geol. Rev.	1.933	0.556	1.067	1.528	1.041	0.981	0.877	0.987	2.374	2.089	2.079	2.159	2.417	3.383	3.558	3.819	3.095	3.993	3.387	3.868	3.809	2.333
Int. J. Min. Reclam. Environ.												0.222	0.392	0.531	0.562	0.500	1.078	1.258	1.727	1.917	2.956	1.114
Int. J. Coal Prep. Util.						0.297	0.179	0.294	0.222	0.286	0.278	0.289	0.200	0.727	0.562	0.855	0.673	1.527	2.020	2.034	2.697	1.012
Mar. Georesources Geotechnol.	0.111	0.444	0.216	0.242	0.195	0.256	0.333	0.186	0.257	0.184	0.452	0.364	0.375	0.383	0.644	0.761	1.159	1.207	1.166	1.716	2.673	0.634
Minerals															1.000	1.500	2.088	1.835	2.250	2.380	2.644	1.957
JOM					0.591	0.692	0.887	1.081	1.485	1.043	1.179	1.421	1.053	1.401	1.757	1.798	1.860	2.145	2.305	2.054	2.474	1.484
Int. J. Miner. Metall. Mater.	0.118	0.099	0.397	0.437	0.311	0.368	0.325	0.342	0.475	0.416	0.322	0.691	0.483	0.573	0.791	0.882	0.943	1.261	1.221	1.713	2.232	1.010
J. Appl. Geophys.	0.517	0.390	0.750	0.562	0.552	0.802	1.065	0.938	1.333	1.294	1.185	1.444	1.327	1.301	1.500	1.355	1.347	1.646		1.975	2.121	1.170
Mining Metall. Explor.	0.207	0.329	0.141	0.293	0.221	0.290	0.191	0.297	0.224	0.229	0.167	0.220	0.379	0.545	0.612	1.714	0.692	0.786	0.784	1.020	1.407	0.512
Acta. Montan. Slovaca.										0.097	0.134	0.084	0.094	0.053	0.329	0.390	0.769	0.973	0.938	1.181	1.413	0.538
Physicochem. Probl. Mineral Pro.										0.355	0.406	0.500	0.580	0.862	0.926	0.977	0.901	1.200	1.062	1.256	1.213	0.853
Acta Geodyn. Geomater.										0.275	0.452	0.530		0.667	0.389	0.561	0.699	0.886	1.062	1.227	1.176	0.720
Arch. Min. Sci.										0.306	0.312	0.350	0.319	0.608		0.448	0.550	0.629	0.589	0.770	1.127	0.546
Gospod. Surowcami. Miner.										0.103	0.135	0.262	0.342	0.632 0.540	0.567		0.481	0.400	0.425	0.588	0.838	0.443
J. S. Afr. Inst. Min. Metall.	0.058	0.097	0.052	0.061	0.113	0.077	0.124	0.108	0.156	0.216	0.121	0.252	0.249	0.176	0.221	0.237	0.300	0.339	0.467	0.643	0.807	0.232
J. Min. Sci.	0.000	0.011	0.012	0.126	0.174	0.226	0.126	0.293	0.187	0.352	0.390	0.189	0.223	0.404	0.239	0.350	0.353	0.435	0.358	0.336	0.456	0.250
Mean IF	0.524	0.323	0.454	0.482	0.449	0.455	0.516	0.564	0.797	0.608	0.640	0.682	0.676	0.893	0.989	1.163	1.198	1.483	1.581	1.966	2.566	1.200

The nine journals that have five years or more, but less 21-year impact factors are as follows: Miner. Process Extr. Metall. Rev., Int. J. Min. Reclam. Environ., Minerals, JOM, Acta. Montan. Slovaca., Physicochem. Probl. Mineral Pro., Acta Geodyn. Geomater., Arch. Min. Sci., and Gospod. Surowcami. Miner.

From 2014 onwards, the mean IFs of the 20 MMP journals show the trend of significant increase. In a word, the IFs of 20 journals over the past 21-years have significantly changed.

Overview of Scientific Outputs in MMP Research Over the Past 21-Year Timespan

Summary of Scientific Outputs in MMP From 2000 to 2020

The timespan of this study ranges from 2000 to 2020, because the IFs in 2021 had not been announced yet when the data were retrieved. A total of 33,235 scientific outputs were distributed in 20 journals over the period from 2000 to 2020. Articles, proceeding papers, and review articles published within these 20 journals from 2000 to 2020 were downloaded for analysis, but not editorials, corrections, reports, reviews, or letters, etc. Moreover, this study only focuses on the scientific outputs written in English. The data collection was retrieved on May 24, 2022, and completed within a single day to avoid database updates. Ethical approval was not necessary for this study, as no human subjects or personal data were involved. Figure 1 shows the flow diagram of the bibliometric process of the study. Figure 2 presents the change of scientific output for the 20 journals of MMP from 2000 to 2020.

Figure 1. Flow diagram of the research process

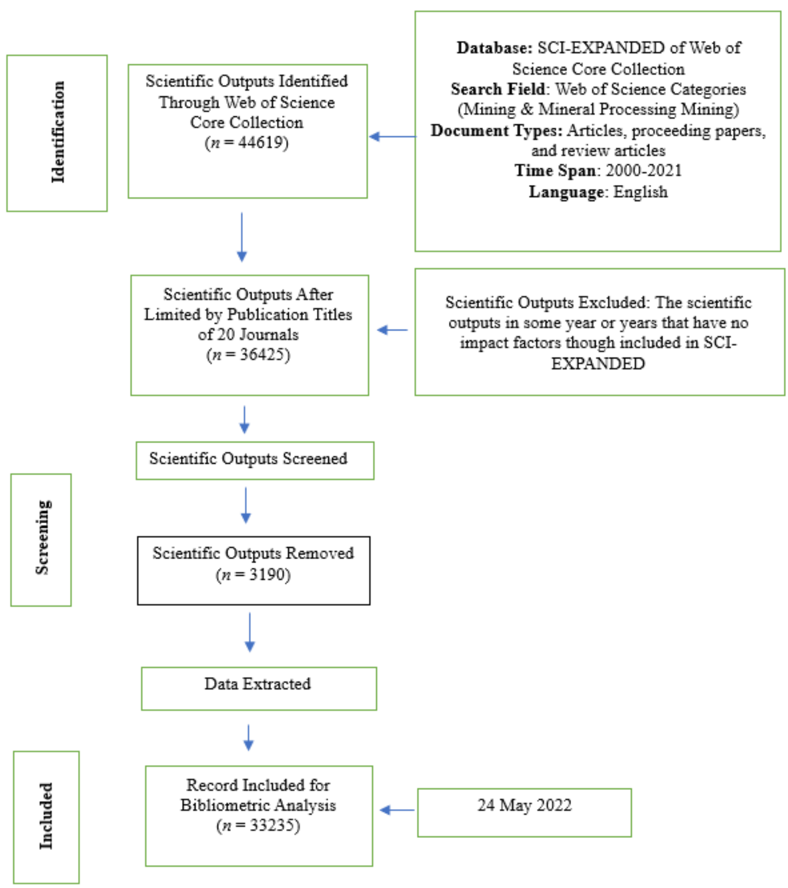
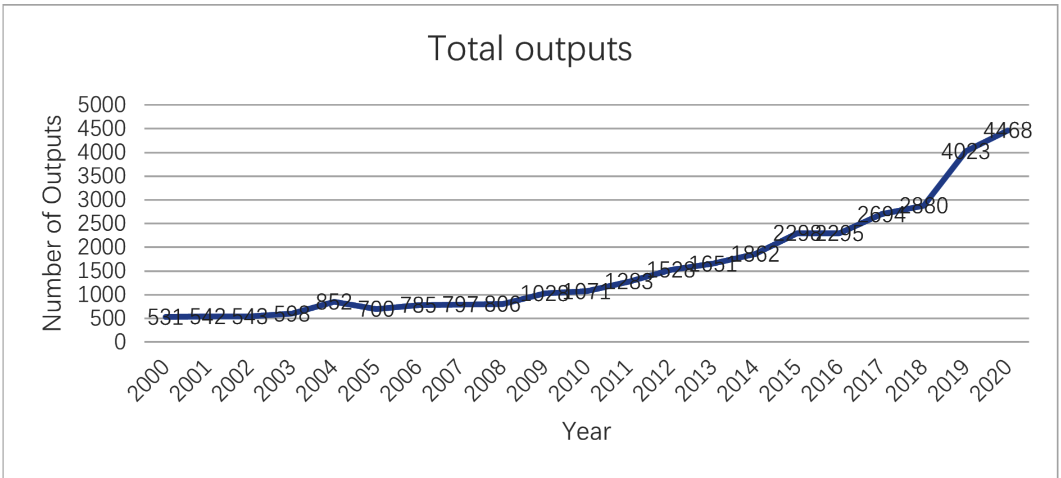


Figure 2. Output the performance in MMP over the past 21 years



As shown in Figure 2, a total of 33,235 scientific outputs were published worldwide between 2000 and 2020 in MMP journals. Scientific outputs of the evaluated journals grew rapidly from 2000 to 2020 and increased eight times more over the 21-year timespan. Especially, in 2019, the number of scientific outputs increased dramatically, with 1,143 scientific outputs totally and 39.69% growth rate this year. Over the past 21 years, the scientific outputs of MMP increased significantly from 531 in 2000 to 4,468 in 2020, with an average annual growth rate of 12.08%. In summary, the number of scientific outputs has dramatically increased from 2000 to 2020.

As is shown in Table 2, the scientific outputs published in Miner. Eng. are 4,569, which accounts for 13.75% with the first rank. JOM is in the second rank and occupies 12.08%, with 4,016 scientific outputs. Followed by Int. J. Rock Mech. Min. Sci., in third rank, with 9.95% and 3,308 scientific outputs.

Summary of 33,235 Scientific Outputs

Table 3 provides an overview of the scientific outputs used in this study. As noted in Table 3, 33,235 scientific outputs were written by 74,554 authors and published by 153 countries. In addition to a total of 740,292 citations, provided over the past 21 years; 30,610 scientific outputs had at least one citation, occupying 92.1%. Of the 33,235 scientific outputs, the average citations per scientific outputs was 24.18, and the average authors per scientific output was 2.24.

Most Productive Countries in MMP Journals During 2000–2020

Science Citation Index Expanded (SCI-Expanded) of the Web of Science Core Collection (WOSCC) shows that 153 countries published scientific outputs of MMP journals within 21 years. Although there was a great geographic breadth of scientific outputs, the Top 15 countries were responsible for more than 90% of the global total output in MMP. Table 4 lists the Top 15 most productive countries in MMP. The following indicators were calculated for each country: ranking, total number of scientific outputs, and percentage of total output.

Table 4 provides detailed information relating to the Top 15 countries in the analyzed years. The sum of the scientific outputs of these Top 15 countries was 32,912. Of these 15 countries, five were in Europe, five in Asia, two in North America, one in South America, one in Oceania, and one in Africa. The People of China ranked as the most productive country, with an obvious advantage (9,966; 29.99%). The second most productive country was the USA (4,348; 13.08%), followed by

Table 2. Scientific outputs for each journal of 20 MMP journals over the 21 years

Journal Names	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total	Percentage
Int. J. Rock Mech. Min. Sci.	98	100	74	85	240	84	105	89	123	141	142	143	147	191	227	225	184	167	258	201	284	3308	9.95%
Miner. Process Extr. Metall. Rev.													27	28	22	42	35	43	36	76	64	373	1.12%
Miner. Eng.	136	146	142	169	148	180	197	175	137	174	170	227	193	234	242	304	232	203	357	392	411	4569	13.75%
Int. J. Min. Sci. Technol.																				115	106	221	0.66%
Ore Geol. Rev.	17	13	23	26	28	45	34	57	67	47	41	67	66	81	173	279	263	518	347	437	546	3175	9.55%
Int. J. Min. Reclam. Environ.												26	23	25	27	37	29	37	35	53	40	332	1.00%
Int. J. Coal Prep. Util.						20	14	13	14	22	23	22	22	26	29	26	29	21	37	96	134	548	1.65%
Mar. Geores. Geotechnol.	20	17	16	25	18	24	19	16	22	20	24	24	23	22	24	58	77	122	93	203	151	1018	3.06%
Minerals															39	52	129	247	590	774	1121	2952	8.88%
JOM					125	103	113	116	119	121	120	144	155	184	257	309	352	367	377	593	461	4016	12.08%
Int. J. Miner. Metall. Mater.	69	72	102	104	119	109	110	130	149	121	125	115	179	171	167	169	168	167	164	168	192	2870	8.64%
J. Appl. Geophys.	63	65	56	60	46	16	65	64	45	106	72	142	157	171	243	238	248	237		228	238	2560	7.70%
Mining Metall. Explor.	37	41	34	34	35	33	31	36	34	32	34	32	34	33	23	29	27	24	27	126	215	951	2.86%
Acta. Montan. Slovaca.										30	45	45	50	32	27	38	37	43	40	35	49	471	1.42%
Physicochem. Probl. Mineral Pro.										8	36	52	57	65	67	64	81	96	119	144	130	919	2.77%
Acta Geodyn. Geomater.										41	42	40	47	48	34	39	40	41	34	40	36	482	1.45%
Arch. Min. Sci.										40	60	56	74	93		70	62	62	63	54	54	688	2.07%
Gospod. Surowcami. Miner.										26	16	19	17	26	15	16	17	27	39	40	40	298	0.90%
J. S. Afr. Inst. Min. Metall.	3	6	3	10	14	14	22	26	26	23	33	29	129	102	122	141	139	133	144	131	80	1329	4.00%
J. Min. Sci.	88	82	93	85	79	72	75	75	70	76	88	100	128	119	124	162	146	139	120	117	116	2154	6.48%
Total	531	542	543	598	852	700	785	797	806	1028	1071	1283	1528	1651	1862	2298	2295	2694	2880	4023	4468	33235	

Table 3. Overview of 33235 scientific outputs

Bibliometric Indicators	Number
Total Outputs	33235
Total Authors	74554
Total Organization	12987
Total Countries	153
Total Citations	740292
Cited Outputs	30610
Average Citations	24.18
Average Authors	2.24

Table 4. Total scientific outputs of top 15 most productive countries

Rank	Region	Total Outputs	Percentage of the World
1	Peoples R China	9966	29.99%
2	USA	4348	13.08%
3	Australia	2996	9.01%
4	Russia	2467	7.42%
5	Canada	2092	6.29%
6	South Africa	1608	4.84%
7	Poland	1568	4.72%
8	India	1201	3.61%
9	Iran	1171	3.52%
10	Germany	1158	3.48%
11	Turkey	1136	3.42%
12	England	957	2.88%
13	France	870	2.62%
14	Japan	740	2.23%
15	Brazil	634	1.91%
Total		32912	

Note: Collaborative outputs were counted more than once; scientific outputs from the People of China included China mainland, Hong Kong, and Macao, excluding Taiwan.

Australia (2,996; 9.01%), and Russia (2,467; 7.42%). The rest of the top-ranking countries were Canada (2,092; 6.29%), South Africa (1,608; 4.84%), Poland (1,568; 4.72%), India (1,201; 3.61%), Iran (1,171; 3.52%), Germany (1,158; 3.48%), Turkey (1,136; 3.42%), England (957; 2.88%), France (870; 2.62%), Japan (740; 2.23%), and Brazil (634; 1.91%). The People of China, the USA, Australia, and Russia were the leading countries with 59.51% of the Top 15 countries.

In this study, the scientific outputs of the Top 15 published countries in the field of 20 MMP journals between the years 2000 and 2020 were compared to provide a more accurate measure to evaluate the development status of MMP in the world. Table 5 shows the scientific outputs for the Top 15 countries from 2000 to 2020.

Table 5. Scientific outputs for top 15 ranking countries from 2000–2020

Journal Name	Peoples R China	USA	Australia	Russia	Canada	South Africa	Poland	India	Iran	Germany	Turkey	England	France	Japan	Brazil	Total
2000	103	84	51	83	34	20	4	34	0	6	5	26	12	14	11	487
2001	99	62	56	82	31	33	6	25	2	12	16	22	10	23	16	495
2002	121	70	46	92	28	28	7	19	4	9	22	21	13	14	12	506
2003	150	65	51	76	45	18	9	15	5	16	28	23	14	20	13	548
2004	217	145	53	75	75	19	4	32	10	19	34	36	13	35	9	776
2005	134	121	44	71	69	38	5	25	9	25	31	34	28	19	23	676
2006	161	141	71	70	56	52	4	21	10	19	48	28	21	24	20	746
2007	198	162	65	70	51	48	3	35	11	29	25	23	22	18	27	787
2008	193	130	69	71	63	39	2	21	11	30	22	26	32	29	17	755
2009	192	141	78	77	63	26	77	42	40	36	43	32	29	15	23	914
2010	193	137	106	73	50	47	106	37	43	30	50	32	27	20	20	971
2011	244	182	115	72	85	81	98	35	64	34	63	24	28	26	23	117
2012	304	172	116	123	75	100	119	54	69	41	73	22	44	19	23	1354
2013	374	197	128	106	101	115	140	52	87	54	64	40	36	30	21	1545
2014	487	264	179	118	123	101	67	67	73	72	75	54	50	50	33	1813
2015	709	279	235	160	129	135	120	82	91	90	82	47	61	43	28	2291
2016	696	292	227	153	141	131	129	86	107	71	63	58	57	38	26	227
2017	991	341	265	186	160	138	120	87	117	104	76	87	61	47	46	2826
2018	1055	343	276	183	184	139	161	96	96	128	73	99	80	85	49	304
2019	1654	485	363	236	244	153	154	156	157	140	116	106	107	75	89	423
2020	1691	535	402	290	285	147	233	180	165	193	127	117	125	96	105	4691
Total outputs	9966	4348	2996	2467	2092	1608	1568	1201	1171	1158	1136	957	870	740	634	32912

As is noted in Table 5, the annual total number of scientific outputs of the People of China always ranks the first from 2000 onwards. It is obvious that an increase is significant in the number of scientific outputs published by the People of China and the USA between 2018 and 2019. Among the Top 15 countries, the number of scientific outputs showed a significantly positive time trend during 2000–2020 ($p<0.001$). This demonstrates that the scientific outputs of the Top 15 countries increased significantly from 2000 to 2020.

CIFs and Mean IFs for the Top 15 Countries

Table 6 provides details of CIFs and mean CIFs from the Top 15 countries. According to the total CIFs calculation, the People of China ranked first with the highest CIFs, and occupied the core position, while the USA (7623.808) took second place in CIFs of scientific outputs. From 2012 on, the total CIFs for the Top 15 countries significantly increased. However, mean CIFs of the People of China ranked in fifth place, the same rank as Canada, and lower than Australia (2.244), Germany (2.085), Brazil (2.059), and France (2.022).

The total mean CIFs were arranged in the following order: Australia (2.244), Germany (2.085), Brazil (2.059), France (2.022), Canada (2.016), People of China (2.016), England (1.954), Japan (1.871), Iran (1.754), USA (1.753), India (1.5725), Turkey (1.36), South Africa (1.19), Russia (0.954), and Poland (0.861).

The descriptive statistics of CIFs for the Top 15 countries show that the People of China had the maximum CIFs, while Brazil had the minimum of CIFs, with mean CIFs 3894.006 and SD as 4883.017 over the past 21-year timespan.

Total and Average Citations of Scientific Outputs From the Top 15 Countries

Table 7 presents detailed information on the citations of the Top 15 countries from 2000 to 2020. As shown in Table 7, the People of China had the highest total citations, while it had the relative low average number of citations, and ranked 11th, although the People of China is in the leading position in the total number of scientific outputs. It is noteworthy that Japan has the highest average number of citations per scientific output (26.59) over 21 years, followed by Canada (26.16), England (25.18), and Australia (24.15). However, the annual citations from the People of China grew rapidly from 2012 on, and they exceeded the USA in annual citations since 2009. All citations from the Top 15 countries account for 78.91% of the world, although the total scientific outputs of those top-ranking countries occupy more than 90% of the world.

Scientific Outputs Distributed in MMP 20 Journals for the Top 15 Countries and the Top 5 High-Impact MMP Journals

In the past 21 years, the Top 15 countries have published 32,912 scientific outputs (Table 8). It needs to be mentioned that Mining Eng. shares the largest number of total scientific outputs among the 20 journals, followed by Ore Geol. Rev. and JOM, while Acta. Montan. Slovaca. shares the least number of scientific outputs.

As noted in Table 8, five journals (Miner. Eng., Ore Geol. Rev., JOM, Minerals, and Int. J. Miner. Metall. Mater.) dominate more than 50% (58.82%) of all scientific outputs in the 21-year timespan, with percentages as 13.76%, 12.80%, 12.45%, 10.73%, and 9.08%, respectively. The Top 15 countries have published 19,016 scientific outputs in the top five journals. The People of China published the most scientific outputs (6,674; 36.175%) in the top five MMP journals, followed by the USA (2,590; 14.039%), Australia (2,235; 12.114%), Canada (1,320; 7.155%), Germany (7,59; 4.114%), South Africa (736; 3.989%), England (648; 3.512%), Russia (541; 2.932%), Iran (525; 2.846%), India (508; 2.754%), Japan (449; 2.434%), France (444; 2.407%), Brazil (424; 2.298%), Turkey (395; 2.141%), and Poland (201; 1.089%). As shown in Table 7, 71.996% of People of China's scientific outputs were published in the five top-ranking journals, while only 8.217% of the scientific outputs in Poland were published in those five journals.

Table 6. CIFs and mean IFs for scientific output for top 15 countries

Journal Name	Peoples R China	USA	Australia	Russia	Canada	South Africa	Poland	India	Iran	Germany	Turkey	England	France	Japan	Brazil	Mean CIFs
2000	35.746	49.166	34.287	2.664	21.885	9.177	1.034	12.712	0	3.22	2.799	13.006	6.44	4.239	5.377	201.752
2001	21.182	26.156	24.768	4.138	14.281	12.759	0.864	11.094	0.82	5.33	6.804	10.47	4.591	12.03	7.044	162.331
2002	56.116	39.41	29.631	8.88	16.489	15.618	0.636	10.509	3.399	6.963	12.226	15.666	10.149	8.375	7.254	241.321
2003	71.83	33.38	29.9	11.81	22	5.63	2.405	6.259	1.19	8.981	14.666	12.7	9.107	12.5	5.528	247.886
2004	108.221	80.195	32.226	16.462	48.49	7.408	2.264	19.634	5.611	13.875	21.411	21.487	9.495	24.517	5.925	417.221
2005	55.375	66.214	27.675	20.931	40.226	22.462	2.775	10.519	5.161	12.217	15.197	19.605	17.594	7.311	15.548	338.81
2006	70.904	103.622	60.884	14.24	49.728	38.212	2.634	13.595	6.591	15.684	29.68	24.588	19.167	14.337	19.132	482.998
2007	104.684	142.487	57.377	22.686	43.132	31.51	1.529	20.408	8.24	25.066	16.573	18.225	20.491	14.914	25.832	553.154
2008	122.538	158.053	87.541	29.748	69.332	35.56	2.053	14.031	8.197	47.559	20.979	33.669	50.21	35.331	23.574	738.375
2009	161.461	137.819	110.853	43.693	76.948	25.258	24.883	34.067	40.107	45.47	35.432	43.509	34.863	17.235	23.318	854.916
2010	141.488	148.323	124.743	32.156	61.427	38.193	38.381	36.786	42.672	38.358	45.068	36.245	31.9	23.931	23.341	863.012
2011	276.083	228.775	148.053	20.764	101.654	87.643	45.952	38.469	60.589	50.461	55.861	34.876	37.942	35.125	29.801	1252.048
2012	258.709	180.31	146.386	40.567	84.548	57.093	44.789	42.873	50.098	52.758	53.423	24.496	42.78	18.743	27.026	1124.599
2013	439.68	266.194	189.983	58.405	157.659	100.634	103.785	54.754	84.136	86.228	67.455	58.162	54.32	48.133	31.576	1801.104
2014	830.449	428.571	306.39	62.95	206.289	81.607	52.103	86.367	102.197	116.286	102.622	98.651	82.283	105.345	63.469	2725.579
2015	1322.206	497.27	554.18	105.65	259.601	109.229	88.844	128.233	163.835	176.302	111.758	89.947	116.32	80.262	62.748	3866.385
2016	1195.086	514.109	526.595	102.822	293.093	131.318	115.25	143.275	158.44	134.997	92.982	127.254	130.399	70.301	58.423	3794.344
2017	2297.532	807.976	788.814	240.731	457.55	177.056	100.389	169.699	232.628	255.794	122.464	247.435	168.6	120.727	119.538	6306.933
2018	2535.554	887.908	786.113	252.285	507.653	219.843	180.632	197.089	210.762	342.163	138.395	260.108	224.456	217.242	143.52	7103.723
2019	4312.119	1179.773	1129.905	424.318	709.648	325.249	214.442	357.965	392.492	382.039	241.044	282.704	287.521	196.345	256.505	10692.069

continued on following page

Table 6. Continued

Journal Name	Peoples R China	USA	Australia	Russia	Canada	South Africa	Poland	India	Iran	Germany	Turkey	England	France	Japan	Brazil	Mean CIFs
2020	5670.763	1648.097	1527.107	608.789	974.932	381.617	469.546	483.763	476.384	594.552	338.64	397.569	400.777	317.877	351.11	14641.523
Total CIFs	20087.726	7623.808	6723.411	2124.689	4216.565	1913.076	1495.19	1892.101	2053.549	2414.303	1545.479	1870.372	1759.405	1384.82	1305.589	58410.083
Mean CIFs	2.016	1.753	2.244	0.861	2.016	1.190	0.954	1.575	1.754	2.085	1.360	1.954	2.022	1.871	2.059	1.775

All five most published journals by the People of China were among the top five influential journals. However, four in Australia were among the top five journals. In the USA, three journals are ranked in the top five journals, while no journals in Poland were ranked in the top five journals. Most of the top-ranking countries have two or three published journals fall within the top five journals.

Descriptive Analysis of Bibliometric Indicators of Top 15 Countries

To overview the descriptive analysis of bibliometric indicators, Table 9 lists the descriptive statistics of those indicators for the studied countries.

Table 9 presents the descriptive statistics of the Top 15 countries in the analyzed period. The total scientific outputs range from 634 (Brazil) to 9,966 (China), with a mean of 2194.13±611.65 and median as 1201.11±2368.89. The mean and median for the total CIFs was 3894.006±1260.790 and 1913.076±4883.017; here those values vary between 1305.589 (Brazil) and 20087.726 (People of China).

As for the mean CIFs, the values changed from 0.861 (Russia) to 2.244 (Australia), with a mean and median as 1.714±0.112 and 1.871±0.433, respectively. Statistical analysis shows that the mean of the total citations of the Top 15 was 38944±10434, with the range as 10404 (Poland), 153246 (People of China) and median as 20805±40411. It is obvious that the average citations are totally different, with a range of 6.64 (Poland), and 26.59 (Japan). The People of China did not even reach 18.636±1.729, the mean of the average citations. For the percentage of the world citations, the People of China were 20.70% and was superior to 1.41% (Poland), with a mean and median as 5.26%±1.41% and 2.81%±5.46%, respectively.

Comparison of Total Scientific Outputs, CIFs, and Total Citations for the Top 15 Countries

As is shown in Table 10, the ranking position of the Top 15 countries shows a somewhat change among total scientific outputs, CIFs, mean CIFs, total citations, and average citations. It is notable that the People of China is the first country and in the lead position for total output, CIFs, and total citations, while the USA is ranked second by total output, CIFs, and citations, and Australia is ranked in third position in these three aspects. The rank orders of mean CIFs and average citations are significantly different with those of total scientific outputs, CIFs, and total citations among the Top 15 countries. However, it is clear that the People of China, the USA, and Australia have the same rank order in scientific outputs, CIFs, and citations in the top three.

The number of total scientific outputs and CIFs for the Top 15 countries shows a strong correlation ($p<0.001$, $r_s = 0.983$). The Spearman correlation coefficient ($p<0.001$, $r_s = 0.961$) between CIFs and total citations is slightly low in comparison with that between the number of total scientific outputs and CIFs, while the Spearman correlation coefficient of the number of total scientific outputs and citations is 0.937, even lower than the two mentioned above. However, the three Spearman correlation coefficients show a significant positive correlation, because the correlation coefficients of are greater than 0.7.

Table 7. Total and average citations of articles from the top 15 countries

Journal names	Peoples R China	USA	Australia	Russia	Canada	South Africa	Poland	India	Iran	Germany	Turkey	England	France	Japan	Brazil	Total
2000	2523	4244	2125	1358	722	722	47	697	0	171	148	1586	770	219	295	15627
2001	1976	2338	3039	421	1323	620	81	821	40	221	881	576	525	947	570	14379
2002	1643	3413	1410	452	1433	687	39	558	321	343	544	1392	969	560	905	14669
2003	2643	2411	2101	375	2737	463	87	527	136	821	1705	1268	669	925	524	17392
2004	2945	6906	1977	406	6687	286	117	673	170	691	1892	1539	378	1997	147	26811
2005	1164	3715	1454	574	2014	852	56	710	278	731	1121	1855	1288	564	883	17259
2006	3765	6763	2628	1536	2728	1310	74	770	198	2222	1653	946	853	1919	758	28123
2007	5238	5236	3048	326	4871	763	11	937	572	1214	1115	480	1635	1221	848	27515
2008	3970	4276	2600	1061	2970	791	29	722	442	942	522	923	1208	723	1245	22424
2009	5121	4903	3570	1018	2801	426	554	1419	1086	1536	1182	994	1396	926	766	27698
2010	4869	3792	3665	536	1908	844	942	1160	965	799	1259	785	749	836	984	24093
2011	7867	4436	4577	329	2508	1469	861	980	1512	813	1403	760	1027	1478	395	30415
2012	7596	5118	4795	752	2016	875	1047	1000	1334	1371	1611	772	1501	357	417	30562
2013	8882	6355	3417	703	2987	1253	1221	1078	1383	1734	1213	1532	902	861	510	34031
2014	11986	7083	4799	902	3633	849	569	866	1529	1763	1074	1327	1133	1818	726	40057
2015	16997	6847	6189	1030	3066	880	947	1222	1594	1913	1098	1331	1167	848	335	45464
2016	11840	5764	4988	1046	2287	1029	852	1162	1166	1471	692	1532	1188	886	538	36441
2017	14631	5729	5033	1264	2435	839	682	859	1246	1901	602	1634	931	590	713	39089
2018	13100	4170	3755	851	2168	993	772	1025	1086	1526	837	1439	975	948	477	34122
2019	14920	3653	4541	1175	2164	866	671	1103	1237	1111	650	924	981	600	649	35245
2020	9570	2466	2656	747	1273	563	745	679	757	872	474	506	560	455	421	22744
Total Citations	153246	99618	72367	16862	54731	17380	10404	18968	17052	24166	21676	24101	20805	19678	13106	584160
Average citations	15.38	22.91	24.15	6.84	26.16	10.81	6.64	15.79	14.56	20.87	19.08	25.18	23.91	26.59	20.67	279.55
Percentage of World	20.70%	13.46%	9.78%	2.28%	7.39%	2.35%	1.41%	2.56%	2.30%	3.26%	2.93%	3.26%	2.81%	2.66%	1.77%	78.91%

Besides, the Spearman correlation of the number of total scientific outputs and average citations showed no significance ($p>0.001$, $r_s = -0.131$), and the number of total scientific outputs and mean CIFs also showed no significant correlation ($p>0.001$, $r_s = -0.655$).

Visual Analysis of Contributions for 153 Countries, the Top 15 Countries, and 20 MMP Journals by VOSviewer Software

VOSviewer software was used to visually analyze the scientific outputs of MMP for the Top 15 countries. The various countries' contributions made it possible to link the knowledge and skills of researchers and their institutions (Pu et al., 2016). The bibliographic coupling of the VOSviewer software was used to quantify the references of a set of documents (Ravi et al., 2016), specifically the countries involved (Rojas-Sola & Aguilera-García, 2015). In the bibliographic coupling of countries, at least one document per country was used as the threshold. A total of 153 countries reached this threshold.

Figure 3 demonstrates the bibliographical coupling analysis of the 153 countries. As is shown in Figure 3, 153 countries and 7,570 links are present, with a total link strength of 30,383,777. The 153 countries were grouped into 12 clusters, which are differentiated by colors. As noted in Figure 3, the

Table 8. Scientific outputs in MMP journals for the top 15 countries between 2000–2020

Journal Names	PRC	USA	Australia	Canada	Russia	SA	Poland	India	Turkey	Iran	Germany	England	France	Japan	Brazil	Total outputs	% of totally outputs
Int. J. Rock Mech. Min. Sci.	1102	539	324	302	34	26	41	112	157	161	123	142	202	175	30	3470	10.73%
Miner. Process Extr. Metall. Rev.	80	50	34	18	8	24	3	54	27	25	2	3	5	3	22	358	1.11%
Miner. Eng.	749	258	1111	551	32	534	25	121	179	118	141	223	74	87	246	4449	13.76%
Int. J. Min. Sci. Technol.	71	61	31	25	4	8	8	7	3	6	3	1	2	0	5	235	0.73%
Ore Geol. Rev.	1532	307	686	354	143	104	22	87	67	153	188	155	141	93	106	4138	12.80%
Int. J. Min. Reclam. Environ.	49	49	49	66	1	12	9	19	32	18	5	6	1	9	2	327	1.01%
Int. J. Coal Prep. Util.	165	71	41	15	1	30	7	125	57	21	4	4	0	9	5	555	1.72%
Mar. Geores. Geotechnol.	516	115	29	24	6	2		108	24	57	17	21	18	51	3	991	3.07%
Minerals	1020	286	242	208	293	57	136	19	29	24	206	121	148	107	39	2935	9.08%
JOM	1000	1702	164	185	66	34	18	185	63	75	203	125	69	104	31	4024	12.45%
Int. J. Miner. Metall. Mater.	2373	37	42	22	7	7		9	57	155	22	24	12	59	2	2915	9.02%
J. Appl. Geophys.	651	367	67	164	43	13	24	99	81	89	197	90	177	32	102	2196	6.79%
Mining Metall. Explor.	119	429	51	68	0	11	9	100	58	23	7	7	4	8	35	929	2.87%
Acta. Montan. Slovaca.	6	3	3	3	31	0	67	5	29	5	8	4	0	0	0	164	0.51%
Physicochem. Probl. Mineral Pro.	288	14	16	22	3	7	291	3	148	57	8	8	4	2		871	2.69%
Acta Geodyn. Geomater.	46	4	5	2	15	1	153	2	9	19	10	2	2	1	2	273	0.84%
Arch. Min. Sci.	52	10	4	4	3	1	472	7	17	76	2	8				656	2.03%
Gospod. Surowcami. Miner.	15		1	5			233		13	11		2				280	0.87%
J. S. Afr. Inst. Min. Metall.	82	63	95	58	3	741	5	32	50	41	17	27	12	3	5	1234	3.82%
J. Min. Sci.	52	14	16	13	1775	3	47	22	39	38	5	1	6	4	1	2036	6.30%
Total	9968	4379	3011	2109	2468	1615	1570	1203	1139	1172	1168	974	877	747	636	33036	

Note: Collaborative outputs were counted more than once; PRC denotes the People of China; SA is South Africa.

lines that join two countries show the existing interconnection between them; that is to say, it shows the collaboration's strength (Ravi et al., 2016). In Figure 3, solid circles represent the countries, and the size proportion shows the number of scientific outputs. The bigger the solid circle is denoting the more scientific outputs the country published.

As is presented in Figure 3, it is worthy of note that the red solid circle denoted by the People of China is the largest. Among these 153 countries, 7,570 links occurred.

Figure 4 shows the bibliographical coupling analysis of 23 journals. As noted earlier, three journals changed their names during the 21-yearlong period. Thus, a total of 23 journals were analyzed in

Table 9. Descriptive analysis for the top 15 countries

Indicators	Minimum	Maximum	Mean ± SE	Median ± SD
Total outputs	634	9966	2194.13±611.65	1201.11±2368.89
Total CIFs	1305.589	20087.726	3894.006±1260.790	1913.076±4883.017
Mean CIFs	0.861	2.244	1.714±0.112	1.871±0.433
Total citations	10404	153246	38944±10434	20805±40411
Average citations	6.64	26.59	18.636±1.729	20.67±6.698
Percentage of the World Citations	1.41%	20.70%	5.26%±1.41%	2.81%±5.46%

Note: SE is the standard error and SD is the standard deviation.

Table 10. Comparison of total scientific outputs, CIFs, and citations of the top 15 countries

Rank	Total Outputs	CIFs	Mean CIFs	Citations	Average Citations
1	Peoples R China	Peoples R China	Australia	Peoples R China	Japan
2	USA	USA	Brazil	USA	Canada
3	Australia	Australia	Peoples R China	Australia	England
4	Russia	Canada	Japan	Canada	Australia
5	Canada	Germany	USA	Germany	France
6	South Africa	Russia	France	England	USA
7	Poland	Iran	Russia	Turkey	Germany
8	India	South Africa	Iran	France	Brazil
9	Iran	India	Germany	Japan	Turkey
10	Germany	England	England	India	India
11	Turkey	France	India	South Africa	Peoples R China
12	England	Turkey	Turkey	Iran	Iran
13	France	Poland	South Africa	Russia	South Africa
14	Japan	Japan	Poland	Brazil	Russia
15	Brazil	Brazil	Canada	Poland	Poland

Figure 4. Figure 4 displays 253 links and a total link strength of 11,646,411 of 23 journals, classified into five clusters.

Table 11 presents the visual contribution of the Top 15 countries according to the order of total scientific outputs about MMP during the period from years 2000 to 2020.

As is shown in Table 11, the People of China are ranked in the first country and in the leading position through total scientific outputs, total citations, and total link strength, but not in links. The USA is the second-ranked country in scientific outputs, citations, and total link strength, while its link dominates in the first rank. For Australia, it is ranked third, not only in total scientific outputs, total citations, and total link strength, but also in links. Among the Top 15 countries from the perspective of visualization, the People of China, Canada, Australia, and Japan are working closely, while the USA, Russia, Poland, Germany, England, and France are close to each other at work. The rest of the five countries have more links with one another in this aspect.

Figure 3. Bibliographical coupling analysis of countries

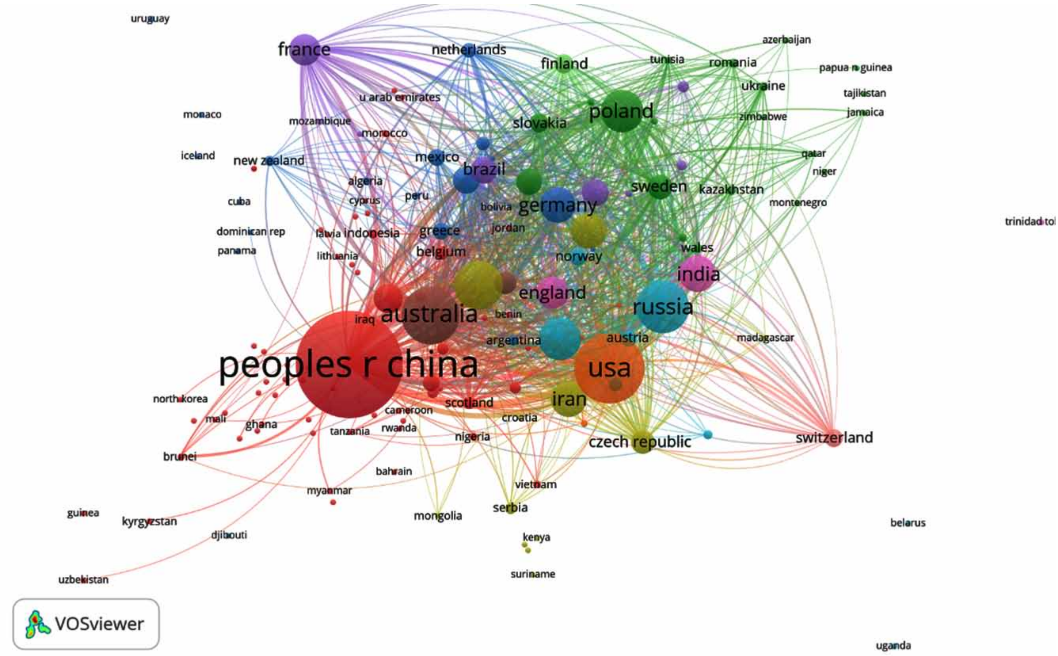


Figure 4. Bibliographical coupling analysis of 23 journals

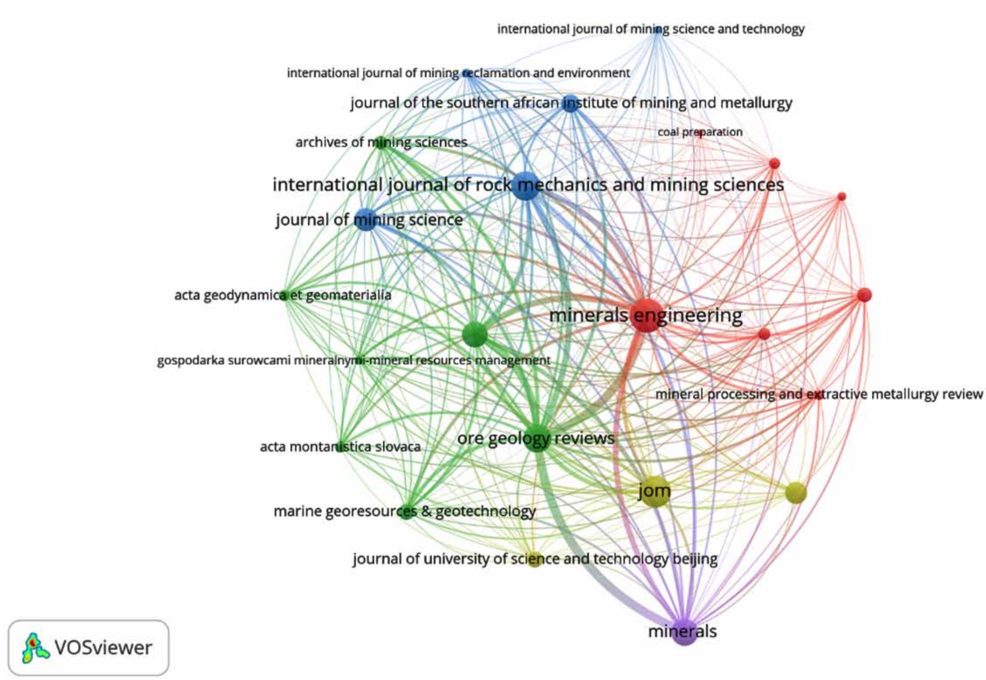


Table 11. Visual analysis of the top 15 countries

Rank	Country	Scientific Outputs	Citations	Total Link Strength	Links
1	Peoples R China	9966	153246	2967	86
2	USA	4348	99618	2263	88
3	Australia	2996	72367	2132	85
4	Russia	2467	15634	554	59
5	Canada	2092	55367	1470	83
6	South Africa	1608	17380	599	62
7	Poland	1568	10404	326	57
8	India	1201	18968	365	49
9	Iran	1171	17052	495	44
10	Germany	1158	24166	1159	79
11	Turkey	1136	21676	308	41
12	England	957	24001	1002	76
13	France	870	20807	935	85
14	Japan	740	19678	559	53
15	Brazil	634	13106	261	41
Total		32912	583470	15367391	988

Note: Top 15 countries were ranked according to the number of scientific outputs.

DISCUSSION

MMP is a major discipline around the world and is becoming increasingly complicated, especially in recent years. To the author's knowledge, this is the first study to use bibliometric analysis to evaluate the scientific outputs of MMP over the past 21-years timespan from 2000 to 2020. The scientific outputs in MMP of the Top 15 countries account for over 90% of MMP scientific outputs worldwide. Therefore, this study selected 15 top-ranking countries for comparison. As is known, bibliometric analysis has some limitations, although it also has many advantages. To evaluate the results correctly, the limitations should be taken into consideration and discussed briefly.

This study selected 20 journals in MMP. The descriptive statistics (minimum, maximum, mean, median, standard error (SE), and standard deviation (SD)) of IFs for 20 journals over the past 21 years showed that the mean IF of the 20 evaluated journals was 1.200, with a SD of 0.892 and a range of 0.011–7.135. It is obvious that this discipline is minor. This means the researchers of this discipline are relatively small, compared to those of major disciplines. From 2014 on, the mean IFs of MMP journals shows a significant increase. This may be caused by the fast development of MMP and funding incentives worldwide.

This study concerns the trend of an increase in scientific outputs in MMP from 2000 to 2020. The annual number of scientific outputs showed a general increase, especially in 2019, with an increase of 1,143 scientific outputs annually. The number of scientific outputs of MMP in year 2020 was more than eight times that of year 2000. This result showed a fast growth of the cumulative number of scientific outputs and implied that the science category of MMP strongly developed within the past 21-year timespan. This increase may be due to various respects, such as economic development, the increase in GDP, growth in research and funding incentives, etc.

The comparison of 15 top-ranking countries showed that researchers from the People of China published the most scientific outputs in MMP among the 15 top-ranking countries over the past 21 years, increasing from 103 to 1,691, 16 times more than year 2000. This rapid growth may have been caused by the continuous increase in GDP and increasing number of researchers in MMP. In addition, the People of China is the second largest economy in the world, with a population of over 1.4 billion; therefore, it has great potential to make great progress in MMP research. In addition to the improvement in economic status, the increase in research and development funding was undoubtedly the main reason for the progress of China's scientific output (Schulman, 2005). Moreover, the People of China have the largest population in the world, and therefore accumulated many scientific outputs in MMP. Meanwhile, researchers in MMP were increasingly involved in MMP studies because of the rapid growth in the economy and funding. Certainly, other factors such as incentive reward plans and career needs would stimulate research output (Shehatta & Al-Rubaish, 2019). Undoubtedly, the People of China is the most productive country in scientific outputs of MMP, and it is dominant in number. However, CIFs, mean CIFs, and the average citations have increased rapidly during the studied period, especially in recent years. In a word, The People of China still have a long way to go to achieve the academic quality of scientific outputs.

The IF is a measure of the frequency with which the average article in a journal has been cited in a particular year (Tan et al., 2014). It is used to measure the importance of a journal by calculating the number of times its articles are cited (Van Eck & Waltman, 2010). Thus, it is usually used to measure and compare the influence of a journal. However, IF is still a good indicator for the quality evaluation of a journal, although it has many deficiencies and controversies (Waltman et al., 2010; Wang et al., 2019).

In addition, the CIF can be generally expected to be more suitable in characterizing the quality achieved by the corresponding nation than by using only the publication number (Zhang et al., 2007). The quality of the work by a researcher is often judged through the citations received by his/her scientific works (Zeng et al., 2008). Thus, the CIFs and total citations have vital significance in evaluating the quality between countries. The general trend of CIFs of scientific outputs from the People of China has increased significantly over the past 21 years, from 35.746 in 2000, to 5670.763 in 2020. However, the data on total scientific outputs, CIFs, and citations make the point that while more scientific outputs, CIFs, and citations came out of the People of China, this amount did not change the mean CIFs and average citations. This suggests that although the People of China has made great progress in its number of scientific outputs, the mean CIFs and the average number of citations are relatively low in comparison with other countries. Another reason that leads to the low average citations is the very recent nature of the boom in publications from the People of China (Bhattacharya et al., 2015). All those data denote that it is very urgent for MMP researchers from the People of China to improve the quality of their scientific outputs.

Bibliographical coupling analysis of countries shows that research on MMP by 153 countries are interconnected, and 7,570 links occurred among those 153 countries, which denotes that the study of MMP has become the focus worldwide. The People of China have 86 links, and has cooperated with 86 countries on this respect of research. Bibliographical coupling analysis of 23 journals demonstrates that the 23 journals have strong interconnections with one another, with a total link strength of 11,646,411. Twenty-three journals classified into one category were meaningful.

Additionally, this research has certain limitations that need to be taken into consideration, which include:

1. This study only considers the MMP journals listed in the Science Citation Index Expanded (SCIE) in 2020, while some other MMP-related journals that are not included in SCIE have not been identified. Some articles, proceeding papers, and review articles are related to MMP, and those outputs contributed to MMP research, but they were published in other journals. The reason

may be that the authors may seek higher IF for their outputs. This phenomenon also appeared in surgical journals and urological journals (Zou et al., 2016).

2. The international collaborative outputs were counted more than one time.
3. This study only focuses on the scientific outputs written in the English language. Some good research outputs may be published due to the language barriers, especially for outputs written by authors in non-English speaking countries. To the best of the author's knowledge, not all Chinese scholars in MMP write well in English, especially some elder doctors.
4. This study did not consider the population size and GDP.

Later studies may take these limitations into consideration to extend the subject matter dealt with in this research. It will provide new research outcomes from another perspective.

Nevertheless, despite all these disadvantages, this study provides verifiable information and deeper insight into the scientific outputs as indicators of MMP research among the Top 15 countries. Although bibliometric data are a good way to evaluate scientific output, there is no standard available. Different methods result in different conclusions.

CONCLUSION AND FUTURE RESEARCH

In summary, this study used big data analysis to analyze scientific outputs based on the Science Citation Index Expanded (SCI-Expanded) of the Web of Science Core Collection (WOSCC) database to provide a landscape of MMP scientific outputs over a 21-year timespan from year 2000 to year 2020. In this study, insights were made into various aspects, including total scientific outputs, the most productive journals, total scientific outputs of the Top 15 countries, total CIFs, mean CIFs, total citations, average citations, percentage of citations of each country in the world, using systematic bibliographic analysis and visualization tools. The main findings of this study can be summarized as follows:

1. The mean of IFs for 20 MMP journals displays the general trend of increase from 2000 to 2020. From 2014 on, it shows a significant increase in the analyzed period.
2. The total number of scientific outputs shows a significant increase from 531 in 2000 to 4,468 in 2020, with an average annual growth rate of 12.08%.
3. Of the Top 15 countries, the numbers of scientific outputs demonstrate a significantly positive time trend during 2000 to 2020 ($p<0.001$). The People of China have made great progress in MMP research over the past 21 years and still dominate in first place from year 2000 on. However, it is worth mentioning that the People of China have the highest scientific outputs, CIFs, and total citations, but lower mean CIFs and average citations per scientific output among the top-ranking countries. Australia took first place in the mean CIFs in the research outputs, followed by Brazil. Japan had a dominant position in the average citations of the Top 15 productive countries, although its total scientific outputs ranked 14 among the 15 top-ranking countries.
4. The Top 5 most productive journals contribute more than 50% (58.82%) of all scientific outputs in the world. The People of China published the most scientific outputs (6,674; 36.175%) in the Top 5 MMP journals. Moreover, all five most published journals by the People of China researchers were in the top five influential journals.
5. From the perspective of visual analysis, 20 MMP journals had 253 links, a total link strength of 11,646,411, and were classified into five clusters. One hundred fifty-three countries in the world are involved in the research of MMP, 7,570 links were present, with a total link strength of 30,383,777. The People of China launched the research of MMP to 86 countries in the world.

MMP will continue to be one of the most important research fields throughout the world. The scientific outputs of MMP will increase dramatically in the near future. It is better that future study focus one of aspects, such as the mining safety, dust control, disaster control, cleaner coal production, and consumption, etc. Additionally, future study should take other databases into consideration in order to cover more important journals in MMP.

DATA AVAILABILITY

The data used to support the findings of this study are included within the article.

AUTHOR NOTE

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