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Abstract: Hydrogen fuel is one of the clean fuels that can replace non-renewable energy sources. Engineering innovations in extraction and distribution are the key challenges to this alternative fuel [1]. The bibliometric analysis had been conducted to understand the active authors, organizations, journals, and countries involved in the research domain of “Hydrogen fuel” [2], [3]. All published articles related to “Hydrogen fuel” from “Scopus”, were analyzed using the VOS viewer to develop analysis tables and visualization maps. This article had set the objective to consolidate the scientific literature regarding the “Hydrogen fuel” and also to find out the trends related to the same. The most active journals in this research domain were identified as International Journal of Hydrogen Energy and Journal of Power Sources. The most active country was the United States of America. The leading organizations in this research domain were the Russian Academy of Sciences of Russia and Argonne National Laboratory of the United States of America. The most active authors were Tomasov A.A and Jacobson M.Z.

Keywords: Hydrogen fuel, Bibliometric analysis, VOS viewer

1. Introduction

Hydrogen fuel is one of the promising solutions to the energy carved world, which is looking for an alternative fuel against the non-renewable resources. Hydrogen is a non-poisonous, colorless, odorless, non-toxic, and tasteless element. Hydrogen is much lighter than air and gasoline vapor. Hydrogen is more prone to leakages due to its low viscosity [4][5]. The major attractive features of hydrogen as an alternative fuel are efficiency, reliability, and environmental benefits. However, the fuel is having the demerits of high manufacturing cost, poor distribution channels, and environmental pollution during the extraction of hydrogen. Hydrogen fuel can be produced from a number of domestic resources like water, hydrocarbons, and organic matter. The main challenge for hydrogen fuels is the extraction of hydrogen fuel cells from their origins. The main two processes of hydrogen extraction are by electrolysis from water and by steam reforming. The major uses of hydrogen fuel are in energy production and as fuels for vehicles. The most promising niches for future research can be on the challenges related to technology for extracting hydrogen.

1.1 Research Objectives

a) To consolidate the literature regarding the Hydrogen fuel
b) To find out the trends related to research in the Hydrogen fuel

The following research questions are framed for conducting bibliometric analysis systematically.

1.2 Research Questions

a) Who are the active researchers working on Hydrogen fuel?
b) Which are the main organizations and countries working on Hydrogen fuel?
c) Which are the main journals related to Hydrogen fuel?

1.3 Significance of this research

Hydrogen fuel is a clean fuel with ecological and economic effects. There are a lot of limitations for the complete replacement of non-renewable resources by alternative fuels, especially, Hydrogen fuel. This article points out the need for future research regarding Hydrogen fuel, its extraction technology, costs, and benefit. This bibliometric analysis will be a useful platform for future researchers by realizing the top researchers, organizations, and countries involved in Hydrogen fuel systems. This bibliometric article is arranged in four sections. The first section is the introduction, followed by the discussion of the methodology by which the research was conducted. The third section deals with results and discussion. The fourth section deals with the conclusion.

2. Research Methodology

Scopus resource was used to prepare this bibliometric analysis regarding “Hydrogen fuel”. For the article selection, the Boolean used was TITLE (“Hydrogen fuel”) on 03/01/2021. All the tables in this paper were created by using Microsoft Excel and VOS Viewer. Grammarly was used for spelling and grammar checks. Mendeley was used for article review and citation. This paper had been inspired by bibliometric analysis in its presentation style, analysis, and methodology from the works [7-11].
3. Results and discussion

1.1 Results
This first round of search produced an outcome of 1187 documents, in nine languages, out of which 1110 documents were in English. The classification of document categories is shown in Figure 1. For improving the quality of the analysis, we had selected only the peer-reviewed articles and all other documents had not been considered. Thus after using filters “Article” and “English” the second round search produced an outcome of 524 English articles (both open access and others) and had been used to conduct bibliometric analysis and visualization using VOS Viewer. The English research articles in this domain since 1967 had been shown in Figure 2.

Figure 1: Classification of the documents on “Hydrogen fuel”, Source: www.scopus.com

Figure 2: Period wise publication of articles, Source: WWW.scopus.com

Co-authorship analysis of top authors had been shown in figure 3. For a better presentation of the analysis, the parameters used were the minimum number of documents of an author as four and the minimum number of citations of authors as one. This combination plotted the map of 26 authors, in 15 clusters. The overlay visualization map of co-authorship analysis plotted in Figure 3, points out the major researchers with their strong co-authorship linkages and clusters involved.
The citation analysis of top authors had been shown in table 1, along with co-authorship links. For the citation analysis, the parameters used were the minimum number of documents of an author as one and the minimum number of citations of an author as one.

Table 1: Highlights of most active authors

<table>
<thead>
<tr>
<th>Description</th>
<th>Authors</th>
<th>Documents</th>
<th>Citations</th>
<th>Link strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>Authors with the highest publication and co-authorship links</td>
<td>Tomasov A.A</td>
<td>10</td>
<td>26</td>
<td>43</td>
</tr>
<tr>
<td>Authors with the highest citation</td>
<td>Jacobson M.Z.</td>
<td>03</td>
<td>809</td>
<td>04</td>
</tr>
</tbody>
</table>

In Co-occurrence analysis, we had used all keyword analyses, by keeping the minimum number of occurrences of a keyword as 20. This combination plotted the map of 27 thresholds, in five clusters. The overlay visualization of co-occurrence analysis of keywords has been shown in Figure 4.
The leading research organization engaged in the research regarding “Hydrogen fuel” with the highest number of publications and citations were the Russian Academy of Sciences of Russia and Argonne National Laboratory of United States of America (Refer to table 2).

<table>
<thead>
<tr>
<th>Organizations</th>
<th>Country</th>
<th>Documents</th>
<th>Citations</th>
<th>Average Citations per document</th>
</tr>
</thead>
<tbody>
<tr>
<td>Russian Academy of Sciences</td>
<td>Russia</td>
<td>19</td>
<td>402</td>
<td>20.0</td>
</tr>
<tr>
<td>Argonne National Laboratory</td>
<td>United States of America</td>
<td>12</td>
<td>595</td>
<td>49.6</td>
</tr>
</tbody>
</table>

Co-authorship analysis of the countries engaged in the research on “Hydrogen fuel” had been shown in Figure 5. For a better presentation of the analysis, the parameters used were the minimum number of documents of an author as seven and the minimum number of citations of authors as one. This combination plotted the map of 21 countries, 5 clusters. The overlay visualization map of co-authorship analysis plotted in Figure 5, points out the main countries with their strong co-authorship linkages and clusters involved.

![Figure 5: Co-authorship analysis on basis of countries](image)

The citation analysis of top countries had been shown in table 3, along with co-authorship links. For the citation analysis, the parameters used were the minimum number of documents of a country as one and the minimum citations of the country as one.

<table>
<thead>
<tr>
<th>Description</th>
<th>Country</th>
<th>Documents</th>
<th>Citations</th>
<th>Average citations per documents</th>
<th>Link strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>The country with the highest publication, citation, and co-authorship links</td>
<td>United States of America</td>
<td>128</td>
<td>3495</td>
<td>27.3</td>
<td>39</td>
</tr>
</tbody>
</table>

The most active country in this research domain was the United States of America with the highest number of publications, citations, and co-authorship links.
Link analysis and citation analysis were used to identify the most active journal in this research domain. We have taken the parameters of the minimum number of documents of a journal as one and the minimum number of citations of a journal as one for the link analysis and citation analysis. Highlights of the most active and relevant journals related to the “Hydrogen fuel” are shown in table 4. Table 4 shows the journal activity of this research domain through parameters of publication volume, citations, and co-authorship linkages. International Journal of Hydrogen Energy was the most active journal with the highest publications, citations, and co-authorship links, followed by Journal of Power Sources.

<table>
<thead>
<tr>
<th>Description</th>
<th>Journal details</th>
<th>Documen ts</th>
<th>Citatio ns</th>
<th>Average citations per documents</th>
<th>Link strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>Journal with the highest publications, citations, and co-authorship links</td>
<td>International Journal of Hydrogen Energy</td>
<td>143</td>
<td>3573</td>
<td>24.98</td>
<td>44</td>
</tr>
<tr>
<td></td>
<td>Journal of Power Sources</td>
<td>27</td>
<td>1218</td>
<td>45.1</td>
<td>25</td>
</tr>
</tbody>
</table>

From the above discussion regarding the bibliometric patterns in the research regarding the Hydrogen fuel, this research had observed a gradual increase in research interest regarding the Hydrogen fuel from the starting of the millennium and the momentum is going on positively. This point out the relevance and potential of this research domain (Refer to Figure 2). The most active author in this research domain is Tomasov A.A and Jacobson M.Z. with the highest publication, citations, and co-authorship links (Refer to table 1). The overlay analysis of top countries researching Hydrogen fuel indicates that the United States of America was the leading country in research regarding Hydrogen fuel with the highest publications, citations, and co-authorship links (Refer to Figure 3). The top journals of this research domain were identified as International Journal of Hydrogen Energy and Journal of Power Sources. From these wide sources of information, researchers can focus on leading journals, authors, organizations, and countries engaged in the research regarding Hydrogen fuel.

4. Conclusion
Hydrogen fuels is an interesting research domain and the most active journals related to this alternative energy source are the International Journal of Hydrogen Energy and Journal of Power Sources. The most active country was the United States of America. The leading organizations engaged in the research regarding Hydrogen fuel [6–10] were the Russian Academy of Sciences of Russia and Argonne National Laboratory of the United States of America. The most active authors who had made valuable contributions related to Hydrogen fuel were Tomasov A.A and Jacobson M.Z. This research domain offers a new avenue for researchers and future research can be on the extraction of hydrogen, technologies, distribution of hydrogen fuel, and cost reduction in extraction.

References