A Bibliometric Analysis of Dairy Wastewater Treatment

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Abstract

Dairy-based industries are one of the industries that consume more water for the production of large quantities of milk and milk products. The water is employed in cleaning, cooling systems, segregation, and packing units. Thus, the effluents discharged release water heavily characterized by different nutrients, COD, BOD, and organic and inorganic substances. Thus, wastewater discharge becomes a significant concern. Utilizing the proper technology and strategies for wastewater treatment as well as managing wastewater becomes crucial. Using the Scopus database, this present study examines global research trends in wastewater treatment technologies between 2000 and 2023. The currently available database has been examined using criteria such as trends in publication numbers, authors, sources and countries. Scopus revealed 1611 journal articles, 215 conference proceedings, 117 review papers, and 74 book chapters during this period, as of March 2023, with the keywords' Dairy, wastewater and treatment. The analysis showed that the top papers on dairy wastewater treatment technologies were from India and the United States.

Keywords: Dairy Wastewater, treatment, Bibliometric Analysis, Scopus, Global Research Trends

1. INTRODUCTION

  The ever-growing global population and industrialization have created greater demand than ever for the diminishing quantity of water, making it vulnerable in many parts of the world[1]. The safe disposal of solid and liquid waste is of ever-increasing concern to human civilization [2]. Dairy

Wastewater treatment methods are classified into four prominent approaches: physical, chemical, biological, and hybrid[3]. Industrial establishments adopt to different treatment technologies based on the available resources and economic feasibility. On the contrary scientific communities focus more on the efficiency of treatment technologies for achieving the required effluent standard for safe disposal. The current work is a bibliometric analysis of trends utilizing the Scopus database to set out the past, present, and future research landscapes. It examines the development of research in dairy wastewater treatment technology. Scopus is regarded as one of the important, subject-specific peer-reviewed archives[4]–[6]. As of March 2023, data on wastewater treatment technology from 2000 to 2023 was gathered based on six main factors: journals, growth pattern, countries, authors, institutions and citations.

2. DATA-COLLECTION & METHODOLOGY

Academic literature from 2000 to 2023 was obtained using the Scopus database. This included articles, conference proceedings, reviews, etc. The terms "wastewater," "treatment," and "Dairy" were used to search the database for research abstracts, titles, and keywords. The received raw data revealed 2047 records in total after being refined in terms of papers with free and paid access[7]. Using the Scopus "Results analysis" tool and the Biblioshiny web interface for bibliometric studies, the data were then statistically evaluated in terms of annually publications, research institutes, and countries[8]–[10]. Table 1 represents a Statistical summary of metadata of bibliometric analysis from 2000 to 2023. The number of different publishing categories is displayed in Table 2. In terms of publications, research articles have contributed the most, making up over 78.82% of the database. It indicates the expansion of inventions based on experimental observations and progress in this industry.

Table 1. Statistical summary of Research articles collected.

DESCRIPTION	RESULTS
Time-span	2000:2023
Documents	2044
Sources (Journals, Books, etc)	667
Average citations per doc	24.28

Annual Growth Rate %	1.15
Document Average Age	8.29
References	73766
ARTICLE CONTENTS	
Keywords Plus(ID)	11385
Author's Keywords (DE)	4610
AUTHORS	
Authors	6080
Authors of single-authored docs	83
AUTHORS-COLLABORATION	
Single-authored docs	95
Co-Authors per Doc	4.16
International co-authorships %	18.1

Table 2. Type of Publication in Dairy Wastewater Treatment

DOCUMENT TYPES	NUMBER
Article	1611
Conference paper	215
Review	117
Book and book chapter	74
Conference review	11
Others	16

3. BIBLIOMETRIC ANALYSIS AND RESULTS

Based on the database results, bibliometric analysis was applied systematically to support worldwide research trends in dairy wastewater treatments[11]. The information gathered allowed for evaluating a study field's development and contribution from various journals, nations, Institutions/organizations, categories, and scholars[12].
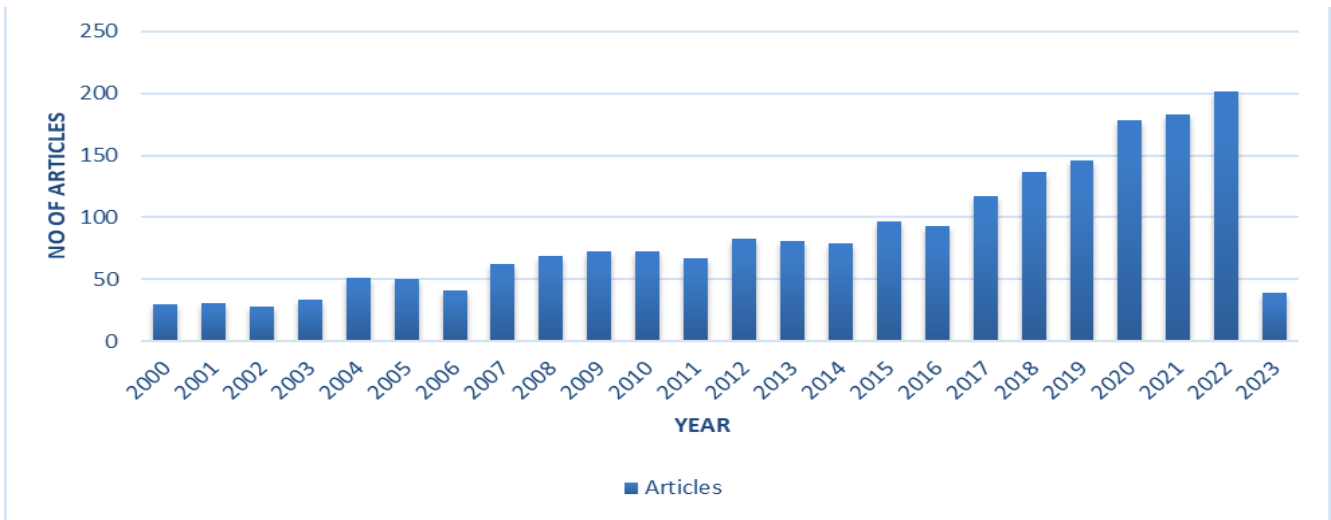
Fig.1 The breakdown by year of publications on dairy wastewater treatment from 2000 to 2023.

A. Growing trends in Dairy Wastewater treatment

Data received indicated that there has been a tremendous increase in research into dairy wastewater treatment methods throughout years. Fig. 1 depicts the patterns in annual increase for research papers on dairy wastewater treatment from 2000 to 2023. The graph (Fig.1) demonstrates that, over the last two decades, there has been a rise in publications on dairy wastewater treatment methods from 30 to 203 till the year 2022. This means there has been an increase in publications during the previous two decades from 2000 to 2022 of 676% and an annual growth rate of 1.37%. The journal articles contributed the highest number of publications with 78.8%, followed by conference papers and review papers with 10.5% and 5.8% each. The increasing trend in publications has shown significant development and progress in the field of dairy wastewater treatment to address the difficulties of industrial effluent treatment. This also indicates introductions of many innovative methods included in this field which was reflected in the outcomes of all those published research articles based on experimental studies.
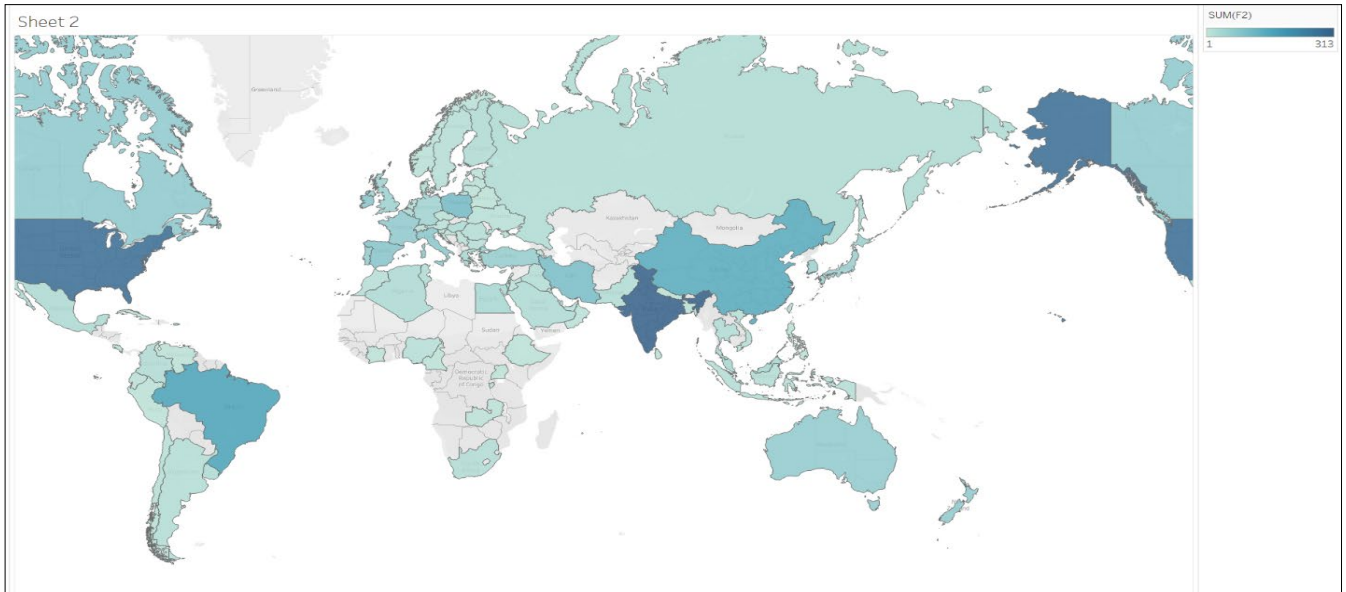
Fig. 2 Geographical locations of research on the treatment of dairy wastewater

Table 3 Shows the Average citation per year in Dairy wastewater treatment

Year	Mean TC per Article	Number	Mean TC per Year	Citable Years
2000	60.9	30.00	2.54	24
2001	53.94	31.00	2.35	23
2002	29.43	28.00	1.34	22
2003	42.74	34.00	2.04	21
2004	40.35	51.00	2.02	20
2005	33.1	50.00	1.74	19
2006	92.05	41.00	5.11	18
2007	29.13	62.00	1.71	17
2008	39.32	69.00	2.46	16
2009	37.53	73.00	2.50	15
2010	39.7	73.00	2.84	14
2011	28.43	67.00	2.19	13

2012	20.61	83.00	1.72	12
2013	23.09	81.00	2.10	11
2014	31.71	79.00	3.17	10
2015	31.18	97.00	3.46	9
2016	21.68	93.00	2.71	8
2017	20.59	117.00	2.94	7
2018	21.03	137.00	3.51	6
2019	19.21	146.00	3.84	5
2020	14.69	178.00	3.67	4
2021	10.42	183.00	3.47	3
2022	3.64	203.00	1.82	2
2023	0.66	41.00	0.66	1

Fig.3 Three field plots

Sources' Production over Time
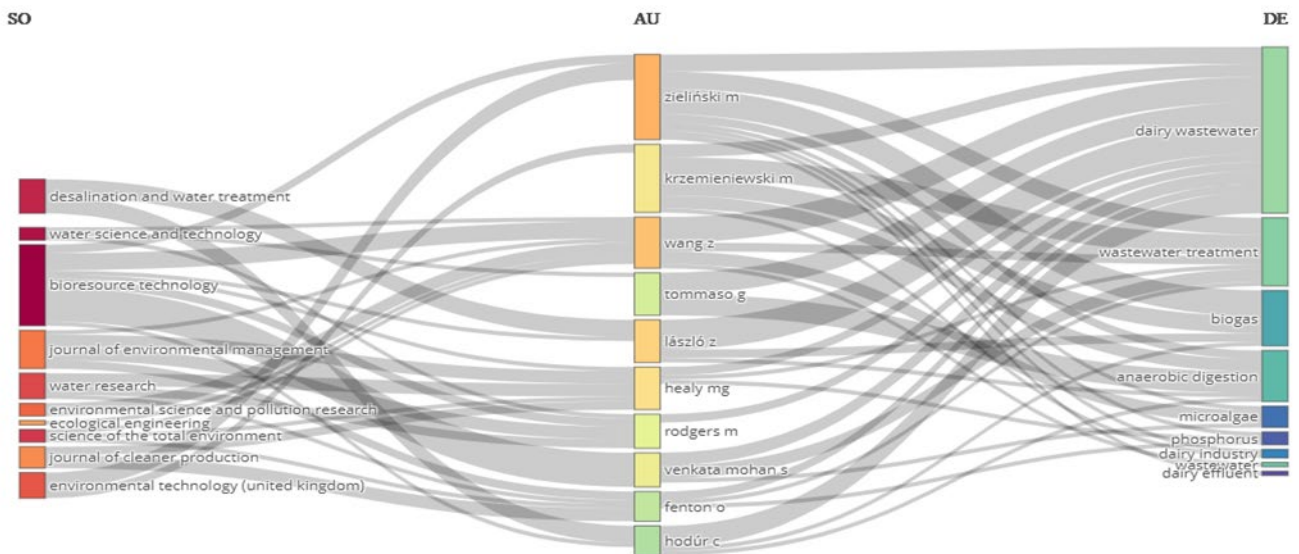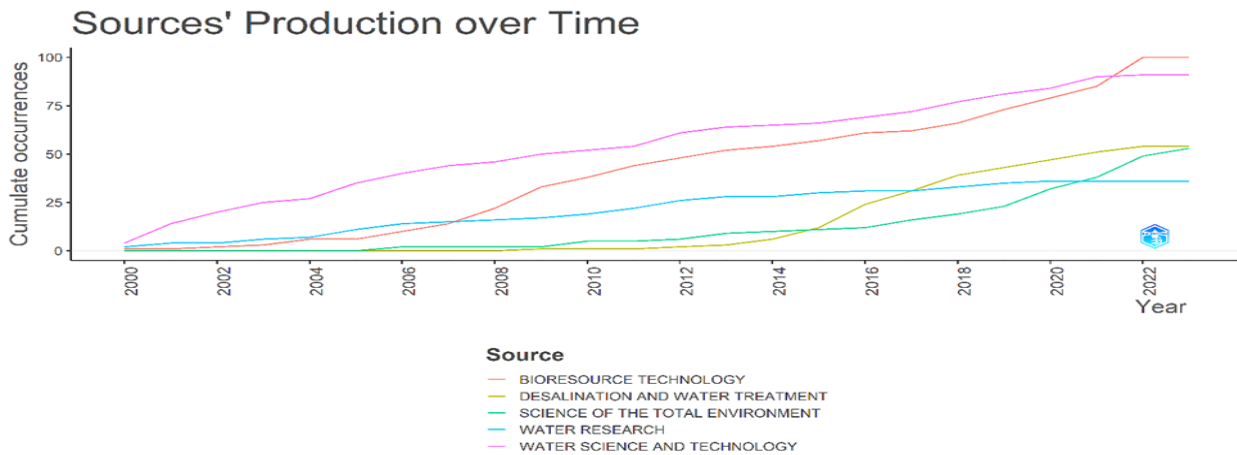
Fig.4 Shows the year-wise publication pattern in the top 5 - journals from the year 2000 to 2023*Geographical regional analysis*

B.   Geographical regional analysis

The locations are depicted in Fig. 2 based on the regional distribution of documents related to dairy wastewater treatment technology. The map was generated with the help of Tableau Desktop version Software[13]. The map reveals that India, the United States, Brazil, China, and Poland are the top five publishing nations. The research in the field of Dairy wastewater treatment is evenly distributed on the map and majorly dominated by India with 313, the USA with 282, and Brazil with 163 publications, respectively. As India is the largest producers of milk and its associated milk products, therefore lots of dairy waste treatment plants are being installed, which makes India in the top of the category of countries based on the number of publications.

C.   Average Citation Per Year

The study was then conducted based on the average number of citations made in papers on dairy wastewater treatment, both annually and per article. The research on this subject was published between 2000 and 2023. Table 3 shows the total of publications, 2022 had the highest number of articles published on dairy wastewater treatment, with 203 documents. The highest number of Mean Total citations per Article was found in 2006, with an average of 92.05 citations, and the Mean Total Citations per Year was the highest citation occurred in 2006 at 5.11. This means the articles published from 2005 to 2010 are cited more than other years from the data drawn for analysis from 2000 to 2023. This indicates the innovative research, practical applications and capabilities of those scientific writing to resolve current issues.

D. Three Field Plots

Three field plots are shown in fig. 3. It is a picture consisting of three elements in it. The names of the journals are followed by a list of the regular contributing Authors to each one, followed by a list of the subjects on which each author frequently researches issues related to dairy wastewater treatment. The rectangle's size demonstrates the significant number of articles linked to each of these components. The plot shows that out of 10 significant journals, Bioresource Technology had the maximum number of publications in Maroon Rectangle as shown in the plot. The contributing authors Zielinski M[14], Venkata Mohan[15], Laszlo Z[16] and Wang Z[17] for the Bioresource Technology Journal.

The next element in the middle shown in the plot has the Top 10 Authors' names linked to the journal. In addition, these authors' names are linked with a third element which shows the topic keywords. The size of the rectangle represents the number of research publications done by the author on dairy wastewater treatment. It can be found in the graph in the third element that biogas and anaerobic digestion are the major keywords of the research in this domain apart from dairy wastewater and wastewater treatment.

E. Journals analysis on Dairy wastewater treatment

 The names of the top 10 journals with high productivity that accounted for 23.84% of total Dairy wastewater treatment publications have been shown in Table 4. Journal of Bioresource Technology, Water science and technology and Desalination and Water Treatment published almost 245 papers in the mentioned domain. Bioresource Technology Journal was found to have a cite score of 17.4, although Water Research and Journal of Cleaner Production has Cite score of 18 and 15.8, respectively.

Table 4 Journals for Dairy wastewater treatment with Articles count

Sources	Articles	Citescore
Bioresource Technology	100	17.4
Water Science and Technology	91	3.4
Desalination & Water Treatment	54	1.7
Science of the Total Environment	53	1.806
Water Research	36	18
Environmental Technology	33	5.4

Environmental Science & Pollution Research	32	6.6
Journal of Environmental Management	32	11.4
Journal of Cleaner Production	31	15.8
Ecological Engineering	26	7.7

The Bioresource Technology journal was found to lead, followed by Desalination and Water Treatment and Science of the Total Environment in the year 2023 with the cumulative value. There has been an increase in publication patterns in all the top 5 journals (Fig.4). But comparatively, risen from 2014 to till date. Water Science and Technology is been most preferred journal in this domain for authors and it evident with graph from 2000-2020.
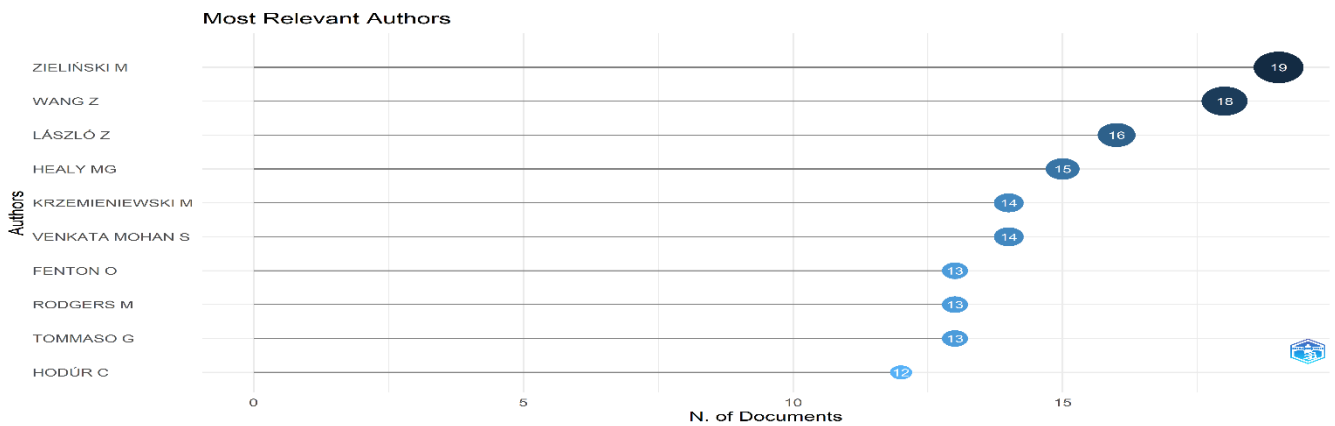
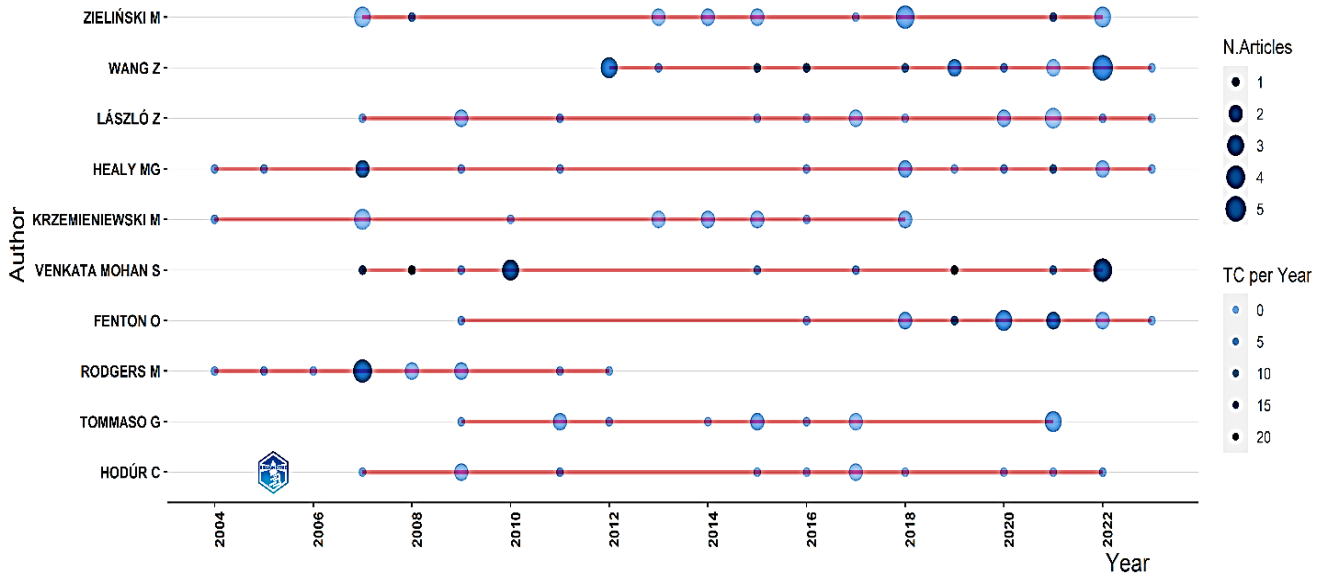**Fig. 5 Top 10 Most Relevant Authors in Dairy Wastewater treatment**

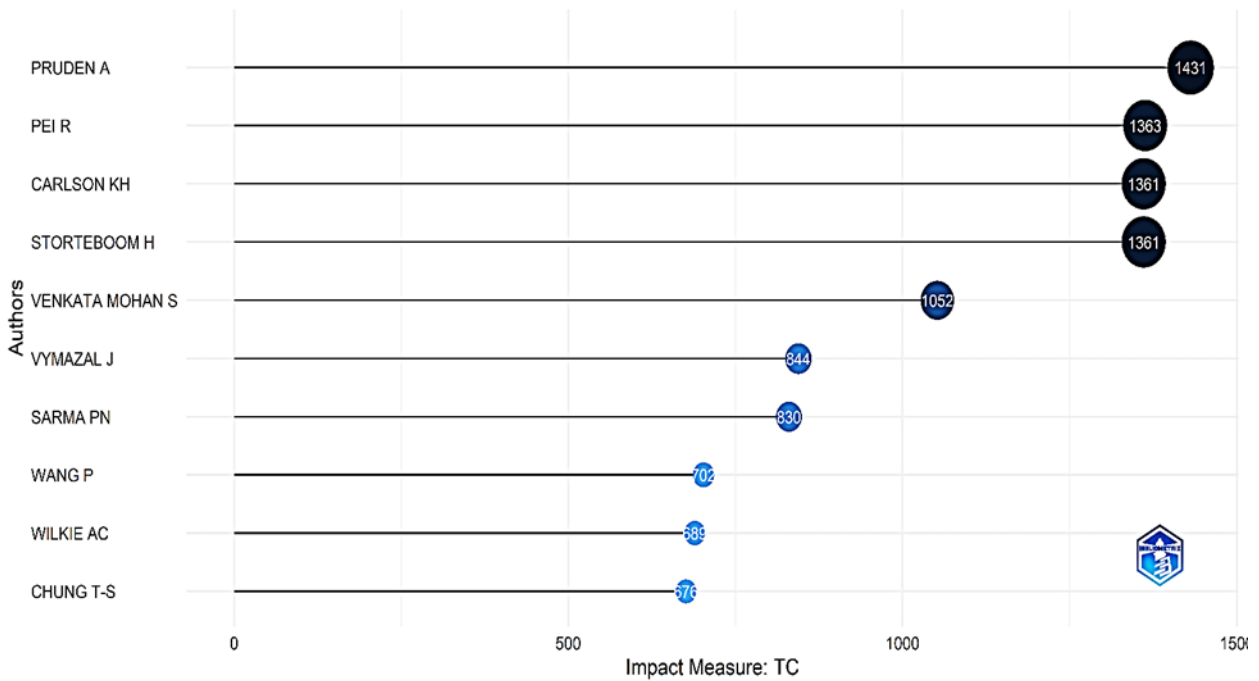**Fig.6 Top 10 Author's Production over time from the year 2000-2023 in Dairy Wastewater treatment**

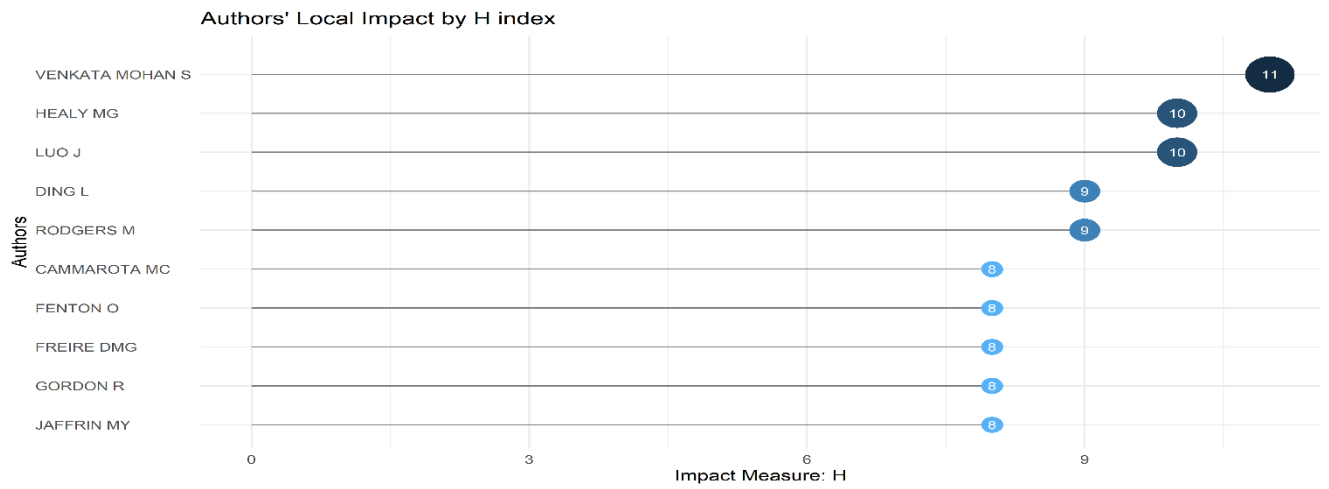
Fig.7 Author's Local impact by TC index

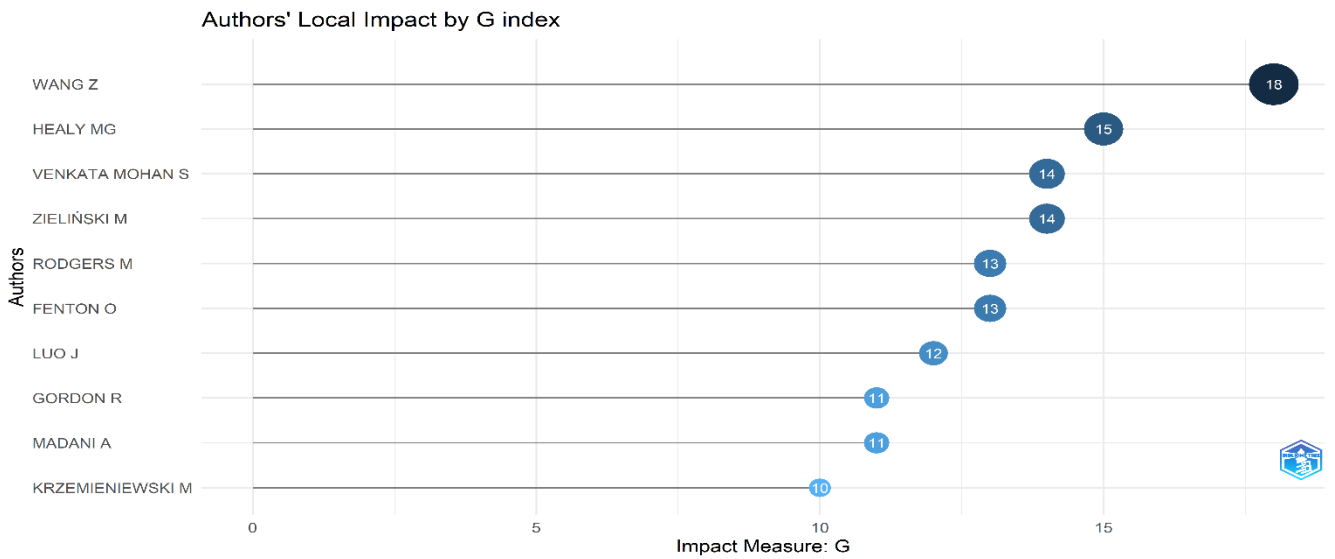**Fig. 8 Top 10 Author's local impact by H-index**

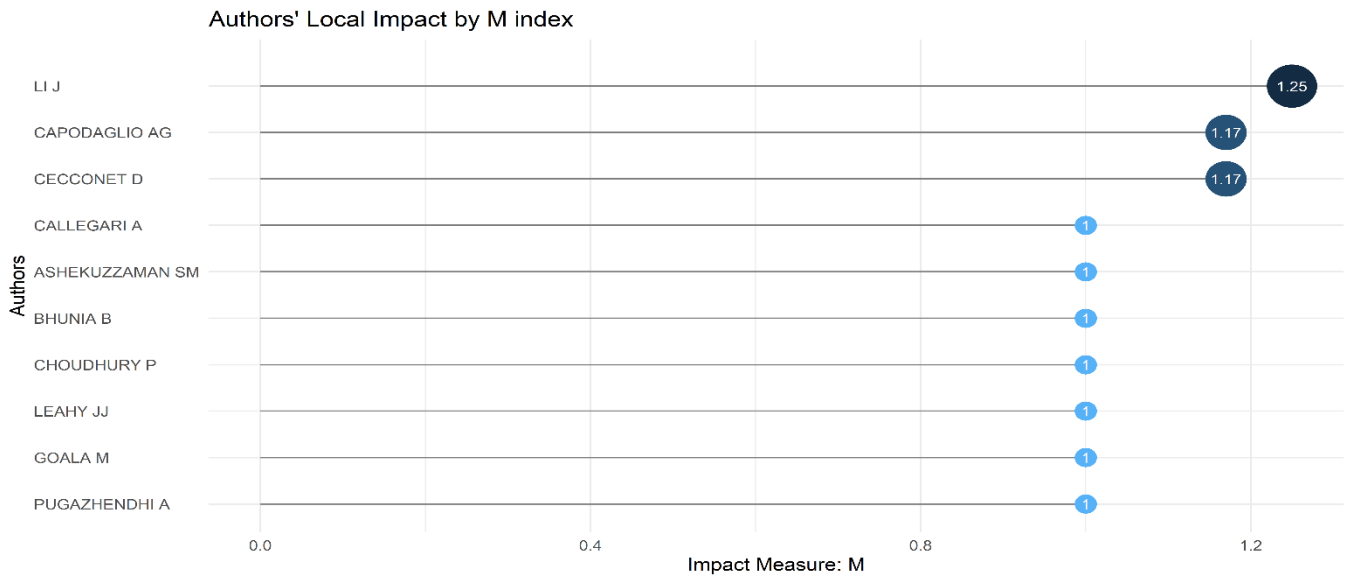**Fig.8 Top 10 Author's local impact by G-index**

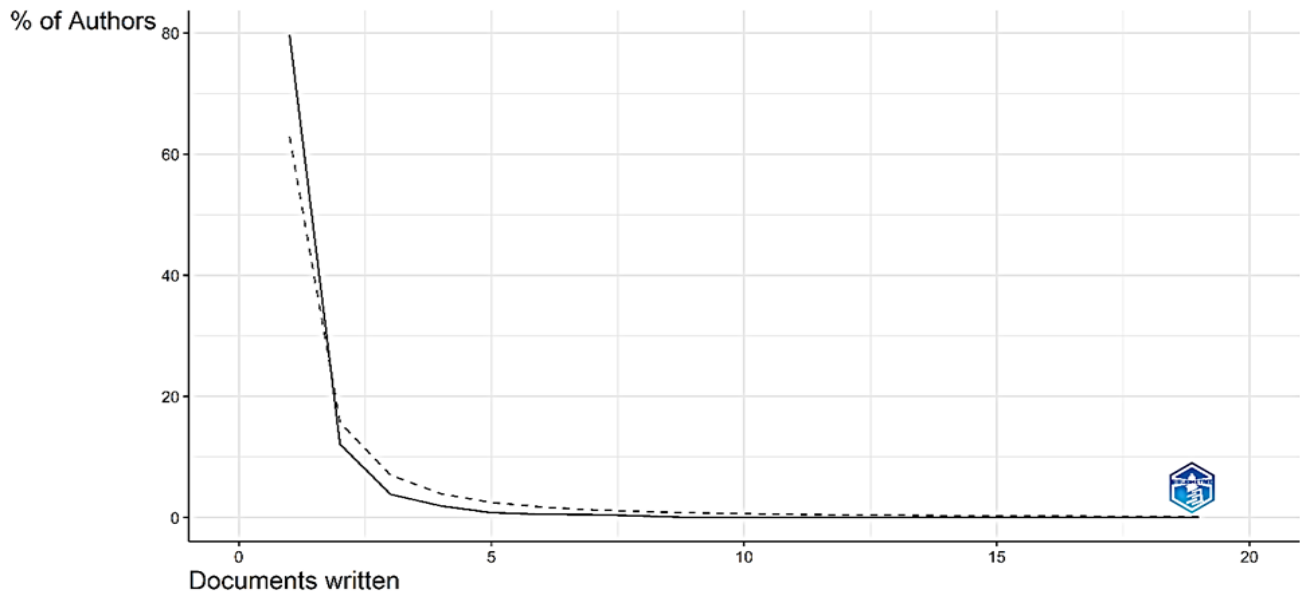**Fig. 9 Top 10 Author's local impact by M-index of publications**

Fig.10 Distribution of Scientific Productivity

F. Authorship

The research on the dairy waste water treatment included 2047 papers from a total of 6089 authors. Table 5 presents the top 10 most active authors in the field. The authors' analysis is also shown in Figures 5 & 6. In terms of author local impact by total citations (TC) as shown in Fig.7, Pruden A is the foremost cited author (1431 TC), followed by Pei R(1363 TC), Carlson KH(1361 TC), and Storteboom H (1361 TC). The top 10 authors in terms of productivity over time and their H-index are shown in Fig.8. An author-level measure known as the author H-index attempts to evaluate the productivity of a scientist or academic as well as the effect of citations on their articles[18], [19]. The index includes a list of the scientific authors' most famous works as well as the number of times those works have been mentioned in other papers. Fig.8 shows that Venkata Mohan S. is at the top of the list. Amongst the most publication, Zieliński M (19), Wang Z(18), and László Z(16) have more article publications compared to all the authors, as shown in Table 5. The g-index is the highest number of citations for an article with at least g^2 citations [20]. The author in this domain are Wang Z(18), Healy MG(15) and Venkata Mohan S(14) having more g-index as shown in fig.9. Similarly, the m-quotient (or m-index) is a variant of the h-index and is defined as an individual's h-index divided by the number of years since his or her first publication[21]. The top 3 authors with highest M-index are Li J, Capodanglio AG and Cecconet D with 1.25, 1.17 and 1.17 each. Further, we use Lotka's law[22] (Fig.10), which states that authors' contributions make up about 60% of all publications in a particular field; as a result, it rewards authors with more publications and can be validated for authors with ten or more articles. Based on this law, only 9 authors have ten or more publications. Zieliński M, Wang Z, and Venkata Mohan S have contributed most over the time in the recent years from 2016-2023 as shown in fig.6. Thus, it will be very useful to identify the peers in the domain of the research.

Table 5. Top 10 most active authors on Dairy wastewater treatment research work

Authors	Articles	Articles Fractionalized
Zieliński M	19	4.64
Wang Z	18	3.17
László Z	16	2.98
Healy Mg	15	4.03
Krzemieniewski M	14	3.56

Venkata Mohan S	14	4.66
Fenton O	13	2.95
Rodgers M	13	4.03
Tommaso G	13	2.08
Hodúr C	12	1.97

G. Universities Contributing to Dairy Wastewater Treatment and Subject Analysis

The top 15 universities/organizational affiliations contribution to Dairy wastewater Treatment research has been shown in the figure 10. Wastewater treatment technology has been an area of significant research work has come from the University of Galway, Universidade de São Paulo and the Bialystok University of Technology, as shown in figure 11. These major contributing universitieis/institutions are primarily from Asia, North America and the European continents. This graph will be very useful for the researchers who are seeking to change their current institution and pursuits research in the domain of dairy wastewater treatment.
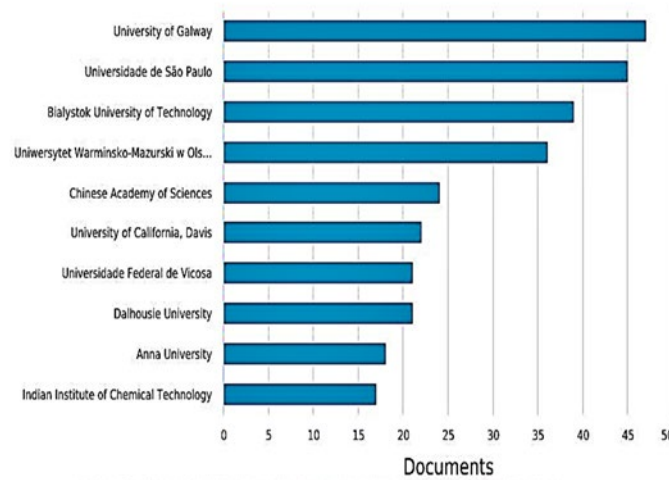

Fig. 11 Details of the best universities in terms of productivity

The articles in dairy wastewater treatment are categorised according to subject areas in Figure 12. The graph clearly illustrates that Environmental Science (31.5%) has seen the most research activity, followed by Chemical Engineering (12.4%), Engineering (11.1%), and

Agriculture (9.4%). Earth and planetary sciences, energy, chemistry, biochemistry, material science, and other multidisciplinary areas made up the majority of the remaining papers. This can be useful for the researcher to understand how his/her domain of expertise can contribute for high chances of publications in this research topic. This also shows domains whose contributions are very less, thus researcher from those domains have the potentials to provide new approaches in this field of research.
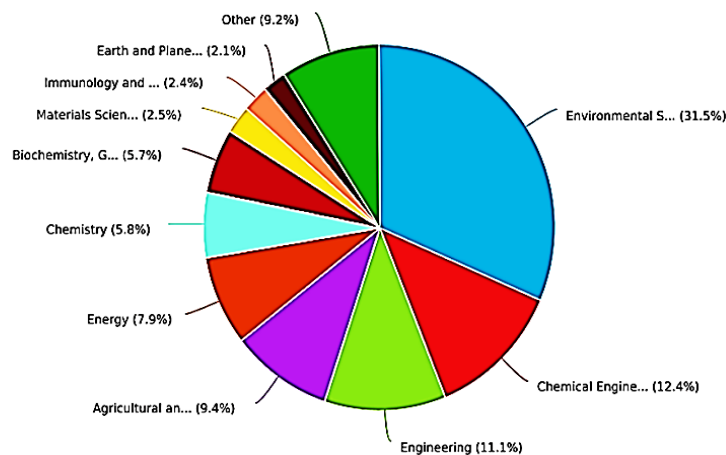

Fig.12 Distribution of publications in dairy wastewater treatment according to subject areas

CONCLUSION

The ever-growing number of publications on dairy wastewater treatment has increased significantly in the past two decades, indicating that people are concerned about wastewater treatment and remediation. Additionally, it highlighted how the research community is aware of the rise in wastewater caused by urbanization and pollution, which calls for the creation of cutting-edge treatment techniques. There is a need for better, efficient and economical systems of treatment as well as strict rules in view of the increasing volume and changing nature of dairy effluent. According to the data obtained by Scopus, English has been a major language of research publications. Based on the analysis, Bioresource Technology was found to be the most widely published journal in the field of dairy wastewater treatment. Significant contributions in country-wise research were from India, the United States, Brazil, China, and Poland.

Researchers are developing advanced technologies for dairy wastewater remediation. It has gradually evolved from the core subjects like

Environmental science, Chemical Engineering and Engineering to a multi-disciplinary approach combining agricultural and biological sciences, energy, chemistry, biochemistry and material science. This has led to a rise in research with new concepts and technologies for treatment. Thus, the Bibliometric analysis will be very useful for researchers those who wants to understand the dynamic nature of publication in the domain of dairy wastewater treatment. It gives an upper hand to understand and predict the future research trends in this domain.

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