MedCrave
Step into the World of Research
International journal of Biosensors and Bioelectronics

Research Article

Open Access
CrossMark

Bibliometric analysis on nanoparticle modified screen-printed carbon electrode for *E.coli* detection using scopus database

Abstract

Foodborne and waterborne infections are major causes of worry around the world. Escherichia coli (E. coli) pathogenic strains like O157:H7 are a leading cause of food and water-borne illness epidemics all over the world. E. coli is a pathogen present in the lower intestinal of warm-blooded species, it is used to detect fecal contaminants in specimens collected. Human infections can be caused by even low levels of E. coli O157:H7 (10–100 viable organisms). The standard techniques for food assessment are mainly conducted in centralized laboratories and involve long analysis times and complex instrumentation. Sensors based on screen-printed electrodes (SPEs) had grown in popularity in this context due to their favorable properties, such as ease of use and portability, which allow for quick analysis in point-of-need circumstances. The application of SPE-based sensors in the management of food contamination as beneficial analytical techniques to traditional techniques offers for quick inspection at any step in the food manufacturing process, reducing food waste and preventing foodborne infections. However, a screen-printed electrode (SPE) may not be as durable as a traditional electrode, such as a glassy carbon or gold disc, and the surface of its working electrode is not as perfect as that of a mirror-like polished solid electrode, the advantages of SPEs in terms of cost and size have led to an increase in their use as (bio) sensing transducers in recent years. The field of research for detection of E.coli using sensors is very extensive and actively studied by researchers in this area of interest. Here, publication for E.coli and nanoparticle sensor growth research were analyzed from Scopus databases. The keywords were biosensor, *E.coli,* screen printed electrode and nanoparticle reported from 2012 to 2021. This bibliometric analysis concluded that E.coli biosensors development involved multidisciplinary collaborations of biology, analytical chemistry, optoelectronics, material science, engineering and data science and each subject area plays an important role in establishing biosensors for E. coli detection.

Keywords: bibliometric analysis, *e.coli,* biosensor, nanoparticle, screen printed carbon electrode

Volume 8 Issue 1 - 2022

Nik Muhammad Ramzi Nik Yusoff, Yusairie Mohd, Muhammad Noor Jalil, Lim Ying Chin, Zainiharyati Mohd Zain

Electrochemical Material and Sensor (EMaS) Research Group, Faculty of Applied Sciences, Universiti Teknologi MARA 40450 Shah Alam Selangor, Malaysia

Correspondence: Zainiharyati Mohd Zain, Electrochemical Material and Sensor (EMaS) Research Group, Faculty of Applied Sciences, Universiti Teknologi MARA 40450 Shah Alam Selangor, Malaysia, Tel 016-4958178, Email Zainihar@uitm.edu.my

Received: April 11, 2022 | **Published:** June 09, 2022

Introduction

Foodborne infections produced by harmful bacteria have always posed a severe danger to people's health and nations' economies. Foodborne illness is predicted to sicken 48 million people in the United States each year, hospitalize 128,000 people, and kill 3000 individuals, according to the Centers for Disease Control and Prevention (CDC). The most prevalent E. coli serotype associated with foodborne outbreaks is Shiga toxin-producing E. coli (STEC) serotype O157:H7. Each year, about 63,000 instances of E. coli O157:H7 infection are reported in the United States, with about 2100 of those cases resulting in hospitalization and up to 20 deaths. Multistate foodborne outbreaks linked to this pathogen in recent years have raised serious concerns about inspection and monitoring to ensure the safety of food products and reduce the occurrence of foodborne illness, particularly due to the increasing consumption of minimally processed products such as fruits, vegetables, and ready-to-eat (RTE) products.[1]

Nanoparticles (NPs) are very small materials that range in size from 1 to 100 nm. They can be divided into many categories based on their features, forms, and sizes. Fullerenes, metal NPs, ceramic NPs, and polymeric NPs are among the various groups. Because of their large surface area and nanoscale size, NPs have unique physical and chemical characteristics. According to reports, their optical qualities are affected by their size, which results in variable hues due to absorption in the visible area. Their distinctive size, shape, and structure influence their reactivity, toughness, and other qualities. They are good candidates for a variety of commercial and domestic applications, including catalysis, imaging, medicinal applications, energy-based research, and environmental applications, due to these features. Contribute, mercury, and tin heavy metal NPs are said to be so hard and robust that decomposition is difficult, which can lead to a variety of environmental toxicities.[2]

Screen printed electrodes (SPEs) created using low-cost fabrication procedures are becoming popular in miniaturized electrochemical sensors, with applications in clinical,[3] environmental, and pharmaceutical analysis.[4] Because of their stability, electrical conductivity, and wide surface area, they can be improved further by including nanoparticles,[5] conducting polymers,[6] and carbon-based compounds.[7] The use of biosensors in the electroanalytical monitoring of biological analytes has been decentralized and revolutionized thanks to the advent of screen-printed technology and its coupling with an electrochemical approach. In comparison to other techniques such as gas chromatography and mass spectrometers, sensors based on a screen-printed electrode (SPE) are cost effective, can be mass manufactured in large quantities, and can be developed for

commercial use for on-site use.[8] Ink mixing with the modifying agent, electrochemical deposition of a metallic precursor, or drop casting of a prepared nanoparticulated material are three common ways for changing the electrode surface in these devices. The first approach is performed prior to ink drying and involves more crucial parameters, such as curing temperature and mixing recipes, that must be closely monitored to achieve batch reproducibility.[9] The other two approaches are more suitable for working with commercially available SPEs because they are performed on their surface following electrode preparation.

Biosensors are described as an analytical instrument that combines a biologically generated molecular identification molecule with a suitable physicochemical transducing mechanism, such as antibodies, phages, aptamers, or single-stranded DNA. Optical, electrochemical, thermometric, piezoelectric, magnetic, and other transducing elements are common. Biosensors provide an electrical or optical signal proportionate to the analyte's particular interaction with the biosensor's recognition molecule. Electrochemical biosensors convert biological interactions into electronic signals that may be measured and recorded in a practical manner. From small protein molecules to big infections, biosensors can detect a wide spectrum of targets. A biosensor is a device for detecting pathogenic antigens that does not require highly skilled staff to use, unlike traditional approaches. Furthermore, biosensors that are very sensitive and selective can produce data faster than culture-based approaches, making them ideal for practical and field use.[10]

Material and methods

A bibliometric analysis was conducted with the goal of analyzing the various improvement techniques that have been employed till now. A bibliometric reviews' main purpose is to look into how existing research on a specific field is evolving currently now. The studies' conclusions could be useful in guiding and guiding upcoming scholars in the sector. Moreover, bibliometric research can be used to detect patterns in study, top authors who've already authored related publications, and significant publications. A review article is distinguished from a bibliometric paper by these characteristics.[11] The bibliometric data for this study was gathered using the Scopus database. I gathered information such as author affiliations, nations, titles, abstracts, and other details. Other performance measures in sensor, *E.Coli* and nanoparticles were also gathered, including total citations, total publications, and the number of single articles by top countries.

Data source and search strategy

On 23 August 2021, the necessary information was obtained through a Scopus data system. It was achieved by narrowing our search to the subject of *E.Coli,* sensor, and nanoparticle in the abstract and title on Scopus. These keywords were focused on data mining to analyze the worldwide trend. Although there are 194 publications were found but exclusion was made to a year of publication from 2012 and below. This is because we want to avoid from picking up outdated information. A total 169 publications were gathered and analyzed from 2012 until 2021 by using the query string is as follows: (TITLE-ABS (*E.Coli,* sensor, and nanoparticle)).

Bibliometric map

The authors used VOS Viewer software to analyses the bibliographical data in order to create a bibliometric map in this study. This is due to the fact that VOS Viewer is renowned as a tool for visualizing bibliometric data by creating a bibliometric map, which will be shown in the next sections of this work. In the following sections, bibliometric maps exported from VOS Viewer will be used to display co-authorship and author keyword patterns.[12] Items are included in maps, according to the VOS viewer manual version 1.6.17. The objects of interest in this study are countries or author keywords, for example. Any two objects can have a link connection or relationship with each other. A strength value, which is a positive number, is assigned to each link. The higher the value, the stronger the link. The number of articles co-authored by two associated countries is represented by the link strength between countries in co-authorship analysis, whereas the overall link strength is the total strength of a country's co-authorship relationships with other countries. Similarly, in co-occurrence analysis, the intensity of the link between author keywords represents the frequency of articles in which two keywords appear together. The user manual contains information on how to use the VOS viewer.[13,14]

Analysis of co-authorship

Articles on *E.Coli,* sensors, and nanoparticles were published by 80 countries who collaborated to write studies on this topic. To ensure that country names were not repeated in multiple acronyms, a thesaurus file was created. In the thesaurus file, similar nation names were grouped together, such as "USA" and "United States," which were both classed as "United States." The five continents to which the connected countries/territories belonged were Africa, America, Asia, Europe, and Oceania.

Analysis of co-occurrence

For the co-occurrence analysis, 437 author keywords were studied from 149 articles. Similar to co-authorship analysis, a thesaurus file was constructed before constructing the bibliometric map of author keywords. This is to prevent the co-occurrence analysis from being influenced by an identical author phrase. The author keywords "bacteria detection," "bacterial detection," and "bacterial sensor," for example, were all combined together in the "bacteria detection." The minimum number of occurrences of a keyword to be evaluated in VOS viewer was set to five. The average publication year, number of occurrences, and link strength of the keywords were seen using the overlay visualization method. The color of a keyword represents the average year of publication of the papers in which it appears.

Results and discussion

Publication output and growth of research interest

As shown in Figure 1, the trend for the publication starting from 2012 to 2017 steadily increase until 2020. Up to August 2021 there are 17 articles were published. 2020 recorded the highest article published which are 28 articles. The growth of the scope of this research slowly growing where only 132 empirical articles were published from 2012 until 2021 and all articles were published in English. Based on the analysis, the subject of the chemistry area is the focus in the study of *E.Coli,* sensors, and nanoparticle. It can be classified by the number of articles published as follows: Chemistry (70 articles), Engineering (62 articles), Materials Science (56 articles), Chemical Engineering (20 articles), Computer Science (19 articles), Energy (6 articles), Environmental Science (6 articles), Medicine (6 articles), Agricultural and Biological Sciences (6 articles), and Immunology and Microbiology (5 articles). Top journals reported on this subject is tabulated in Table 1.

Preferred journals

Table 1 shows a list of ten journals ranked by the volume of research articles and Scopus citations received for their articles. All

the periodicals were published by seven independent publishers, according to Table 1. Elsevier is the publisher with the most journals with four out of ten meanwhile the other publisher such as American Chemical Society, Royal Society of Chemistry, Springer Nature, Electrochemical Society, Conference Proceeding and SPIE publish one journal for each. Biosensor and Bioelectronic published by Elsevier not only has the most citations (691) but one of their articles from 2016, Low-Fouling Surface Plasmon Resonance Biosensor For Multi-Step Detection Of Foodborne Bacterial Pathogens In Complex Food Samples was also the most cited article with 118 citations.

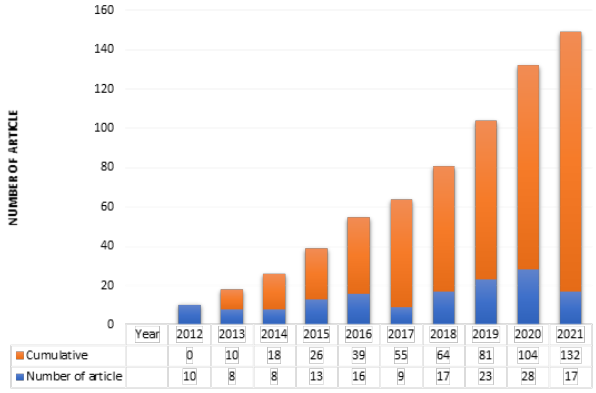

Figure 1 Publication output and growth for E.Coli sensors from 2012 to 2021.

Biosensors and Bioelectronic is the most leading journal that published the greatest number of papers (TP: 16, 10.7%) in detection of *E.Coli* using nanoparticle followed by Sensors and Actuator B Chemical (TP: 14, 9.4%), Analytical Chemistry (TP: 5, 3.3%) and Talanta (TP: 4,2.7%). The Cite Score 2020 analysis showed that three journals score more than 10.0 which are Biosensors and Bioelectronics (19.4), Sensors and Actuator B Chemical (14.0) and analytical chemistry (11.0). Other than that, four journals score more than 5.0 namely Talanta (9.4), Microchimica Acta (8.8), Journal of the Electrochemical Society (6.6) and Spectrochimica Acta Part A Molecular And Biomolecular Spectroscopy (5.8). The Cite Score is one of the most important bits of information, since it can help future readers decide which journals to publish their work.[14]

Leading countries, top institutions and international collaboration

This section focused on the top 15 countries having the most Scopus articles. Table 2 reveals that China ranked first among the 15 main countries, with 36 publications under its control, accounting for 24.2% of all publications worldwide (149 papers). This indicates that China is the leading contributor to detection of *E.Coli,* nanoparticles and sensors research, followed by the Indian (32 articles), United States (21 publications), South Korea (13 publications), and the Malaysia (10 publications). In addition to Table 2, Table S1 & S2 in the supplementary material section contains a detailed list of the top 30 leading countries and institutions**.**

Over half of the countries scored greater than 50% in single-country publications (SCP), with Brazil having the highest SCP value (100 percent). Saudi Arabia's SCP value was the lowest among the other countries, at only 40 percent and only publish 5 articles. The significance of SCP in this study should be stressed to readers since it reveals the frequency with which the nations involved cooperate.[14] As a result, the higher the SCP value, the more frequently the country collaborates with other countries to share its expertise.

The co-authorship was reviewed using VOSViewer to visualise the data in addition to giving the data in Table 2. Each country was placed in its own spot on the map, as shown in Figure 2, with the greater the relationship between the countries, the closer both countries were on the map.[14] The lines that connected each country on the globe also highlighted the strength of ties. The thicker the line, the stronger the bond between the countries. Figure 3 shows that China, which had the most publications, had the largest typeface in the map, followed by the India and others.

The United Kingdom had the most affiliations (16 links, 23 co-authorship), followed by the United States (15 links, 20 co-authorship), China (12 links, 18 co-authorship), Japan (8 links, 12 co-authorship), South Korea (9 links, 11 co-authorship), Saudi Arabia (9 links, 9 co-authorship), India (8 links, 9 co-authorship), and other countries, according to the analysis of co-authorship. . Furthermore, the majority of countries had less than 15 co-authorships, according to this data. This highlighted the importance of governments collaborating with more international countries in the future to increase knowledge sharing results across borders. Countries can help to ameliorate the scenario by increasing research funding, encouraging variety in institutions, and encouraging a research-friendly work atmosphere.[12] For Pakistan, Egypt, and Sweden, there is a little of productive academic institutions shows because it is not reach the minimum TPC which is 3.

Leading authors

The Scopus database was used to extract the data of most of the world's leading authors. Table 3 lists the top 15 active authors in sensors, nanoparticle, and *E.Coli* field. Among the top 15 authors were scientists from Malaysia, India, Turkey, Czech Republic, Saudi Arabia, Italy, and Iraq. Four of the 15 authors were first authors, four was second, and the majority (7/15) were third or higher authors. Two authors have highest publication which is 5. The author is Abdullah, H. and Mukherji, S. Majority of the authors (9/15) publish 3 articles from 2012 until 2021.

Table 1 List of top 10 journals reported on nanoparticle, sensors, and *E.Coli* research with their most cited article

Journal	TP (%)	TC	Cite Score 2020	The most cited article (reference)	Times cited	Publisher
Biosensors And Bioelectronics	16-10.7	691	19.4	Low-fouling surface plasmon resonance biosensor for multi-step detection of foodborne bacterial pathogens in complex food samples	118	Elsevier Ltd
Sensors And Actuator B Chemical	14-9.4	240	14	Gold nanoparticles as colorimetric sensor: A case study on E. coli O157:H7 as a model for Gram-negative bacteria	63	Elsevier Ltd
Analytical Chemistry	5-3.3	134	11	Quantification of 8-oxodGuo lesions in double-stranded DNA using a photoelectrochemical DNA sensor	52	American Chemical Society

Table Continued...

Journal	TP (%)	TC	Cite Score 2020	The most cited article (reference)	Times cited	Publisher
Talanta	4-2.7	49	9.4	Electrical detection of pathogenic bacteria in food samples using information visualization methods with a sensor based on magnetic nanoparticles functionalized with antimicrobial peptides	21	Elsevier Ltd
Analytical Methods	4-2.7	42	4.8	A sensitive and regenerative electrochemical immunosensor for quantitative detection of: Escherichia coli O157:H7 based on stable polyaniline coated screen-printed carbon electrode and rGO-NR-Au@Pt	23	Royal Society of Chemistry
Microchimica Acta	4-2.7	37	8.8	Ultrasensitive peptide-based multiplexed electrochemical biosensor for the simultaneous detection of Listeria monocytogenes and Staphylococcus aureus	12	Springer Nature
Spectrochimica Acta Part A Molecular And Biomolecular Spectroscopy	4-2.7	191	5.8	Hydrothermal green synthesis of magnetic Fe3O4-carbon dots by lemon and grapefruit extracts and as a photoluminescence sensor for detecting of E. coli bacteria	99	Elsevier Ltd
Journal Of the Electrochemical Society	3-2.7	10	6.6	Highly sensitive and selective electrochemical sensor for detection of escherichia coli by using L-Cysteine functionalized iron nanoparticles	9	Electro chemical Society, Inc.
Materials Today Proceedings	3-2.7	6	1.8	Green synthesis of copper oxide (CuO) nanoparticles by Punica granatum peel extract	4	Conference Proceeding
Proceedings of SPIE The International Society for Optical Engineering	3-2.7	3	0.8	Detection of bacteria using bacteriophage with hollow gold nanostructures immobilized fiber optic sensor	3	SPIE

TP, total publication, TC, total citation; SPIE, international society for optics and photonics

Table 2 The top 15 most productive countries and academic institutions in sensors, nanoparticles, and E.Coli.

	Country	TPC	SCP (%)	Productive academic institutions	TPI
1	China	36	18.8	Ministry of Education China	5
2	India	32	16.1	Indian Institute of Technology Bombay	5
3	United States	21	8	Iowa State University	2
4	South Korea	13	4	Korea Advanced Institute of Science and Technology	3
5	Malaysia	10	5.4	Universiti Kebangsaan Malaysia	6
6	Turkey	8	4	Hacettepe Üniversitesi	4
7	Iran	7	2.7	Shahid Beheshti University	2
8	Saudi Arabia	5	1.3	King Faisal Specialist Hospital and Research Centre	2
9	Austria	4	1.3	Technische Universitat Graz	1
10	Czech Republic	4	2	Institute of Photonics and Electronics of the Academy of Sciences of the Czech Republic	3
11	Germany	4	2	Rheinisch-Westfälische Technische Hochschule Aachen	1
12	Pakistan	4			
13	Brazil	3	2	Universidade de São Paulo	2
14	Egypt	3			
15	Sweden	3			

TPC, total publications of the country; SCP, single-country publications; TPI, total publications of the academic institutions

Among all 15 authors, Homola, J. had the highest citation of 118 citations in sensors and *E.Coli* studies followed by Zourob, M. (81 citations), Denizli, A. (64 citations). Hashim, U. and Nadirah, S. recorded the same citation amount which is 43 citations. Table 3 shows that the majority of the writers are from Malaysia, and the outcome is consistent with the country's leadership position, as Malaysia is one of the most active countries in this field.

Author keywords

129 author keywords were identified, of which 78.9% (405 author keywords) were used once, 15.6% (40 author keyword) were used twice, 3.5% (6 author keywords) were used thrice, 0.8% (1 author keywords) were used for four times, and 2.3% (1 author keywords) were used for twelve times. To avoid using the same keywords, a

thesaurus file was created with similar author keywords renamed. As a consequence of the new research, a total of 453 author keywords (minimum of one occurrence) were created corresponding to 46 clusters. A cluster is a collection of nodes that are linked in some way. In a network, each node is allocated to a single cluster. A resolution parameter, which in this analysis was 1, determines the number of clusters.

Table S1 The leading Cite Score journals in biosensor, nanopartiles and E.Coli studies (minimum 25 research articles)

Rank	Name of journal	Cite score in 2020	Publisher	Amount of publication
1	Biosensors And Bioelectronics	19.4	Elsevier Ltd	16
2	Sensors And Actuators B Chemical	14	Elsevier Ltd	14
3	Analytical Chemistry	11	American Chemical Society	5
4	Analytical Methods	9.4	Elsevier Ltd	4
5	Microchimica Acta	4.8	Royal Society of Chemistry	4
6	Spectrochimica Acta Part A Molecular And Biomolecular Spectroscopy	8.8	Springer Nature	4
7	Talanta	5.8	Elsevier Ltd	4
8	Journal Of The Electrochemical Society	6.6	Electrochemical Society, Inc.	3
9	Materials Today Proceedings	1.8	Conference Proceeding	3
10	Proceedings Of SPIE The International Society For Optical Engineering	0.8	SPIE	3
11	2015 Workshop On Recent Advances In Photonics Wrap 2015		Institute of Electrical and Electronics Engineers Inc.	2
12	ACS Applied Materials And Interfaces	14	American Chemical Society	2
13	Advanced Functional Materials	24.1	Wiley-Blackwell	2
14	Aip Conference Proceedings	0.7	American Institute of Physics Inc.	2
15	Analyst	6	Royal Society of Chemistry	2
16	Biosensors	5.4	Multidisciplinary Digital Publishing Institute (MDPI)	2
17	Chemistryselect	3.1	Wiley-Blackwell	2
18	International Journal Of Electrochemical Science	2.7	Electrochemical Science Group, University of Belgrade	2
19	Nanomaterials	5.4	Multidisciplinary Digital Publishing Institute (MDPI)	2
20	Plasmonics	4.4	Springer Nature	2
21	17th International Conference On Miniaturized Systems For Chemistry And Life Sciences Microtas 2013		Chemical and Biological Microsystems Society	1

For 2015 Workshop on Recent Advances in Photonics Wrap 2015 and 17th International Conference on Miniaturized Systems for Chemistry and Life Sciences Microtas 2013 journals, there is no Cite Score obtained from Scopus website.

Table S2 The top 20 most productive institution in biosensor, nanoparticle, and E.Coli

Rank	Institution	Country	No. of Publications
1	Universiti Kebangsaan Malaysia	Malaysia	7
2	Ministry of Education China	China	5
3	Indian Institute of Technology Bombay	India	5
4	Hacettepe Üniversitesi	Turkey	4
5	King Faisal Specialist Hospital and Research Centre	Egypt	3
6	Jiangsu University	China	3
7	Chinese Academy of Sciences	China	3
8	Korea Advanced Institute of Science and Technology	South Korea	3
9	Institute of Photonics and Electronics of the Academy of Sciences of the Czech Republic	Czech Republic	3
10	Universiti Malaysia Perlis	Malaysia	3
11	Alfaisal University	Saudi Arabia	3

Table Continued...

Rank	Institution	Country	No. of Publications
12	Iowa State University	United States	2
13	SASTRA Deemed University	India	2
14	Korea University	South Korea	2
15	Beni-Suef University	Egypt	2
16	Universidade de São Paulo	Brazil	2
17	CNRS Centre National de la Recherche Scientifique	French	2
18	Purdue University	Unite States	2
19	Linköpings Universitet	Sweden	2
20	Empresa Brasileira de Pesquisa Agropecuária - Embrapa	Brazil	2

Table 3 The top 10 productive authors in detection of E.Coli, nanoparticles, and sensors

Author	Scopus Author ID	Year of 1st publication	TP	TC	PlumX (social media)	Current affiliation	Country
Abdullah, H.	2.6E+10	2014a	5	24	0	Universiti Kebangsaan Malaysia, Department of Electrical, Bangi	Malaysia
Mukherji, S.	5.72E+10	2016c	5	35	1	Indian Institute of Technology Bombay, Mumbai	India
Hamid, A.A	7.1E+09	2014c	4	16	0	Universiti Kebangsaan Malaysia, Department of Biological Sciences and Biotechnology, Bangi	Malaysia
Kondabagil, K.	6.5E+09	2016c	4	27	0	Indian Institute of Technology Bombay, Department of Biosciences and Bioengineering, Mumbai	India
Denizli, A.	7.1E+09	2019c	3	64	2	Department of Chemistry, Hacettepe University, Ankara	Turkey
Halkare, P.	5.72E+10	2016a	3	27	0	Department of Biosciences and Bioengineering, IIT Bombay	India
Hashim, U.	2.26E+10	2014c	3	43	2	Institute of Nano Electronic Engineering, Universiti Malaysia Perlis, Kangar	Malaysia
Homola, J.	7.01E+09	2014b	3	118	2	Institute of Photonics and Electronics, Czech Academy of Sciences, Chaberská 57, Prague	Czech Republic
Nadirah, S.	5.6E+10	2014a	3	43	2	Institute of Microengineering and Nanoelectronics, Universiti Kebangsaan Malaysia, Bangi	Malaysia
Naim, N.M.	3.98E+10	2015b	3	14	0	Department of Electrical, Electronic and System Engineering, Faculty of Engineering and Built Environment, Universiti Kebangsaan Malaysia, Bangi	Malaysia
Punjabi, N.	5.53E+10	2016b	3	27	0	Department of Biosciences and Bioengineering, IIT Bombay	India
Wangchuk, J.	5.72E+10	2016b	3	27	0	Indian Institute of Technology Bombay, Department of Biosciences and Bioengineering	India
Zourob, M.	9.94E+09	2017c	3	81	1	King Faisal Specialist Hospital and Research Center	Saudi Arabia
Alsadooni, J.F.K.	5.72E+10	2019a	2	1	0	Ministry of Higher Education and Scientific Research	Iraq
Bolhan, A.	5.61E+10	2014c	2	8	0	Department of Electrical, Electronic and System Engineering, Universiti Kebangsaan Malaysia	Malaysia

*Role in co-authorship, superscripts

a First author

b Co-author

c Third author and above

Terminology and concept

"*Escherichia Coli*" was the most regularly used term in previous study, according to co-occurrences of author keywords. Figure 3 shows that there were 396 occurrences and 82 linkages to extra relevant phrases, with the highest size variation among other author keywords. This author keyword is commonly utilized because it is the primary subject of this analysis, as seen by the fact that all of the publications in Table 1 are about "*Escherichia Coli"*.

Several author keywords were often used in reference to *E.Coli* research, including "biosensor," which had 186 occurrences and 63 links, making it the second most common after "*E.Coli*". Author keyword for "Sensor" has 48 occurrences and 41 links follow by "bacteria detection" for 42 occurrences with 26 links, "surface plasmon resonance" with 39 occurrences and 22 links, "bacteria" for 48 occurrences and 34 links.

Topic of interest

The number of articles in which the two keywords appear together is indicated by the number of link strength. Figure 3 shows a link strength between two author keywords based on bibliometric analysis. The author keyword "*E.coli*" and "bacteria" have 11 link strength. Foodborne and waterborne infections are major causes of concern around the world. Globally, gastrointestinal diseases kill roughly 2.2 million people each year, according to the World Health Organization. E. coli pathogenic strains like O157:H7 are a major cause of food and water-borne illness epidemics all over the world.[15]

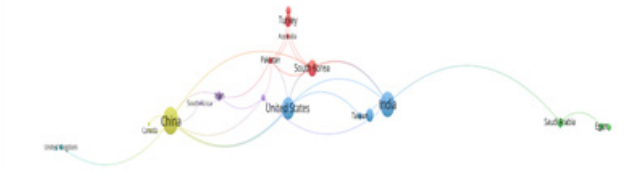

Figure 2 A screenshot of a bibliometric map created based on co-authorship with network visualization mode. The following URL can be used to open Figure 2 in VOSviewer https://bit.ly/3DmcdWh

Figure 3 A screenshot of the bibliometric map created based on author keywords co-occurrence with overlay visualization mode. Minimu occurrences of a keyword are set to five. The following URL can be used to open Figure 4 in VOSviewer https://bit.ly/3ofdGcJ

E. coli O157:H7 is a bacterial disease that is widely detected in cattle's intestinal tracts and spreads to customers through ground beef. When the bacteria are consumed, it causes severe, bloody diarrhea as well as terrible stomach pains. A complication known as hemolytic uremic syndrome (HUS) can occur in a tiny percentage of cases, causing profuse bleeding and kidney failure. The current policy of the United States Department of Agriculture's Food Safety and Inspection Service (USDA-FSIS) toward E. coli O157:H7 is zero tolerance, which means the pathogen's absence must be verified using USDAFSIS's well-defined sampling plan and measurement method.[10]

Aside from that, the bibliometric research revealed that the strongest connection strength between the author keywords "*E.coli*" and "biosensor" is 71. With these two keywords, a total of 71 publications have been published. Biosensors use biological recognition elements (such as enzymes, antibodies, and oligonucleotides) to provide specific quantitative and semiquantitative analytical information; these provide measurable signals when used with a transducer element. Advanced biosensor devices have been developed through extensive research as a result of the success of glucose-detecting glucometers, pregnancy test kits, and point-of-care systems. Biosensors have become important tools for diagnosing infectious diseases (such as tuberculosis, HIV, and diarrhoea), metabolites (such as glucose, cholesterol, lactate, uric acid, urea, ammonia, dopamine, creatinine, and ascorbic acid), proteins, hormones, entire cells, and nucleic acids). These advanced sensing devices, which can detect diseases in their early stages, aid in disease prevention and treatment while lowering medical expenditures. Biosensors are widely utilised in the fermentation industry, as well as in biodefense, metabolic engineering, and plant biology.[16] Various biosensors with various biological and biomimetic components are known, as are transducer elements whose physiochemical operation classifies the sensor as optical, piezoelectric, electrochemical, or other. Electrochemical detection is one of the most prominent, effective, sensitive, quick, and cost-efficient techniques among these.[8]

Next, author keyword for "*E.Coli"* and "surface plasmon resonance" (SPR) had 17 strength link. Surface plasmon resonance (SPR) is an optical phenomenon in which a p-polarized light beam satisfies the resonance condition by activating electrons and generating a surface plasmon wave (SPW). A noble metal, usually gold, is deposited over a dielectric medium, such as quartz, in the geometry of an SPR sensor. At the metal-dielectric interface, an evanescent electromagnetic field is created and propagates into the surrounding medium. SPR detects only surface-confined interactions because the evanescent field declines rapidly from the surface. The intensity of reflected light is considerably diminished when SPR occurs. Tapered fibre shape has lately been exploited for SPR-based sensing. Fiber-based SPR sensors provide a number of advantages, including low cost, compact size, and the potential for multichannel and distant sensing.[17]

Keyword for "*E.coli"* and electrochemical biosensors scored a 3 strength link during the analysis of keyword. Electrochemical biosensors are analytical devices that convert biochemical events like enzyme-substrate reactions and antigen-antibody interactions into electrical signals (e.g., current, voltage, impedance, etc.).[18] An electrode is a crucial part of an electrochemical biosensor, as it serves as a firm substrate for biomolecule immobilization (enzyme, antibody, and nucleic acid) and electron mobility. Relying on the functional groups on the electrode in the presence or absence of supporting materials, several chemical modification procedures are used, including amine- and carboxyl (1-ethyl-3-(3-dimethylaminopropyl) carbodiimide: EDC), aldehyde- (hydrazide), and thiol (maleimide).[19] Carbon-based (carbon nanotubes and graphene) and non-carbon-based nanomaterials are the two types of electrochemical biosensors now available (metallic and silica nanoparticles, nanowire, and indium tin oxide, organic materials). Because of their huge active surface area and effective electron transfer rate, carbon allotropes can be used as electrodes and supporting scaffolds. For increasing the electrochemical characteristics of biosensors, non-carbon nanomaterials are employed as alternate supporting components of the electrode.[20]

Furthermore, the research revealed that author keywords for "*E.Coli*" and "bacteria detection" got 7 strength link. Traditional laboratory-based methods of bacterial detection and identification have extensive processing times, low sensitivity and specificity, and necessitate specialized equipment and experienced users, making them expensive and not available in many countries.[21] Typically, specimens (such as blood, saliva, urine, or a food sample) are sent for microbiological investigation utilizing a variety of techniques, including microscopy and cell culture, biochemical assays, immunological tests, and genetic studies. Microscopy is a reasonably quick but non-specific method of staining bacteria and studying their

morphology and staining pattern, whereas cultivating bacteria on selective media under specified growth conditions can take several days. Furthermore, not all bacteria can be cultured in the laboratory. The development of molecular techniques such as genetic analysis has made it possible to identify bacterial strains more quickly.[22] Due to the small sample size required, PCR, an exceptionally sensitive technology for identifying bacteria based on their genetic material, does not require a bacterial culture stage.[23]

Author keyword for "*E.Coli*" and "fluorescence" also got 7 strength link when using VOSviewer to analyze the author keyword. Fluorescence spectroscopy is currently a widely utilized method across a wide range of scientific areas. These include bioimaging, medical diagnostics, and biosensing, where high sensitivity of fluorescence-related technologies is desired but low quantum yields limit their practical applicability. Enhancing fluorescence sensitivity is a major challenge. Inorganic nanoplatforms paired with fluorophores or organic dyes have been employed to improve the detection performance of fluorescence-based biosensors in recent years.[24,25] These additions provide several advantages over traditional biosensors, including sensitivity (low limit of detection), selectivity (minimizing false-positive signals), real-time analysis, label-free detection, small sample volume requirements, high-throughput screening, high stability, and the ability to be miniaturized.[26,27] Scientists from all over the world have studied the use of nanostructures and fluorogenic chemicals to detect harmful germs optically.[28]

The bibliometric analysis also reveals that author keyword for "*E.Coli*" and "immunosensors" also got a strong strength link which is 12. Immunosensors are affinity ligand-based biosensor devices that are connected to a transducer via an immunochemical reaction. To establish a stable complex, the fundamental idea relies primarily on molecular recognition between antigens and antibodies. Immunosensors based on electrochemistry, optics, and microgravimetry have previously been reported. The development of immunoassay technology has been a triumphant narrative, particularly in clinical applications, and this remains a fascinating area of research.[29]

Limitation of study

For this bibliometric investigation, only empirical research from journal articles was included in the query string, with a limited range of years from 2012 to 2021. This could explain why the investigation was unable to uncover more information from the first year, despite the fact that the issue of biosensors and pathogens had been present for many years. This search approach may then neglect types of journal articles, such as review papers, as well as other sources of information, such as book chapters and conference proceedings, resulting in the information being unable to develop further. Furthermore, the data mining was restricted to the Scopus database, thus limiting the search results. Future research should combine Web of Science (WOS) and PubMed to produce a more comprehensive result with no time limit.

Conclusion

Over a ten-year period from 2012 to 2021, 149 publications in the Scopus database show an increase in the use of biosensors and pathogens. Many countries from all continents offered opinions and answers to this investigation, including China, India, the United States, South Korea, and others. Pathogen analysis and biosensors will continue to rise as pathogens are impossible to eradicate and will continue to exist in our lives. Biosensors technology will continue to advance and it is a vital field that contributes and assists us greatly in our daily lives.

Acknowledgments

None.

Conflicts of interest

The author declares there is no conflict of interest.

References

1. Xu M, R Wang, Y Li. Electrochemical biosensors for rapid detection of *Escherichia coli* O157:H7. *Talanta*. 2017;162:511–522.
2. Khan I, K Saeed, I Khan. Nanoparticles: Properties, applications and toxicities. *Arabian Journal of Chemistry*. 2019;12(7):908–931.
3. Arduini F, Laura Micheli, Danila Moscone, et al. Electrochemical biosensors based on nanomodified screen-printed electrodes: Recent applications in clinical analysis. *TrAC Trends in Analytical Chemistry*. 2016;79:114–126.
4. Ibanez-Redin G, D Wilson, D Gonçalves, et al. Low-cost screen-printed electrodes based on electrochemically reduced graphene oxide-carbon black nanocomposites for dopamine, epinephrine and paracetamol detection. *J Colloid Interface Sci.* 2018;515:101–108.
5. Agrisuelas J, MI González-Sánchez, E Valero. Hydrogen peroxide sensor based on in situ grown Pt nanoparticles from waste screen-printed electrodes. *Sensors and Actuators B: Chemical*. 2017;249:499–505.
6. Qin Q, X Bai, Z Hua. Electropolymerization of a conductive β-cyclodextrin polymer on reduced graphene oxide modified screen-printed electrode for simultaneous determination of ascorbic acid, dopamine and uric acid. *Journal of Electroanalytical Chemistry.* 2016;782:50–58.
7. Hernandez-Ibanez N, Leticia García-Cruz, Vicente Montiel, et al. Electrochemical lactate biosensor based upon chitosan/carbon nanotubes modified screen-printed graphite electrodes for the determination of lactate in embryonic cell cultures. *Biosens Bioelectron*. 2016;77:1168–1174.
8. Jaiswal N, I Tiwari. Recent build outs in electroanalytical biosensors based on carbon-nanomaterial modified screen printed electrode platforms. *Analytical Methods*. 2017;9(26):3895–3907.
9. Chu Z, J Peng, W Jin. Advanced nanomaterial inks for screen-printed chemical sensors. *Sensors and Actuators B: Chemical.* 2017;243:919–926.
10. Sharma H, R Mutharasan. Review of biosensors for foodborne pathogens and toxins. *Sensors and Actuators B: Chemical*. 2013;183:535–549.
11. Cobo M, AG López-Herrera, E Herrera-Viedma, et al. Science Mapping Software Tools: Review, Analysis, and Cooperative Study Among Tools. *Journal of the American Society for Information Science and Technology.* 2011;62(7):1382–1402.
12. Yaacob A, JL Gan. Bibliometric Analysis Of Global Research Developments On The Role Of Technology During Covid-19: Current Trends And Future Prospect. *Journal of Content, Community & Communication*. 2021;13.
13. Eck NJ, L Waltman. *Manual_VOSviewer_1.6.17.pdf*. 2021.
14. Md Khudzari J, Jiby Kurian, Boris Tartakovsky, et al. Bibliometric analysis of global research trends on microbial fuel cells using Scopus database. *Biochemical Engineering Journal*. 2018;136:51–60.
15. Jayamohan H, Bruce K Gale, Bj Minson, et al. Highly sensitive bacteria quantification using immunomagnetic separation and electrochemical detection of guanine-labeled secondary beads. *Sensors (Basel).* 2015;15(5):12034–12052.
16. Ahmad R, Otto S Wolfbeis, Yoon-Bong Hahn, et al. Deposition of nanomaterials: A crucial step in biosensor fabrication. *Materials Today Com-*

munications. 2018;17:289–321.

17. Shamkhalichenar H, JW Choi. An Inkjet-Printed Non-Enzymatic Hydrogen Peroxide Sensor on Paper. *Journal of The Electrochemical Society*. 2017;164(5):B3101–B3106.
18. Li H, Xiaowen Liu, Lin Li, et al. CMOS Electrochemical Instrumentation for Biosensor Microsystems: A Review. *Sensors (Basel)*. 2016;17(1):74.
19. Wang Z, Z Dai. Carbon nanomaterial-based electrochemical biosensors: an overview. *Nanoscale.* 2015;7(15):6420–6431.
20. Cho IH, DH Kim, S Park. Electrochemical biosensors: perspective on functional nanomaterials for on-site analysis. *Biomater Res.* 2020;24:6.
21. Fournier PE, Michel Drancourt, Philippe Colson, et al. Modern clinical microbiology: new challenges and solutions. *Nat Rev Microbiol.* 2013;11(8):574–585.
22. Ahmed A, Jo V Rushworth, Natalie A Hirst, et al. Biosensors for whole-cell bacterial detection. *Clin Microbiol Rev.* 2014;27(3):631–646.
23. Burnham CA, KC Carroll. Diagnosis of Clostridium difficile infection: an ongoing conundrum for clinicians and for clinical laboratories. *Clin Microbiol Rev*. 2013;26(3):604–630.
24. Jenie SN, SE Plush, NH Voelcker. Recent Advances on Luminescent Enhancement-Based Porous Silicon Biosensors. *Pharm Res.* 2016;33(10):2314–2336.
25. Moore CJ, Giorgia Giovannini, Filip Kunc, et al. 'Overloading' fluorescent silica nanoparticles with dyes to improve biosensor performance. *Journal of Materials Chemistry B.* 2017;5(28):5564–5572.
26. Yoo SM, SY Lee. Optical Biosensors for the Detection of Pathogenic Microorganisms. *Trends Biotechnol.* 2016;34(1):7–25.
27. Verma MS, Jacob L Rogowski, Lyndon Jones, et al. Colorimetric biosensing of pathogens using gold nanoparticles. *Biotechnol Adv.* 2015;33(6 Pt 1):666–680.
28. Jenie SNA, Yuni Kusumastuti, Fransiska SH Krismastuti, et al. Rapid Fluorescence Quenching Detection of Escherichia coli Using Natural Silica-Based Nanoparticles. *Sensors(Basel)*. 2021;21(3):881.
29. Patra S, Ekta Roy, Rashmi Madhuri, et al. *A technique comes to life for security of life: the food contaminant sensors.* Nanobiosensors. 2017. p. 713–772.