technologies

Review

Application of Blockchain Technology in Environmental Health: Literature Review and Prospect of Visualization Based on CiteSpace

Meiwen Guo [1,2,3], Zhenheng Huang [1,*], Liang Wu [1,*], Cheng Ling Tan [2], Jianping Peng [4], Xingcheng Guo [5] and Hong Chen [1,*]

1 School of Management, Guangzhou Xinhua University, Guangzhou 510520, China
2 Graduate School of Business, Universiti Sains Malaysia, Penang 11800, Malaysia
3 Entrepreneurship Center, Sun Yat-sen University, Guangzhou 510275, China
4 School of Marxism, Sun Yat-sen University, Guangzhou 510275, China
5 School of Management, Guangzhou City University of Technology, Guangzhou 510520, China
* Correspondence: huangzhenheng@xhsysu.edu.cn (Z.H.); wl@xhsysu.edu.cn (L.W.); chenhong6168@126.com (H.C.)

Abstract: Blockchain technology and its applications have recently become a research hotspot. Its three core technologies, distributed ledger, smart contract, and consensus mechanism, provide trust-enhancing features such as tamper-proof records, full traceability, and data decentralization for a wide range of applications. This paper investigates the use of blockchain technology in environmental health. It investigates indicators such as the number of articles published, author collaboration network, research institution network, and keyword co-occurrence in this field between 2014 and 2021. It describes and analyzes the development and connotations of these indicators. Many scholars have conducted in-depth studies on blockchain in various areas. Still, there are few cross-over studies on environmental health and a lack of cross-over studies on technology application in multiple fields. The current study investigates the evolution of research on the application of blockchain technology in environmental health, as well as potential development patterns and research trends, to provide a theoretical foundation for the application and sustainability of blockchain technology in this field.

Keywords: blockchain technology; environmental health; sustainable development; cross-over studies

Citation: Guo, M.; Huang, Z.; Wu, L.; Tan, C.L.; Peng, J.; Guo, X.; Chen, H. Application of Blockchain Technology in Environmental Health: Literature Review and Prospect of Visualization Based on CiteSpace. *Technologies* **2022**, *10*, 100. https://doi.org/10.3390/technologies10050100

Academic Editors: Abdellah Chehri and Sikha Bagui

Received: 2 July 2022
Accepted: 30 August 2022
Published: 7 September 2022

1. Introduction

Blockchain technology addresses the trust issue. It is a multi-disciplinary area involving computer science, mathematical science, etc. The "decentralized" data storage strategy of the technology enables the optimization of the network environment and the revolution of traditional information-sharing strategies, resulting in blockchain's basic attributes of "honesty" and "transparency". The characteristics and attributes of the technology have tackled the issue of information asymmetry in the network environment, boosting trust within blockchains, making resource utilization more efficient, and reducing the waste of resources. Thus, blockchain technology can be applied in a wide range of areas.

In the environmental area, blockchain technology is primarily employed in environmental monitoring, the assessment of environmental protection systems, green development, ecological governance, public governance, energy, etc. In terms of carbon emissions, for example, research by Fawcett and Burgess showed that national and regional governments face difficulty in selecting the models of personal carbon trading, and there exist problems such as unequal distribution and regulatory hurdles in the practice of mandatory individual carbon trading [1,2]. Li et al. suggested that this situation may affect the formation and advancement of low carbon awareness and can change individual behavioral decisions [3]. Fawcett T. argued that personal carbon trading is not a futuristic concept and is one of the effective ways to achieve high-quality carbon emission reduction [4]. Chen et al. noted that management issues in the big data environment might stimulate a paradigm shift in decision-making and business model innovation [5]. Ye et al. designed a carbon market system based on blockchain technology for enterprise-level and individual-level needs for carbon market construction [6]. In terms of environmental monitoring, Zhao and Meng mentioned that blockchain can technically resolve the problems of "data silos", "data right confirmation", and trust-building facing traditional internet, and can curb trust issues such as data falsification and difficulty in responsibility traceability existing in the ecological management of mineral resources [7]. Yang and Hu found that blockchain technology can positively optimize ecological governance, environmental monitoring, ecological trade in the market, and the stimulation of the public's potential for environmental protection [8]. Chod et al., Olsen and Tomlin, and Zhang et al. [9–11] argued that blockchain technology can effectively address the whole process data of carbon quota allocation, reporting, and implementation. They also held that blockchain′s tamper-proof and traceable nature could reduce problems such as data falsification by companies and regulators, lower audit costs, and improve efficiency. Ji et al. argued that the smart contract technology of blockchain can improve efficiency and lower the costs of data statistics and the allocation and collection of carbon credits during the construction of carbon emission reduction mechanisms [12].

There is also some blockchain-based study on digital transformation and ecological development. Ishan and Iván H et al. investigated the impact of the implementation and spread of high-tech such as blockchain on the eco-manufacturing innovative activities in developing nations [13,14]. Allen, D. and Berg, C. et al. [15] believe that manufacturing enterprises will provide conditions for digital transformation and innovation through the stimulation of emerging technologies such as blockchain, resulting in revolutionary development; Yohan H. and Byungjun P. et al. [16] have successfully developed a real-time off-site monitoring system for air quality sensor data transmission, which is an improvement based on blockchain technology and contributes to the traceability of air quality sensor data. Based on blockchain technology, an intelligent data connection mechanism of various equipment is proposed as the foundation for reducing manufacturing enterprises' energy consumption and emissions, providing a new solution for manufacturing enterprises to reduce environmental pressure, reduce energy consumption, and optimize the environment [17].

It is well known that the environment is closely related to health issues, and the solutions to such issues affect the sustainable development of humankind and nature. The environment and health are important areas that scholars have worked on for years. Currently, the exploration of blockchain technology in these two areas is more about environmental issues, and the results indirectly affect the health field, with most studies focusing on green development and carbon trading, etc. However, there are relatively few applications of blockchain technology in the environment and health or in a combination of the two fields that highlight health issues. Given the importance, scarcity, and weakness of such cross-over studies, it is of vital significance to apply blockchain technology in these fields to analyze the literature development and indicator data of this cross-over study.

In addition, research has found that traditional environmental governance still has several flaws, such as data manipulation, falsification of ecological monitoring data, quantification of pollution emissions, a lack of incentives for waste recycling, and environmental public welfare corruption. The application of blockchain technology in these fields needs to be developed in more depth. This study will combine literature data and the lack of research on blockchain in the field of environmental health to make recommendations and locate future research trends.

2. Objects and Methods

2.1. Data Source

With the Web of Science as the retrieval platform, the formula TS = ((blockchain AND environment) OR (blockchain AND health) OR (blockchain AND environment AND health)) was used to obtain 2792 studies from 2014 to 2021.

2.2. Research Methods

CiteSpace software 5.6 was used to conduct a visual analysis of the authors, research institutions, keywords, and literature. Co-occurrence analysis and cluster analysis were conducted on the authors, institutions, and keywords after they were imported into CiteSpace 5.6. The software parameters were set as follows. Under the Time Slicing module, the time span was set to 2014–2021, and the time partition was set to one year as one time unit. "Title", "Abstract", and "Author Keywords" were set. The Node Type was set to "Keywords", the Link Strength to "Cosine", the Scope to "With Slices", and the "TopN" was set to 50 in Selection Criterion to filter out the top 50 most frequent keywords in each year. Pruning option: Pathfinder. Log-likelihood ratio (LLR) and Latent Semantic Indexing (LSI) algorithms were adopted to conduct a cluster analysis of the keywords and labelled as keywords.

3. Results and Analysis

3.1. Trend in the Number of Articles Published

The number of articles published in a discipline generally represents the research intensity of that area, and the changes in the number can reflect the status of development and the research trends. To grasp the research trends of blockchain in the areas of environment and health in general, this paper analyzed the overall trend of the number of articles published from 2014 to 2021, as shown in Figure 1. From 2014 to 2016, the one-digit number of relevant articles grew slowly. From 2017 to 2021, the number of articles published per year began to increase rapidly and reached a peak of 874 in 2020. According to recent literature, the main reason for this phenomenon is that the country has formulated policies in favour of the island tourism development November 2021, 805 articles have been published, which shows the popularity of the research topic. As a result, the number of articles published is expected to keep rising.

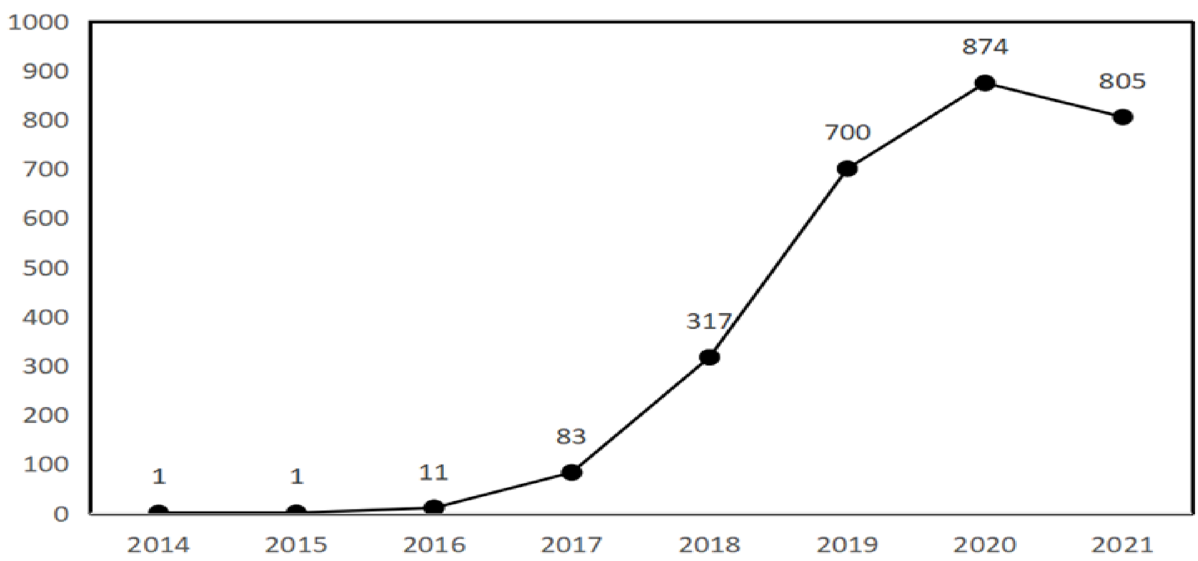


Figure 1. Trend in the Number of Articles Published.

3.2. Author Collaboration Network

The total number of journal articles represents the author's academic status in his or her area of expertise to some extent. An analysis of the authors can shed light on the main collaborations, team collaborations, and major research directions in the specific field. The data were visually analyzed using CiteSpace, where Time Slicing was set to 2014–2021, YearsPerSlice to 1, NodeTypes to Author, and K value of g-index to 25. LRF = 3.0, L/N = 10, LBY = 5, e = 1.0. Other options were set as default. As a result, the network of blockchain organizations researching the fields of environment and health was obtained. Figure 2 shows the author collaboration network, illustrating the core authors of studies on blockchain in the fields of environment and health and their collaborative relationships. The font size represents the number of articles published by the author, and the edges between the nodes represent the collaborative relationships between different authors, with thicker edges referring to closer collaborations. The most prolific and influential authors could be found by analyzing the number of articles published and the connections with the authors.

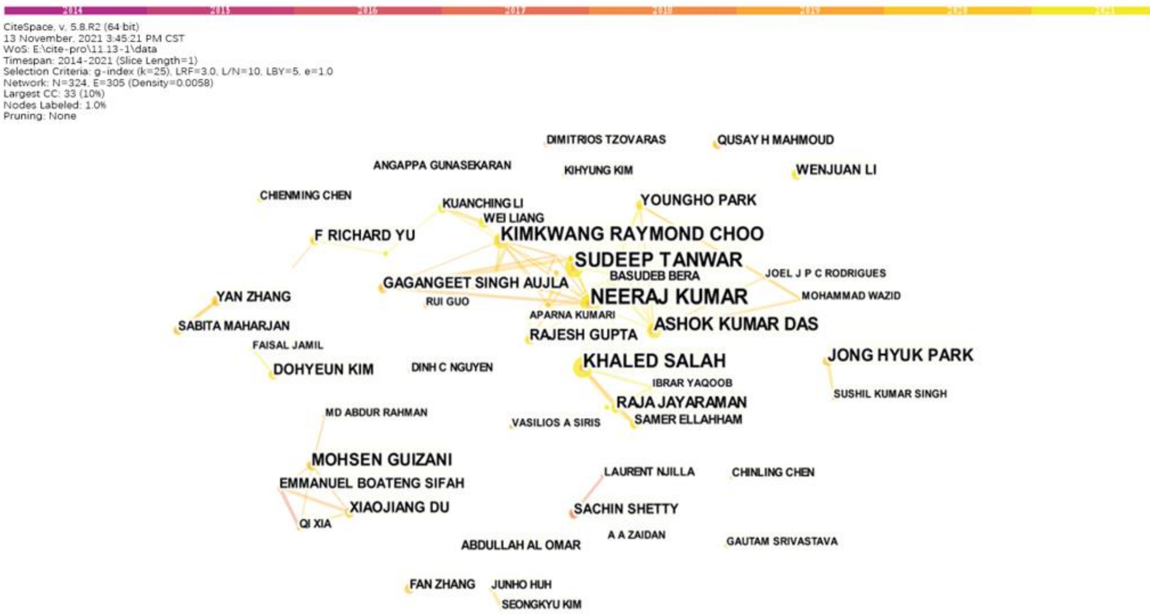


Figure 2. Author Collaboration Network.

Figure 2 shows 324 nodes and 305 edges, with an overall network density of 0.0058, indicating a weak collaboration network among authors in the research area of blockchain in environment and health. The most significant collaborative group is formed by Neeraj Kumar, Sudeep Tanwar, Kimkwang Raymond Choo, etc., with the highest degree of collaboration. The numbers of articles published are not big. The top ten authors in terms of the number of articles published are Neeraj Kumar, Sudeep Tanwar, Kimkwang Raymond Choo, Khaled Salah, Ashok Kumar Das, Mohsen Guizani, Jong Hyuk Park, Raja Jayaraman, Xiaojiang Du, And Rajesh Gupta. Neeraj Kumar has published 26 articles, the largest number among all the authors, followed by Sudeep Tanwar and Kimkwang Raymond Choo, who have published 21 and 18 articles, respectively. Other authors have published 17 articles or fewer. Table 1 is The Top 20 Most Prolific Authors, as follows:

Table 1. The Top 20 Most Prolific Authors.

Rank	Number of Articles	Betweenness Centrality	Average Year	Author
1	26	0.01	2019	Neeraj Kumar
2	21	0	2020	Sudeep Tanwar
3	18	0.01	2019	Kimkwang Raymond Choo
4	17	0	2019	Khaled Salah
5	15	0	2020	Ashok Kumar Das
6	11	0	2019	Mohsen Guizani
7	11	0	2017	Jong Hyuk Park
8	10	0	2020	Raja Jayaraman
9	9	0	2019	Xiaojiang Du
10	9	0	2020	Rajesh Gupta
11	8	0	2019	F. Richard Yu
12	8	0	2019	Gagangeet Singh Aujla
13	8	0	2020	Youngho Park
14	8	0	2019	Dohyeun Kim
15	7	0	2019	Yan Zhang
16	7	0	2017	Emmanuel Boateng Sifah
17	7	0	2017	Sachin Shetty
18	7	0	2020	Wenjuan Li
19	6	0	2020	Wei Liang
20	6	0	2021	Basudeb Bera

To explore the relationship between authors from the perspective of time series, this paper used the Timezone function of CiteSpace to display the interrelationship between authors in the coordinate system with time as the horizontal axis. In the Timezone View, the node′s size represents the frequency of the author′s appearance, the node′s year refers to the author′s first appearance, and the edges between the nodes represent the time when the authors appeared simultaneously.

According to Figure 3, Neeraj Kumar has the biggest node representing the largest number of published articles. This author first appeared in 2019, the node of whom has abundant edges with long time spans, indicating that the author and his studies have important academic status and reference value in this field. As time goes by, there are more authors of related studies. Other productive authors are basically from 2019 to 2021, indicating that the studies gradually matured at this stage, with abundant research results. The most recent co-authors are Sudeep Tanwar and Raja Jayaraman, among others, whose collaborative relationships with prolific authors still exist.

Figure 3. Time Zone View of Authors.

3.3. Research Institution Network

A collaboration network of research institutions illustrates the spatial distribution of research power in a specific field. To identify the institutions that drive the development of studies on blockchain in the fields of environment and health, this study used the collaboration network analysis function of CiteSpace to explore the network relationships between research institutions, which can visually reflect the collaboration between institutions and provide a reference for the scientific evaluation of the influence of institutions in the academic sphere. The data were visually analyzed using CiteSpace, with Time Slicing set to 2014–2021, YearsPerSlice to 1, NodeType to Institution, and K value of g-index to 25. LRF = 3.0, L/N = 10, LBY = 5, e = 1.0. Other options were set as default. Figure 4 shows the distribution network of institutions focusing on blockchain in environmental and health. The node size represents the number of articles published in journals by the specific institution, and the edges between nodes refer to the strengths of collaborations among institutions.

In Figure 4, there are 310 nodes and 521 edges, with a network density of 0.0109, indicating that quite a few institutions study blockchain in the fields of environment and health. Most of these institutions have collaborative relationships, and the largest collaborative network consists of Chinese Acad. Sci., Univ. Chinese Acad. Sci., etc. To dig deeper into the research results and collaborative relationships of institutions studying blockchain in the fields of environment and health, a further analysis was conducted on the data in Figure 4 to get the top 20 institutions in terms of the number of articles published. As shown in Table 2, the top 10 institutions are Chinese Acad. Sci., King Saud. Univ., Univ. Elect. Sci. & Technol. China, Beijing Univ. Posts & Telecommun., Univ. Chinese Acad. Sci., Univ. Texas San Antonio, Xidian Univ., Asia Univ., Nirma Univ., and Tsinghua Univ. Chinese Acad. Sci. has published 47 articles, the largest number among all the institutions, followed by King Saud. Univ. and Univ. Elect. Sci. & Technol. China published 39 and 37 articles, respectively. Other institutions have published 35 articles or fewer.

Figure 4. Institution Collaboration Network.

Generally speaking, there are currently many research collaborations among scholars on blockchain in environment and health, indicating that this area is a research hotspot. Accordingly, The Top 20 Most Prolific Institutions are listed in Table 2.

Table 2. The Top 20 Most Prolific Institutions.

Rank	Number of Articles	Betweenness Centrality	Average Year	Institution
1	47	0.17	2017	Chinese Acad. Sci.
2	39	0.2	2019	King Saud Univ.
3	37	0.06	2017	Univ Elect. Sci. & Technol. China
4	35	0.04	2017	Beijing Univ. Posts & Telecommun.
5	25	0.02	2017	Univ. Chinese Acad. Sci.
6	25	0.11	2019	Univ. Texas San Antonio
7	24	0.04	2018	Xidian Univ.
8	24	0.13	2019	Asia Univ.
9	23	0	2018	Nirma Univ.
10	22	0.01	2016	Tsinghua Univ.
11	20	0.04	2019	Thapar Inst. Engn. & Technol.
12	19	0.09	2019	King Abdulaziz Univ.
13	19	0	2019	Jeju Natl. Univ.
14	19	0.05	2018	Beijing Inst. Technol.
15	18	0.02	2018	Guangdong Univ. Technol.
16	18	0.07	2019	Khalifa Univ.
17	18	0.03	2018	Imperial Coll. London
18	17	0.02	2018	Natl. Univ. Singapore
19	17	0.04	2019	Wuhan Univ.
20	16	0.01	2018	Korea Univ.

Similarly, the Timezone function of CiteSpace was used to analyze collaborative institutions from the perspective of time series. Prolific institutions such as Chinese Acad. Sci., King Saud. Univ., Univ. Elect. Sci. & Technol. China, and Beijing Univ. Posts & Telecommun. are roughly distributed in the period of 2017 to 2019, indicating that research started to get on track during this period, with a large time span of research institutions and a long duration of research. As shown in Figure 5 Timezone View of Institutions:

Figure 5. Timezone View of Institutions.

3.4. Keyword Co-Occurrence

CiteSpace was used to conduct a visual analysis of data, with Time Slicing set to 2014–2021, YearsPerSlice to 1, NodeTypes to Institution, and K value of g-index to 5. LRF = 3.0, L/N = 7, LBY = 5, e = 2.0. Other options were set as default, and a keyword co-occurrence map was generated. The study of high-frequency keywords can explain the research hotspots in a certain field over a period of time. In this paper, 208 keywords were found based on the literature, with 220 edges formed. Figure 6 is the co-occurrence map of hot keywords. The font size represents the frequency of the keywords, the edges between nodes represent the connections established at different times, and the thickness of the edges indicates the intensity of keyword co-occurrence. The top 10 high-frequency keywords are blockchain, internet of things, security, smart contract, internet, privacy, challenge, technology, management, and system. The largest node is "blockchain", followed by "internet of things" and "security". A node is more important in the network when its betweenness centrality is greater. Seen from the indicator of betweenness centrality that represents the importance of a node (see Table 3), "blockchain", "internet of things", "security", and "privacy" have strong intensity with other hot keywords, indicating the relevant studies revolve around these keywords.

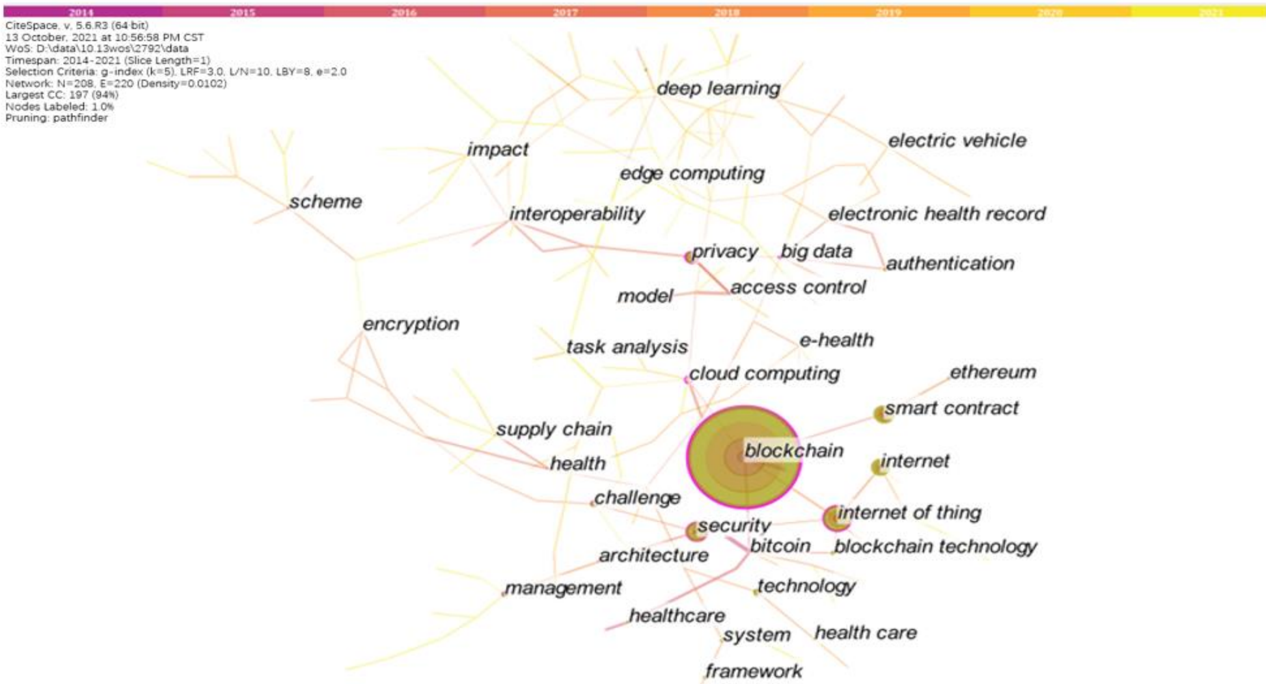


Figure 6. Keyword Co-occurrence.

Table 3. Top 20 High-frequency Keywords (in order of betweenness centrality).

Rank	Frequency	Betweenness Centrality		Keyword
1	1943	0.54	2014	blockchain
2	530	0.39	2017	internet of things
3	411	0.26	2017	security
4	387	0.02	2016	smart contract
5	364	0.09	2018	internet

Table 3. *Cont.*

Rank	Frequency	Betweenness Centrality	Keyword	
6	272	0.24	2016	privacy
7	191	0.12	2018	challenge
8	186	0.04	2018	technology
9	154	0.13	2018	management
10	145	0.07	2018	system
11	135	0.02	2018	framework
12	128	0.01	2017	blockchain technology
13	119	0.02	2017	authentication
14	117	0.02	2016	healthcare
15	104	0.18	2016	access control
16	103	0.02	2017	ethereum
17	101	0.32	2017	big data
18	95	0.84	2017	cloud computing
19	92	0.14	2017	architecture
20	91	0.01	2017	model

3.5. Keyword Clustering

Research hotspot is the focus of scholars in a particular academic field, which reflects main issues discussed in the field at a given time. As an important part of academic papers, keywords are often used to study the research hotspots in a certain field as they embody the essence of the papers. Based on this, this paper used CiteSpace to conduct a cluster analysis of keyword co-occurrence to visually reflect the research hotspots of blockchain in the fields of environment and health. The keyword clustering is shown in Figure 7, in which the colour blocks represent the clustering areas. N (node) = 208, E (edge) = 220, Density (network density) = 0.0102. The modularity (Q value) is related to the density of the nodes. A larger Q value means a better clustering effect, which can be used for a scientific clustering analysis. The average silhouette (S) values can be used to measure the homogeneity of the clusters. A larger S value means higher network homogeneity, indicating that the clusters are highly reliable. According to Figure 7, Q = 0.8261 indicates that the network structure has good clustering quality, and S = 0.5873 indicates high homogeneity and good partition of different clusters. Figure 5 shows all clusters, and the top 10 clusters are 0 blockchain, 1 artificial intelligence, 2 security, 3 transparency, 4 smart grid, 5 traceability, 6 cryptography, 7 reliability, 8 data sharing, and 9 task analysis, as shown in Table 4. The average years of the top ten clusters are from 2017 to 2020, indicating that relevant research matured during this period. The largest cluster "0 blockchain", with an average year of 2017, contains a total of 24 keywords, including blockchain (40.03, 1.0×10^{-4}), ethereum (34.11, 1.0×10^{-4}), IoT (32.89, 1.0×10^{-4}), smart contract (28.35, 1.0×10^{-4}), bitcoin (18.54, 1.0×10^{-4}), cryptocurrency (18.06, 1.0×10^{-4}), healthcare (17.9, 1.0×10^{-4}), internet of things (14.04, 0.001), etc. The second cluster "1 artificial intelligence", with an average year of 2019, contains 16 keywords, including artificial intelligence (22.13, 1.0E-4), machine learning (17.99, 1.0×10^{-4}), deep learning (17.81, 1.0×10^{-4}), IoT-oriented infrastructure (11.63, 0.001), big data (8.9, 0.005), and cps (7.92, 0.005), security and privacy (7.43, 0.01), cyber-physical system (6.31, 0.05), etc.

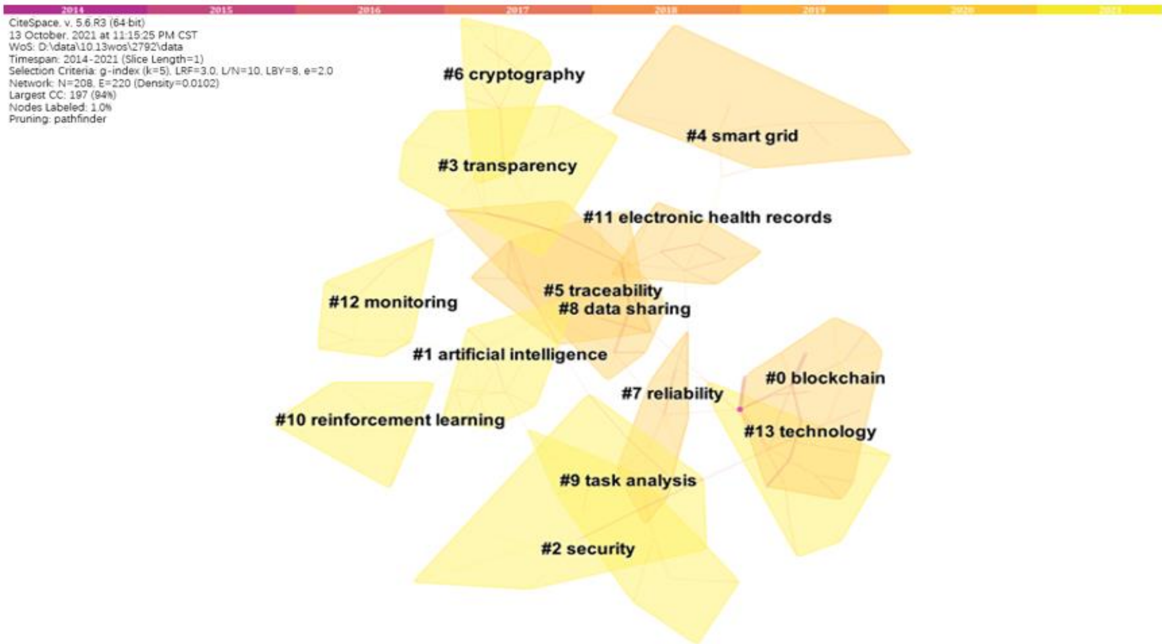


Figure 7. Keyword Clustering.

Table 4. Main Keywords of Clusters.

Cluster ID	Scale	Betweenness Centrality	Average Year	Main Keywords
0	24	1	2017	blockchain (40.03, 1.0×10^{-4}); ethereum (34.11, 1.0×10^{-4}); IoT (32.89, 1.0×10^{-4}); smart contract (28.35, 1.0×10^{-4}); bitcoin (18.54, 1.0×10^{-4}); cryptocurrency (18.06, 1.0×10^{-4}); healthcare (17.9, 1.0×10^{-4}); internet of things (14.04, 0.001)
1	16	0.92	2019	artificial intelligence (22.13, 1.0×10^{-4}); machine learning (17.99, 1.0×10^{-4}); deep learning (17.81, 1.0×10^{-4}); IoT-oriented infrastructure (11.63, 0.001); big data (8.9, 0.005); cps (7.92, 0.005); security and privacy (7.43, 0.01); cyber-physical system (6.31, 0.05)
2	16	0.934	2019	security (12.66, 0.001); surveillance (8.44, 0.005); circular economy (8.44, 0.005); built environment (8.44, 0.005); ethereum (7.43, 0.01); internet of things (IoT) (7.27, 0.01); servers (5.09, 0.05); machine learning (4.57, 0.05)
3	16	0.978	2019	transparency (20.49, 1.0×10^{-4}); readiness (12.68, 0.001); adoption (12.68, 0.001); supply chain management (9.82, 0.005); contracts (9.5, 0.005); initial coin offering (8.95, 0.005); IoT (7.81, 0.01); permissioned blockchain systems (6.33, 0.05)
4	15	0.937	2019	smart grid (32.24, 1.0×10^{-4}); energy trading (25.77, 1.0×10^{-4}); renewable energy (19.31, 1.0×10^{-4}); software-defined networking (19.31, 1.0×10^{-4}); consensus mechanism (12.74, 0.001); electric vehicles (9.13, 0.005); tactile internet (7.48, 0.01); decision making (7.48, 0.01)

Table 4. *Cont.*

Cluster ID	Scale	Betweenness Centrality	Average Year	Main Keywords
5	15	0.924	2018	traceability (27.53, 1.0×10^{-4}); intel sgx (18.12, 1.0×10^{-4}); decentralization (14.64, 0.001); supply chains (12.89, 0.001); p2p (12.07, 0.001); incentive mechanism (12.07, 0.001); logistics (10.1, 0.005); supply chain (7.26, 0.01)
6	13	0.895	2019	cryptography (8.75, 0.005); data integrity (8.75, 0.005); protocols (8.12, 0.005); peer-to-peer computing (8.12, 0.005); detection (7.84, 0.01); IoT security (7.84, 0.01); privacy (7.04, 0.01); internet of vehicles (6.55, 0.05)
7	13	0.942	2018	reliability (22.3, 1.0×10^{-4}); cloud computing (12.47, 0.001); industry 4.0 (11.01, 0.001); e-health (9.07, 0.005); service interoperability (6.07, 0.05); proactive forensics (6.07, 0.05); log security (6.07, 0.05); its (6.07, 0.05)
8	12	0.972	2017	data sharing (22.65, 1.0×10^{-4}); access control (18.4, 1.0×10^{-4}); attribute-based encryption (15.95, 1.0×10^{-4}); distributed ledger technology (13.34, 0.001); privacy (11.95, 0.001); interoperability (10.84, 0.001); healthcare applications (10.39, 0.005); synchronization (10.39, 0.005)
9	12	0.968	2019	task analysis (33.29, 1.0×10^{-4}); resource allocation (22.09, 1.0×10^{-4}); edge computing (21.13, 1.0×10^{-4}); computational modeling (20.24, 1.0×10^{-4}); servers (18.91, 1.0×10^{-4}); resource management (17.44, 1.0×10^{-4}); mobile blockchain (11.03, 0.001); resource pricing (11.03, 0.001)
10	12	0.919	2020	reinforcement learning (31.9, 1.0×10^{-4}); cybersecurity (23.57, 1.0×10^{-4}); pandemics (14.69, 0.001); artificial intelligence (ai) (12.54, 0.001); covid-19 (12.33, 0.001); digital twin (11.04, 0.001); IoT (7.72, 0.01); blockchain (7.51, 0.01)
11	11	0.85	2018	electronic health records (21.02, 1.0×10^{-4}); electronic health record (10.82, 0.005); authorization (9.7, 0.005); hyperledger fabric (8.27, 0.005); electronic medical records (6.52, 0.05); oauth (5.97, 0.05); ict (5.97, 0.05); sleep (5.63, 0.05)
12	11	0.901	2019	monitoring (11.68, 0.001); medical services (11.6, 0.001); sensors (10.81, 0.005); industries (10.05, 0.005); hospitals (9.37, 0.005); bim (8.54, 0.005); information and communication technology (8.54, 0.005); health 40 (8.54, 0.005)
13	11	0.956	2018	technology (13.22, 0.001); distributed ledger (8.43, 0.005); smart contract (6.43, 0.05); system (6.3, 0.05); social sustainability (6.3, 0.05); health care (5.87, 0.05); auditing (4.97, 0.05); indicators (4.97, 0.05)

3.6. Timezone View

To study the evolution of studies on blockchain in environment and health from the time dimension, this paper used the Timezone View of CiteSpace to conduct an analysis. The Timezone View is presented in Figure 8, which clearly shows the literature update and the interrelationship between studies according to the time sequence in a two-dimensional coordinate system with time as the horizontal axis. In the Timezone View, the size of the node refers to the frequency of the keyword, the year of the node indicates when the keyword first appeared, and the edges between the nodes indicate that different keywords appear in an article at the same time, representing the succession of relationships between different periods. The numbers of articles appearing in different years represent the results published at that time and indicate the current period or stage of the field.

The largest node in Figure 8 is "blockchain", which first appeared in 2014, together with another keyword meta-survey in the same year. Related concepts of studies on blockchain in the fields of environment and health span a long time and have a wide range of influence. High-frequency words are concentrated between 2016 and 2018. High-frequency words that first appeared in 2016 include privacy, smart contract, access control, etc. High-frequency words that first appeared in 2017 include security, big data, Internet of Things, etc. High-frequency words that first appeared in 2018 include internet, management, technology, etc. Relevant studies have continued until now, and subsequent studies have gradually put forward different concepts. Recent keywords that have emerged include pandemics, determinant, digital twin, telemedicine, robotics, etc.; the related hotspots can be studied based on these keywords.

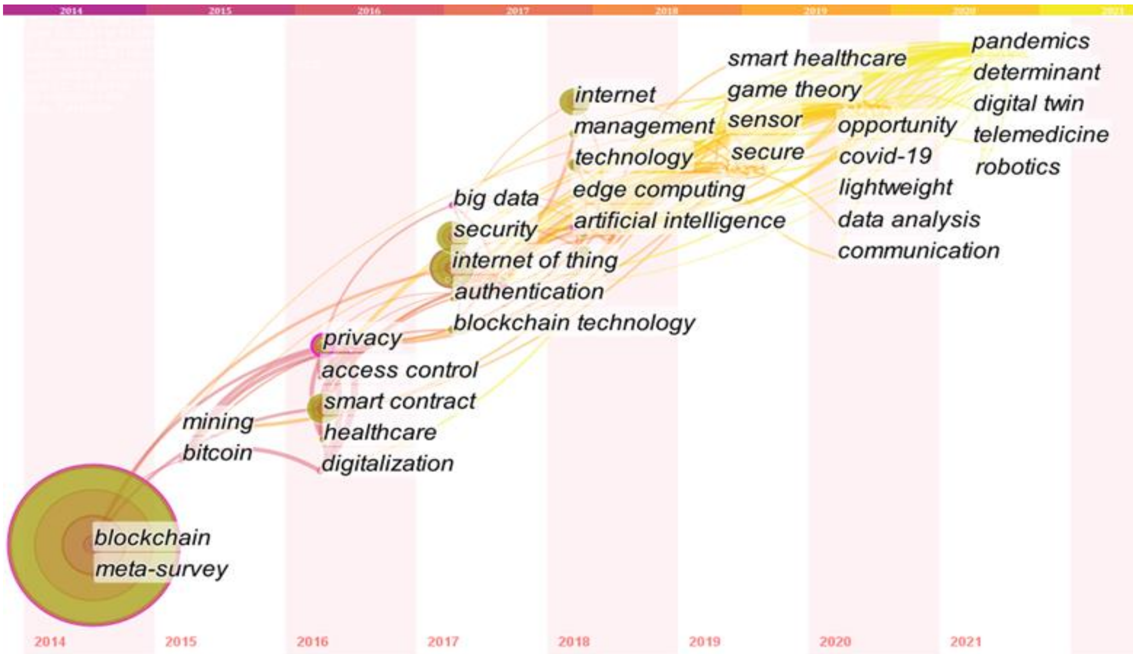
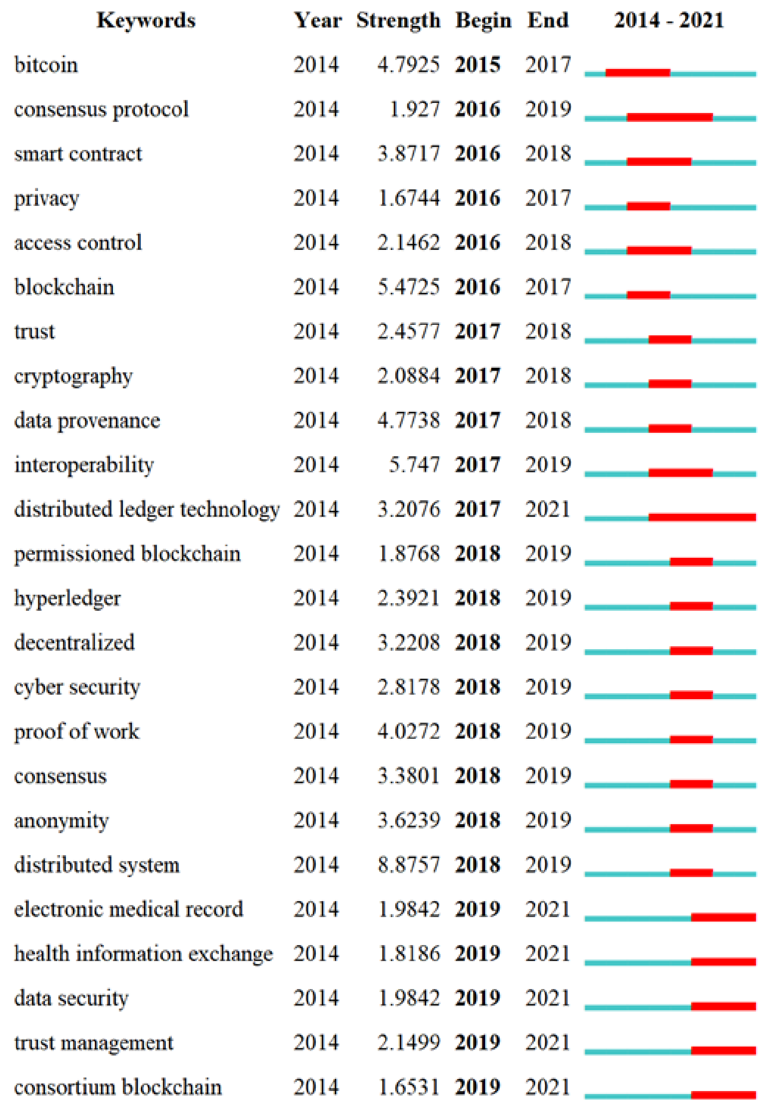


Figure 8. Timezone View of Keywords.

3.7. Keyword Burst

Burst words are those that frequently appear in a certain period of time, and their changes can reflect research hotspots in a specific field during the same period. It is also a kind of judgment basis for the evolutionary trend in the field, which can be clearly shown from the perspectives of the starting time and the strength and duration of the burst. To have a deeper understanding of the development tendency of blockchain in the fields of environment and health, this paper obtained the burst words in the field, as shown in Figure 9. Based on this, this paper provided an outlook on the development trend of studies on blockchain in the fields of environment and health from three perspectives: strength, duration, and starting time of the burst.

In terms of time series, "bitcoin" appeared the earliest in 2015, and "consortium", "trust management", "data security", and "health information exchange" started the latest in 2019, which can serve as the connecting points for future research. In terms of duration, "distributed ledger technology" has the longest burst for five years (2017–2021), followed by "consensus protocol" for four years (2016–2019). In addition, "consortium", "trust management", and "data security" also have a long burst time, indicating that they have been researching hotspots for quite a long time. In terms of strength, the top five keywords are "distributed system" (Strength = 8.8757), "interoperability" (Strength = 5.747), "blockchain" (Strength = 5.4725), "bitcoin" (Strength = 4.7925), and "data provenance" (Strength = 4.7738). Their high burst strengths suggest significant changes in their frequencies. In general, "consortium" and "trust management" are regarded as the latest emerging research hotspots due to their high strengths and proximity in terms of time.



Keywords	Year	Strength	Begin	End	2014 - 2021
bitcoin	2014	4.7925	**2015**	2017	
consensus protocol	2014	1.927	**2016**	2019	
smart contract	2014	3.8717	**2016**	2018	
privacy	2014	1.6744	**2016**	2017	
access control	2014	2.1462	**2016**	2018	
blockchain	2014	5.4725	**2016**	2017	
trust	2014	2.4577	**2017**	2018	
cryptography	2014	2.0884	**2017**	2018	
data provenance	2014	4.7738	**2017**	2018	
interoperability	2014	5.747	**2017**	2019	
distributed ledger technology	2014	3.2076	**2017**	2021	
permissioned blockchain	2014	1.8768	**2018**	2019	
hyperledger	2014	2.3921	**2018**	2019	
decentralized	2014	3.2208	**2018**	2019	
cyber security	2014	2.8178	**2018**	2019	
proof of work	2014	4.0272	**2018**	2019	
consensus	2014	3.3801	**2018**	2019	
anonymity	2014	3.6239	**2018**	2019	
distributed system	2014	8.8757	**2018**	2019	
electronic medical record	2014	1.9842	**2019**	2021	
health information exchange	2014	1.8186	**2019**	2021	
data security	2014	1.9842	**2019**	2021	
trust management	2014	2.1499	**2019**	2021	
consortium blockchain	2014	1.6531	**2019**	2021	

Figure 9. Burst Keywords.

3.8. Co-Citation Analysis

Co-citation analysis investigates the co-citation of literature in a research field to explore the high-level literature in the field, which has a huge impact on the area itself and the other external areas. The more two or more studies are co-cited, the stronger the correlation between them is, and the stronger their roles as high-level literature is. As can be seen from Figure 10, N (node) = 356, E (edge) = 1688, and Density (network density) = 0.0267, forming several significant co-citation relationships. By reviewing the top ten most highly cited studies, as shown in Table 5, the most highly cited articles are those by Christidis, K., followed by the articles by Azaria, A. and Yue, X.

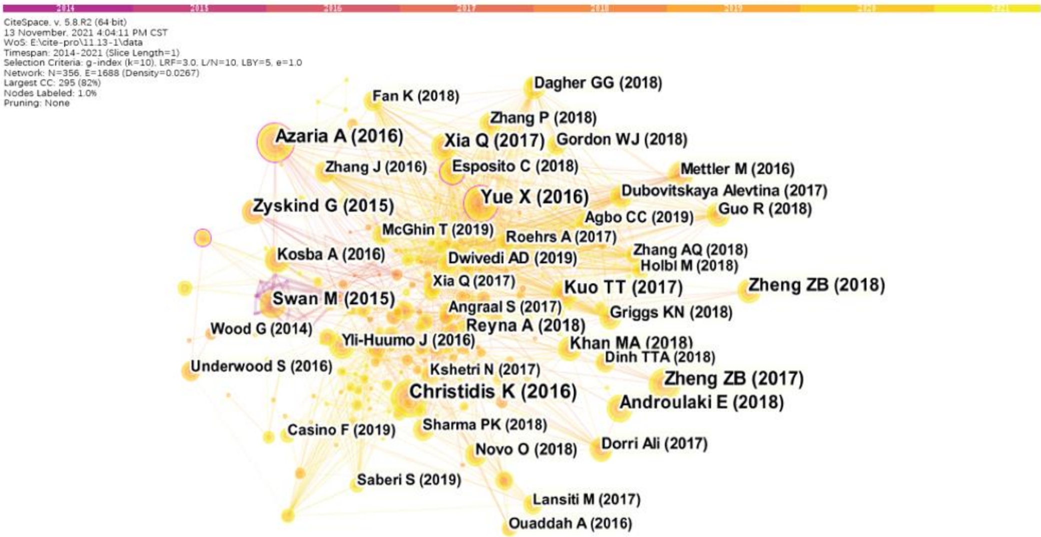


Figure 10. Relationships of Co-citations of Literature.

Table 5. Co-citations of Literature.

Rank	Frequency	Betweenness Centrality	Year	Source Publication
1	260	0.05	2016	Christidis, K., 2016, Blockchains and smart contracts for the Internet of things, Ieee Access, V4, P2292, doi:10.1109/Access.2016.2566339 [18]
2	198	0.1	2016	Azaria, A., 2016, MedRec: Using Blockchain for medical data access and permission management, Proceedings 2016 2nd International Conference on open and big data–OBD 2016, V0, P25, doi:10.1109/OBD.2016.11 [19]
3	179	0.12	2016	Yue, X., 2016, Healthcare data gateways: found healthcare intelligence on blockchain with novel privacy risk control, J. Med Syst., V40, P0, doi:10.1007/s10916-016-0574-6 [20]
4	162	0.03	2017	Zheng, Z.B., 2017, An Overview of Blockchain Technology: Architecture, Consensus, and Future Trends, Ieee Int Congr. Big, V0, P557, doi:10.1109/BigDataCongress.2017.85 [21]
5	149	0.01	2018	Androulaki, E., 2018, Hyperledger fabric: A distributed operating system for permissioned blockchains, EUROSYS 18: Proceedings of the Thirteenth EUROSYS Conference, V0, P0, doi:10.1145/3190508.3190538 [22]
6	143	0.03	2017	Kuo, T.T., 2017, Blockchain distributed ledger technologies for biomedical and health care applications, J. Am Med. Inform ASSN, V24, P1211, doi:10.1093/jamia/ocx068 [23]
7	133	0.02	2018	Zheng, Z.B., 2018, Blockchain challenges and opportunities: A survey, Int J. Web Grid. Serv., V14, P352, doi:10.1504/IJWGS.2018.095647 [24]
8	132	0.08	2017	Xia, Q., 2017, Medshare: Trust-Less medical data sharing among cloud service providers via blockchain, Ieee Access, V5, P14757, doi:10.1109/ACCESS.2017.2730843 [25]
9	131	0.01	2015	Zyskind, G., 2015, Decentralizing privacy: using blockchain to protect personal data, 2015 IEEE Security and Privacy Workshops (SPW), V0, P180, doi:10.1109/SPW.2015.27 [26]

Table 5. *Cont.*

Rank	Frequency	Betweenness Centrality	Year	Source Publication
10	126	0.05	2015	Swan, M., 2015, Blockchain thinking the brain as a decentralized autonomous corporation, Blockchain Blueprint, V0, P0, Editorial Material [27]
11	102	0.04	2018	Khan, M.A., 2018, IoT security: review, blockchain solutions, and open challenges, Future Gener. Comp. Sy., V82, P395, doi:10.1016/j.future. 2017.11.022 [28]
12	95	0.03	2018	Reyna. A., 2018, On blockchain and its integration with loT, Future Gener. Comp. Sy., V88, P173, doi:10.1016/j.future. 2018.05.046 [29]
13	90	0.08	2016	Mettler, M., 2016, Blockchain technology in healthcare the revolution starts here, 2016 IEEE 18th International Conference on E-health networking, V0, P520 [30]
14	90	0.01	2018	Dagher, G.G., 2018, Ancile: Privacy-preserving framework for access control and interoperability of electronic health records using blockchain technology, Sustain Cities Soc, V39, P283, doi:10.1016/j.scs. 2018.02.014 [31]
15	89	0.03	2018	Zhang. P., 2018, FHIRChain: Applying blockchain to securely and scalably share clinical data, Comput Struct Biotec, V16, P267, doi:10.1016/j.csbj. 2018.07.004 [32]
16	88	0.03	2016	Yli-Huumo, J., 2016, Smolander, K. Where is current research on blockchain technology? —A systematic review, PLOS ONE, V11, P0, doi:10.1371/journal.pone. 0163477 [33]
17	88	0.12	2018	Esposito, C., 2018, Blockchain: A Panacea for Healthcare Cloud-Based Data Security and Privacy? Ieee Cloud Comput, V5, P31 [34]
18	88	0.01	2017	Dorri, Ali, 2017, Blockchain for IoT security and privacy: The case study of a smart home, 2017 IEEE International Conference on Pervasive Computing and Communications Workshops (PerCom Workshops), V0, P618, doi:10.1109/PERCOMW.2017.7917634 [35]
19	87	0.02	2016	Kosba, A.; Miller, A.; Shi, E.; Wen, Z., Papamanthou, C., 2016, Hawk: The blockchain model of cryptography and privacy-preserving smart contracts. Inproceedings of 2016 symposium on security and privacy (SP), San Jose, pp. 839–858. [36]
20	87	0.03	2016	Kosba, A., 2016, Healthcare blockchain system using smart contracts for secure automated remote patient monitoring, P Ieee S Secur. Priv., V0, P839, doi:10.1109/SP.2016.55 [37]
21	87	0.02	2018	Griggs, K.N., 2018, A supply chain transparency and sustainability technology appraisal model for blockchain technology, J. Med Syst., V42, P0, doi:10.1007/s10916-018-0982-x [38]

3.9. Distribution of Countries and Regions

This paper set the node type of CiteSpace to Country to analyze the distribution of the countries and regions in which the studies are conducted. A visualization of the collaboration network between countries/regions was generated, as shown in Figure 11. The node size represents the number of articles published in the country/region. The edges between the nodes represent the collaborative relationships between various countries and regions, and the thickness of the edges represents the degree of collaboration. As shown in Figure 11, there are 108 nodes and 667 edges, with an overall network density of 0.1154, indicating that quite a few countries and regions study blockchain in the fields of environment and health, and they closely collaborate. China is the largest among the countries and regions, followed by the United States and India. The collaboration networks between countries and regions are relatively strong. The top 20 most prolific countries and regions are shown in Table 6. China and the US continue to lead the pack, with 713 and 509 articles published, respectively.

From the perspective of betweenness centrality, the number of articles published in most countries and regions shows a positive correlation with centrality. However, the centrality of China is disproportionate, indicating that although China is the first in terms of the number of articles, its centrality is low, and its collaborations with other countries and regions are not ideal, possibly because the research is contained to its own system or there are problems in literature citations. The shortcoming needs to be strengthened in the future.

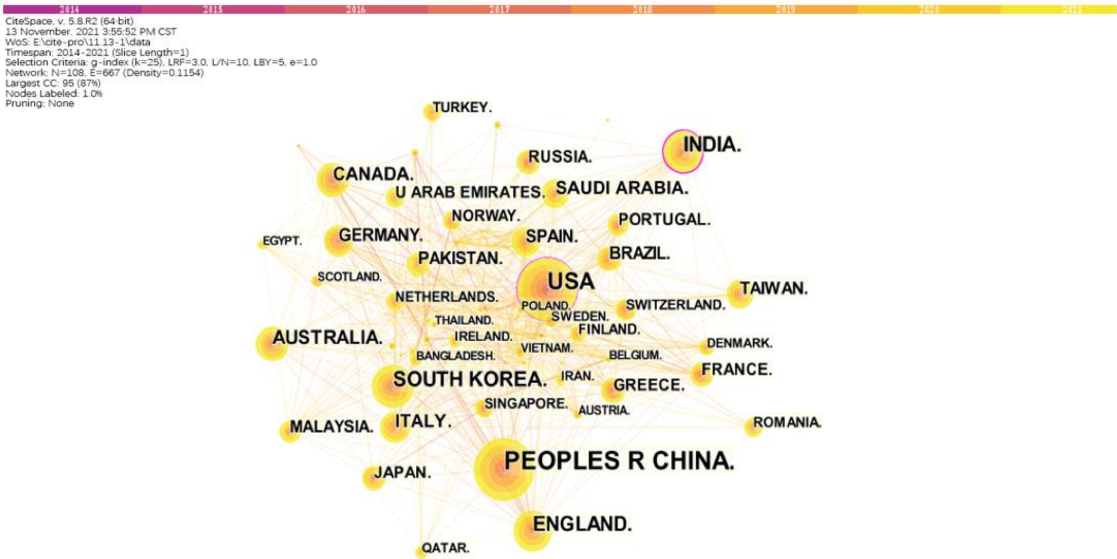


Figure 11. Country/Region Collaboration Network.

Table 6. Top 10 Most Prolific Countries/Regions.

Rank	Number of Articles	Betweenness Centrality	Average Year	Country/Region
1	713	0.06	2016	China
2	509	0.19	2016	USA
3	304	0.26	2017	India
4	238	0.01	2015	South Korea
5	192	0.1	2016	UK
6	134	0.05	2016	Australia
7	123	0.07	2017	Canada
8	123	0.09	2018	Saudi Arabia
9	106	0.05	2016	Italy
10	87	0.05	2018	Taiwan
11	80	0.04	2017	Germany
12	78	0.08	2017	Spain
13	74	0.02	2017	Brazil
14	73	0.04	2018	Pakistan
15	70	0.05	2017	France
16	65	0.02	2018	United Arab Emirates
17	62	0	2017	Japan
18	58	0.01	2017	Russia
19	58	0.03	2017	Greece
20	56	0.09	2018	Malaysia

4. Discussion

This study used the bibliometric technique of CiteSpace to explore the statistics of indicators, such as the number of articles published from 2014 to 2021 on blockchain technology in the fields of environment and health. It has been clearly observed that there are certain patterns in the selection of research topics by scholars and the main areas of research, as well as the contribution of results. According to the statistical data, we divide the application of blockchain technology into three stages, which are discussed as follows:

First is the enlightenment period. Blockchain technology is a contemporary, emerging technology, and its research and development time is relatively short—strictly speaking, less than ten years so far. The earliest blockchain technology was closely related to the financial industry at the beginning of its appearance. During this period, except for applications in the financial industry, there was no sign of the expansion of technical applications in other fields.

On the one hand, its application in the financial industry was still in a primitive and immature state at the time, and people were skeptical about this technology and its application effects when it was immature. On the other hand, the effect fluctuations in the financial field that have appeared in the application are regarded as the performance of the technology is still unstable and unreliable. Therefore, most fields, technology companies and technicians have a wait-and-see attitude during this period. It is especially when the technology system is not yet mature that more people are willing to believe that blockchain is only suitable for technical attempts in the financial field. It is even considered an attempt to limit blockchain technology to the financial field. However, it is safe for other industries. The theoretical development of blockchain technology in this period was also relatively weak, which is why the literature data on blockchain technology developed slowly from 2014 to 2016.

Second is the growing period. Since 2017, governments, scholars, and industry practitioners in several countries have begun to propose and conduct exploratory studies on implementing blockchain technology in other industries. There are various causes for this. On the one hand, using blockchain technology in the banking sector is secure. As blockchain technology's application in the financial field matures, it is continuously promoted in various financial subdivisions and similar industries or similar in the case of the needs of business function applications, it began to explore the expansion of the surrounding fields, gradually getting rid of the unbalanced application of sub-industry applications. There are various degrees of preliminary exploration in the sectors of the economy, digitalization, industrial manufacture, transportation, government services, and people's livelihood from the standpoint of expansion. Particularly noteworthy is the applied research in various areas, such as electronic medical record traceability, doctor-patient transparency, and medical traceability. The application in medical management is the most notable expansion of research on blockchain in the sphere of people's livelihoods. For example, in establishing national health informatization, increasing the service experience of the public, and focusing on solving the problems of difficult and expensive medical care. With the advancement of businesses such as precision medicine, big health, and smart biomedicine, the use of blockchain technology in medical treatment will grow rapidly. Following the acceleration of industrial applications, blockchain enables industrial manufacturing transformation and upgrading, among other things, demonstrating the enormous potential for increasing applications. In short, since 2017, the expansion and application of blockchain technology in the field of environmental health has been expanding over time, with a steady upward trend. It is anticipated to enter a phase of spread and quick expansion.

Third, the spread and a rapid expansion period. People increasingly noticed the extendable application research of blockchain technology after experiencing a growth period. On the one hand, numerous industries have produced spontaneous internal push for industrial change due to intelligent technology. The transition facilitated by the high-tech intelligence period has gotten more attention from numerous industries, such as artificial intelligence and the Internet of Things, which offer the potential for achieving a circular economy and a sustainable supply chain [38]. It has achieved amazing progress in its first sectors as one of the driving technologies of Industry 4.0. As a result, promoting blockchain integration in other domains, such as other developing technologies, is an irreversible trend [39]. According to a survey by Pakwczuk et al., 88% of respondents understand blockchain technology's disruptive industrial innovation capabilities and feel that it can reach greater expansibility in numerous industries and become a mainstream technology [40]. As a result, the extensibility of blockchain technology has been further reflected after 2019. Application exploration in various domains has been recognized by the academic community and the government and industry. All countries have established equivalent support policies and initiatives to encourage industrial R&D expansion and blockchain technology implementation. Although blockchain technology was initially applied in the financial field, the expansion and rapid expansion periods will show a development trend of diversification of application fields, deep integration applications with multiple technologies, and cross-domain deep integration of multiple technologies to maximize the value of blockchain technology [41].

Based on the development context of blockchain and its macro application, it further discusses its application characteristics, deficiencies and suggestion in the field of environment and health.

Firstly, the applications of blockchain technology in cross-over studies in environmental health fields tend to focus on one of the two areas. In other words, scholars tend to discuss blockchain technology in the fields of environment or health, which, to some extent, provides examples of studies on the application of blockchain technology. However, environmental issues today are widely influential research topics around the globe, which are often causally linked to issues in an array of fields, such as environmental health issues. A clearly focused study may lead to information silos that hinder the smooth flow and use of information from various fields. Meanwhile, a unilateral focus on applying blockchain technology in the health field also tends to result in one-sided judgements of problems. Therefore, collaborative applications to multiple fields enable effective communication between fields with causal and logical relationships.

Secondly, the literature results have a limited impact on surrounding fields. The literature results often manifest as theoretical contributions to the field or cross-over areas. Furthermore, the impact of the results on the surrounding areas is insignificant, especially in areas where the correlation is relatively weak, and the effects are indirect. Since most studies on the application of blockchain technology to environmental and health issues present a single nature, their results are limited in addressing the issues involving multiple fields. The formation of this problem is influenced by the direction of research, research conditions, and the depth and breadth of cross-collaboration. Researchers need to conduct logical reasoning, generalization, summarization, and citation on every issue to solve problems involving multiple fields. Some studies involving multiple fields are not a simple integration of studies in the respective fields, which may also involve more complex causal factors, so a single literature study and citation may affect the scientific and accurate nature of research conclusions.

Thirdly, the collaborations in this direction are mainly between organizations, institutions, and individuals, which are relatively close in geography and the field. Few collaborations across multiple fields and borders have been conducted on a large scale. It is well known that environmental and health issues are global problems that attract attention worldwide.

In terms of importance, all countries and institutions in the world should shoulder their responsibility. At the same time, according to the data of collaborative research, there exist limitations on the cross-territory and cross-discipline level since research institutions or personnel prefer to cooperate with those in geographic proximity and the same research field. Under such circumstances, the depth and breadth of research are one aspect to consider in establishing collaborations. However, there are different environmental and health problems in each geographical area. There is no one-size-fits-all approach to all individual characteristics—big-picture thinking is vital. In addition, each research area has distinctive perspectives, and diverse perspectives can provide more dimensions of innovative ideas and solutions. Therefore, it is advisable to promote openness and diversity while respecting freedom and willingness while establishing standards for research collaboration to avoid falling into stereotypical thinking.

5. Future Development Trends and Challenges

In recent years, research on the application of blockchain technology has gradually increased, presenting multiple opinions on research ideas, methods, and field applications and obtaining some different findings. For example, Watanabe, H. and Fan, H.W. [42] proposed expanding the application of blockchain technology in various fields of the Internet of Things so that blockchain technology is good at protecting data transmission between logical nodes to achieve an ideal state and enhance the application field's security. This has certain enlightenment for the field of environment and health. Chattaraj, D. and Bera, B., et al. [43] combined technologies, such as voting-based consensus algorithm verification and adding blocks, to blockchain to help vehicles, roads, road signs, and traffic lights adjust to changing conditions to help drivers improve safety, ease congestion, and reduce pollution for the Internet of Vehicles (IoV). Rana, A., Rawat, A.S. et al. [44] also developed an architecture for deploying the Internet of Vehicles via cloud servers and node authentication APIs. Connecting the hardware to the blockchain network generates ideas for developing innovative pollution monitoring systems, safeguarding the environment, establishing fresh air, and living a healthy life. Song, G.H., Lu, Y.J. et al. [45] investigated blockchain-based solutions in light of China's rapid economic development and an increase in the quantity and kind of hazardous waste and presented a blockchain-based HWT management system framework for government regulation. New solutions for solid waste management were offered. Almutairi, K., and Dehshiri, S.J.H. [46] strongly support the use of blockchain technology in the field of sustainable energy supply and feel that new technologies such as blockchain can assist increase trust, transparency, accountability, information sharing, and cooperation in this field et al. The study looked into the requirements and problems of blockchain use in renewable energy supply chains and discovered that "high investment cost" is the most significant barrier to blockchain application in sustainable energy supply chains. Li, Y., Lim, M.K. et al. [47] are also investigating the use of blockchain technology to reduce environmental pollution and costs in the urban electricity distribution industry. As a smart city, this study creates an open vehicle routing model for urban distribution that considers environmental pollution issues. The contract's mathematical logic to reduce total cost, including carbon emissions and pollutant emissions, and also built a genetic algorithm to enable smart contract implementation, and confirmed the efficiency of smart contracts through a practical case study.

Zhong, B.T., Guo, J.D. et al. [48] evaluated the application effect of blockchain technology in the construction environment in terms of pollutant discharge and environmental protection. The study looks into the possibilities of blockchain in OCEM and develops a prototype system that can be fine-tuned in real-world circumstances. According to research, blockchain can assist OCEM by delivering reliable environmental data and enabling continuous monitoring. Lotfi, R., Kargar, B. et al. [49] proposed a resource-constrained time-cost-quality-energy-environment trade-off problem in the context of blockchain technology and solved the model using GAMS-CPLEX as an example. Zhao, H.D., Liu, J.G. et al. [50] took the Japanese ocean dumping of nuclear waste as an example of the question of whether nuclear-contaminated seafood will stop being sold in the blockchain-supported market and explore technical ways to resolve conflicts between products and contaminated products. The study found potential equilibrium strategies for domestic products and two types of products, and from the perspective of government penalties, the incentives for polluting products that exist in the market, and provides ideas for solving specific problems in the fields of water pollution and health under the background of blockchain technology.

Siddique, A.B., Kazmi, R. et al. [51] proposed that indoor air pollution is more dangerous to residents than outdoor air pollution and that monitoring indoor air quality can reduce health risks for residents. The study proposes an indoor air quality index monitoring system that uses a data-driven model to predict the air quality index through neural network algorithms and blockchain. This study found that IoT-based smart blockchain technology plays a key role in providing scalability, privacy, and reliability. Nizeyimana, E., Nsenga, J. et al. [52] found that blockchain technology has certain advantages in real-time monitoring of air pollution peaks in a short period of time and can effectively reduce pollution sources.

In summary, we understand that traditional environmental governance still has a number of flaws, such as data manipulation, falsification of environmental monitoring data, quantification of pollution emissions, a lack of incentives for waste recycling, and environmental public welfare corruption. Future research will focus on how to support the digital transformation of the environmental health business through the full use of blockchain and construct a new intelligent green ecological order. There are several research avenues to consider: As blockchain technology is used in the environmental business, its technical performance, particularly data transfer and computational power, should be continuously enhanced, and blockchain technology should be pushed with stronger technical assistance. In-depth vertical application in the environmental field. Furthermore, the diverse application scenarios of blockchain technology can offer theoretical and applied research and innovation opportunities in the field of environmental health. At a time when the ecological environment is highly appreciated by the worldwide community, the use of blockchain technology will have a significant impact on the environmental business. Increase the use of blockchain technology in the field of environmental industrial subdivisions, and bring multidimensional, diverse, and multi-technology integration effects to this field, such as trusted digital traceability, decentralized intelligent production, industrial cloud service platform, engineering data Monitoring management, and so on. In addition, improve the technological application and innovation of locally targeted underlying platforms. The development of the blockchain underlying platform promotes independent regional environmental problem solving, encourages independent research and development and technical architecture innovation, avoids the problem of poor technical compatibility, and formulates targeted regional environmental governance strategic plans and directions. Finally, innovative solutions to environmental problems. In the future, combining blockchain and environmental industry segmentation with inadequate scenario popularization will focus on intelligent green ecological planning studies.

6. Conclusions

This study conducted a statistical analysis of studies on the application of blockchain technology in the environment and health. The literature was analyzed from nine aspects, including the trend in the number of articles published, author collaboration network, research institution network, keyword co-occurrence, co-citation analysis, keyword clustering, keyword burst, time zone, and the distribution of countries and regions. Then, the characteristics expressed by the data were described. Lastly, this study discussed the features of cross-over literature studies, the characteristics of the collaborations, the impact of the contributions, etc. At the same time, the present study proposed that the crossing of multiple fields should be encouraged in the studies on the application of blockchain technology to avoid limitations caused by the lack of fields. By doing so, the contributions of the studies can have a more profound influence on related fields. In addition, the collaborations should cater to applicable territories and fields as much as possible. Since environment and health are globally important, collaborations across multiple fields, across borders, and on a large scale should be recommended.

The main contributions of this study are first based on literature statistics. The application of blockchain technology is divided into three stages: the enlightenment period, the growing period, the spread and rapid expansion period, and the analysis. Second, on the basis of the above, we pointed out the insufficiency of the research and offered suggestions for future research. Third, we noted future research trends.

Author Contributions: Conceptualization, M.G. and L.W.; methodology, L.W., C.L.T.; formal analysis, M.G., Z.H. and L.W.; investigation, Z.H., X.G. and H.C.; resources, L.W., J.P., X.G. and H.C.; data curation, Z.H., L.W., C.L.T. and J.P.; writing, M.G., Z.H. and L.W.; writing—review and editing, M.G., Z.H., L.W.; supervision, L.W., C.L.T. and J.P.; project administration, M.G., L.W.; funding acquisition, M.G., Z.H. and L.W. All authors have read and agreed to the published version of the manuscript.

Funding: This paper was funded by "The 13th Five-Year" plan research project of philosophy and social sciences of Guangdong province (grant number: GD17YGL03); and Guangdong Youth Research Project (grant number: 2019GJ043), the Guangdong Higher Education Teaching Research and Reform Project (grant number: 2019J054); and the collaborative education project of industry-university cooperation of the Ministry of Education (grant number: 202102209025).

Institutional Review Board Statement: The study was conducted according to the guidelines of the Personal Information Protection Law of the People's Republic of China. All participants provided informed consent after having the study described to them before data collection activities.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: This study aims to apply blockchain technology in the fields of the environment and health from the Web of Science. All literature involved in the analysis is from the Web of Science database.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Fawcett, T. Personal carbon trading: A policy ahead of its time? *Energy Policy* **2010**, *38*, 6868–6876. [CrossRef]
2. Burgess, M. Personal carbon allowances: A revised model to alleviate distributional issues. *Ecol. Econ.* **2016**, *130*, 316–327. [CrossRef]
3. Fawcett, T.; Parag, Y. An introduction to personal carbon trading. *Clim. Policy* **2010**, *10*, 329–338. [CrossRef]
4. Li, W.; Long, R.; Chen, H.; Yang, T.; Geng, J.; Yang, M. Effects of Personal Carbon Trading on the Decision to Adopt Battery Electric Vehicles: Analysis Based on A Choice Experiment in Jiangsu, China. *Appl. Energy* **2018**, *209*, 478–488. [CrossRef]
5. Chen, G.; Zeng, D.; Wei, Q.; Zhang, M.; Guo, X. Paradigm shift and enabling innovation in decision making in big data environment. *Manag. World* **2020**, *36*, 95–105.
6. Ye, Q.; Gao, C.; Jiang, G. Design of China′s future blockchain carbon market system under big data environment. *Manag. World* **2022**, *38*, 229–249.
7. Zhao, J.; Meng, T. Technology empowerment: How blockchain reshapes governance structure and model. *Contemp. World Social.* **2019**, *3*, 187–194.
8. Yu, Y.; Hu, W. Research on trust governance network in ecological governance system. *Qinghai Soc. Sci.* **2017**, *1*, 47–52.
9. Chod, J.; Trichakis, N.; Tsoukalas, G.; Aspegren, H.; Weber, M. On the Financing Benefits of Supply Chain Transparency and Blockchain Adoption. *Manag. Sci.* **2020**, *66*, 4378–4396. [CrossRef]
10. Olsen, T.L.; Tomlin, B. Industry 4.0: Opportunities and Challenges for Operations Management. *Manuf. Serv. Oper. Manag.* **2020**, *22*, 113–122. [CrossRef]
11. Zhang, N.; Wang, Y.; Kang, C.; Cheng, J.; He, D. Blockchain technology in energy Internet: Research framework and typical applications. *Chin. J. Electr. Eng.* **2016**, *36*, 4011–4023.
12. Ji, B.; Chang, L.; Chen, Z.; Liu, Y.; Zhu, D.; Zhu, L. Application and market mechanism design of power carbon emission trading based on blockchain technology. *Power Syst. Autom.* **2021**, *45*, 1–12.
13. Ishan, M.; Sudeep, T.; Sudhan, T.; Neeraj, k. Blockchain for 5G-enabled IoT for industrial automation: A systematic review, solutions, and challenges. *Mech. Syst. Signal Processing* **2020**, *135*, 63–82.
14. Iván, H.; Solano, E.; Andrés, M. Control and monitoring for sustainable manufacturing in the industry 4.0: A literature review. *IFAC Proc.* **2019**, *52*, 195–200.
15. Allen, D.; Berg, C.; Markeytowler, B. Blockchain and the evolution of institutional technologies: Implications for innovation policy. *Res. Policy* **2020**, *49*, 38–65. [CrossRef]
16. Yohan, H.; Byungjun, P.; Jongpil, J. A novel architecture of air pollution measurement platform using 5G and blockchain for industrial IoT applications. *Procedia Comput. Sci.* **2019**, *155*, 728–733.
17. Sikorski, J.; Haughton, J.; Kraft, M. Blockchain technology in the chemical industry: Machine-to-machine electricity market. *Appl. Energy* **2017**, *195*, 234–246. [CrossRef]

18. Christidis, K.; Devetsikiotis, M. Blockchains and Smart Contracts for the Internet of Things. *IEEE Access* **2016**, *4*, 2292–2303. [CrossRef]
19. Azaria, A.; Ekblaw, A.; Vieira, T.; Lippman, A. MedRec: Using Blockchain for Medical Data Access and Permission Management. In Proceedings of the 2016 IEEE 2nd International Conference on Open and Big Data (OBD), Vienna, Austria, 22–24 August 2016; pp. 25–30.
20. Yue, X.; Wang, H.J.; Jin, D.W.; Li, M.Q.; Jiang, W. Healthcare Data Gateways: Found Healthcare Intelligence on Blockchain with Novel Privacy Risk Control. *J. Med. Syst.* **2016**, *40*, 218. [CrossRef]
21. Zheng, Z.; Xie, S.; Dai, H.; Chen, X.; Wang, H. An Overview of Blockchain Technology: Architecture, Consensus, and Future Trends. In Proceedings of the 2017 IEEE 6th International Congress On Big Data (Bigdata Congress 2017), Honolulu, HI, USA, 25–30 June 2017; pp. 557–564.
22. Androulaki, E.; Barger, A.; Bortnikov, V.; Cachin, C.; Christidis, K.; De, C.; Enyrart, D.; Ferris, C.; Laventman, G.; Manevich, Y.; et al. Hyperledger Fabric: A Distributed Operating System for Permissioned Blockchains. In Proceedings of the Thirteenth Eurosys Conference, Porto, Portugal, 23–26 April 2018; pp. 1–15.
23. Kuo, T.; Kim, H.; Ohno-Machado, L. Blockchain distributed ledger technologies for biomedical and health care applications. *J. Am. Med. Inform. Assoc.* **2017**, *24*, 6–1211. [CrossRef]
24. Zheng, Z.; Xie, S.; Dai, H.; Chen, X.; Wang, H. Blockchain challenges and opportunities: A survey. *Int. J. Web Grid Serv.* **2018**, *14*, 352–375. [CrossRef]
25. Xia, Q.; Sifah, E.; Asamoah, K.; Gao, J.; Du, X.; Guizani, M. Medshare: Trust-Less Medical Data Sharing Among Cloud Service Providers via Blockchain. *IEEE Access* **2018**, *5*, 14757–14767. [CrossRef]
26. Zyskind, G.; Nathan, O.; Pentland, A. Decentralizing Privacy: Using Blockchain to Protect Personal Data. In Proceedings of the 2015 IEEE Security and Privacy Workshops, San Jose, CA, USA, 21–22 May 2015; pp. 180–184.
27. Swan, M. Blockchain Thinking the Brain as a Decentralized Autonomous Corporation. *IEEE Technol. Soc. Mag.* **2015**, *34*, 41–52. [CrossRef]
28. Khan, M.; Salah, K. IoT security: Review, blockchain solutions, and open challenges. *Future Gener. Comput. Syst.* **2018**, *82*, 395–411. [CrossRef]
29. Reyna, A.; Martin, C.; Chen, J.; Soler, E. On blockchain and its integration with loT. Challenges and opportunities. *Future Gener. Comput. Syst.* **2018**, *88*, 173–190. [CrossRef]
30. Mettler, M. Blockchain Technology in Healthcare the Revolution Starts Here. In Proceedings of the 2016 IEEE 18th International Conference on E-Health Networking, Applications and Services (Healthcom), Munich, Germany, 14–16 September 2016; pp. 520–522.
31. Dagher, G.; Mohler, J.; Milojkovic, M.; Marella, P. Ancile: Privacy-preserving framework for access control and interoperability of electronic health records using blockchain technology. *Sustain. Cities Soc.* **2018**, *39*, 283–297. [CrossRef]
32. Zhang, P.; White, J.; Schmidt, D.C.; Lenz, G.; Rosenbloom, S. FHIRChain: Applying Blockchain to Securely and Scalably Share Clinical Data. *Comput. Struct. Biotechnol. J.* **2018**, *16*, 267–278. [CrossRef]
33. Yli-Huumo, J.; Ko, D.; Choi, S.; Park, S.; Smolander, K. Where Is Current Research on Blockchain Technology?—A Systematic Review. *PLoS ONE* **2016**, *11*, e0163477.
34. Esposito, C.; De, S.; Tortora, G.; Chang, H.; Choo, K. Blockchain: A Panacea for Healthcare Cloud-Based Data Security and Privacy? *IEEE Cloud Comput.* **2018**, *5*, 31–37. [CrossRef]
35. Dorri, A.; Kanhere, S.; Jurdak, R.; Gauravaram, P. Blockchain for IoT security and privacy: The case study of a smart home. In Proceedings of the IEEE International Conference on Pervasive Computing and Communications Workshops (PerCom Workshops), Kona, HI, USA, 13–17 March 2017; pp. 618–623.
36. Kosba, A.; Miller, A.; Shi, E.; Wen, Z.; Papamanthou, C. Hawk: The Blockchain Model of Cryptography and Privacy-Preserving Smart Contracts. In Proceedings of the 2016 Symposium on Security and Privacy (SP), San Jose, CA, USA, 22–26 May 2016; pp. 839–858.
37. Giggs, K.; Ossipova, O.; Kohlios, C.; Baccarini, A.; Howson, E.; Hayajneh, T. Healthcare Blockchain System Using Smart Contracts for Secure Automated Remote Patient Monitoring. *J. Med. Syst.* **2018**, *42*, 130. [CrossRef]
38. Baic, S.J. A supply chain transparency and sustainability technology appraisal model for blockchain technology. *Int. J. Prod. Res.* **2020**, *58*, 2142–2162.
39. Dalenogare, L.; Benitez, G.; Ayala, N.; Frank, A. The expected contribution f Industry 4.0 technologies for industrial performance. *Int. J. Prod. Econ.* **2018**, *204*, 383–394.
40. Matthew, B.; Rupesh, B.; Sayanika, B. Deloitte's 2020 Global Blockchain Survey from Promise to Reality. Available online: https://www.oracle.com/ie/scm/global-blockchain-survey (accessed on 10 March 2022).
41. Sube, S.; Ankit, B.; Biswajit, M. Digital twin driven inclusive manufacturing using emerging technologies. *IFAC Pap. Online* **2019**, *52*, 2225–2230.
42. Watanabe, H.; Fan, H.W. A Novel Chip-Level Blockchain Security Solution for the Internet of Things Networks. *Technologies* **2019**, *7*, 28.
43. Chattaraj, D.; Bera, B.; Das, A.K.; Saha, S.; Lorenz, P.; Park, Y. Block-CLAP: Blockchain-assisted certificateless key agreement protocol for Internet of vehicles in smart transportation. *IEEE Trans. Veh. Technol.* **2021**, *70*, 8092–8170.

44. Rana, A.; Rawat, A.S.; Afifi, A.; Singh, R.; Rashid, M.A.; Gehlot, A.; Akram, S.V.; Alshamrani, S.S. A Long-Range Internet of Thing-Based Advanced Vehicle Pollution Monitoring System with Node Authentication and Blockchain. *Appl. Sci. Basel* **2022**, *12*, 7547.
45. Song, G.H.; Lu, Y.J.; Feng, H.B.; Lin, H.; Zheng, Y. An implementation framework of blockchain-based hazardous waste transfer management system. *Environ. Sci. Pollut. Res.* **2022**, *29*, 36147–36160.
46. Almutairi, K.; Dehshiri, S.J.H.; Dehshiri, S.S.H.; Hoa, A.X.; Dhanraj, J.A.; Mostafaejpour, A.; Issakhov, A.; Techato, K. Blockchain Technology Application Challenges in Renewable Energy Supply Chain Management. *Environ. Sci. Pollut. Res.* **2022**, *1*, 1–18. [CrossRef]
47. Li, Y.; Lim, M.K.; Wang, C. An intelligent model of green urban distribution in the blockchain environment. *Resour. Conserv. Recycl.* **2022**, *176*, 105925.
48. Zhong, B.T.; Guo, J.D.; Zhang, L.; Wu, H.T.; Li, H.; Wang, Y.H. A blockchain-based framework for on-site construction environmental monitoring: Proof of concept. *Build. Environ.* **2022**, *217*, 109064.
49. Lotfi, R.; Kargar, B.; Gharehbaghi, A.; Hazrati, H.; Nazari, S.; Amra, M. Resource-constrained time-cost-quality-energy-environment tradeoff problem by considering blockchain technology, risk and robustness: A case study of healthcare project. *Environ. Sci. Pollut. Res.* **2022**, *4*, 1–17. [CrossRef]
50. Zhao, H.D.; Liu, J.G.; Zhao, P.F.; Chen, J.H. Will nuclear polluted seafood stop selling in the blockchain-enabled market? Lessons from government punishment and social cognition for retailer's selling. *Mar. Pollut. Bull.* **2022**, *178*, 113608.
51. Siddique, A.B.; Kazmi, R.; Khan, H.U.; Ali, S.; Samad, A.; Javaid, G. An Intelligent and Secure Air Quality Monitoring System Using Neural Network Algorithm and Blockchain. *IETE J. Res.* **2022**, *4*, 1–14. [CrossRef]
52. Nizeyimana, E.; Nsenga, J.; Shibasaki, R.; Hanyurwimfura, D.; Hwang, J. Design of Smart IoT Device for Monitoring Short-term Exposure to Air Pollution Peaks. *Int. J. Adv. Comput. Sci. Appl.* **2022**, *13*, 17–24.