



Review article

Review of global sanitation development

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ABSTRACT

The implementation of the United Nations (UN) Millennium Development Goals (MDGs) and Sustainable Development Goals (SDGs) has resulted in an increased focus on developing innovative, sustainable sanitation techniques to address the demand for adequate and equitable sanitation in low-income areas. We examined the background, current situation, challenges, and perspectives of global sanitation. We used bibliometric analysis and word cluster analysis to evaluate sanitation research from 1992 to 2016 based on the Science Citation Index EXPANDED (SCI-EXPANDED) and Social Sciences Citation Index (SSCI) databases. Our results show that sanitation is a comprehensive field connected with multiple categories, and the increasing number of publications reflects a strong interest in this research area. Most of the research took place in developed countries, especially the USA, although sanitation problems are more serious in developing countries. Innovations in sanitation techniques may keep susceptible populations from contracting diseases caused by various kinds of contaminants and microorganisms. Hence, the hygienization of human excreta, resource recovery, and removal of micro-pollutants from excreta can serve as effective sustainable solutions. Commercialized technologies, like composting, anaerobic digestion, and storage, are reliable but still face challenges in addressing the links between the political, social, institutional, cultural, and educational aspects of sanitation. Innovative technologies, such as Microbial Fuel Cells (MFCs), Microbial Electrolysis Cells (MECs), and struvite precipitation, are at the TRL (Technology readiness levels) 8 level, meaning that they qualify as “actual systems completed and qualified through test and demonstration.” Solutions that take into consideration economic feasibility and all the different aspects of sanitation are required. There is an urgent demand for holistic solutions considering government support, social acceptability, as well as technological reliability that can be effectively adapted to local conditions.

1. Introduction

The United Nations (UN), many local governments, and international organizations have launched programs to deal with the negative impact on human health and the environment caused by the lack of access to adequate sanitation. In the 1990s, 192 UN member states and at least 23 international organizations agreed to the Millennium Development Goals (MDGs) at the World Summits. MDG 6 (Target 10) was intended to halve the proportion of people without sustainable access to safe drinking water and basic sanitation by 2015. In September 2015, the 2030 Agenda for Sustainable Development Goals (SDGs) was adopted by world leaders at the UN, which calls on

countries to begin new efforts to achieve 17 SDGs over the next 15 years, including the goal to “ensure the availability and sustainable management of water and sanitation for all”. To inspire action to tackle the global sanitation crisis, “World Toilet Day”, which was established by the World Toilet Organization in 2001, was declared an official UN holiday in 2013. Every November 19th since then, UN-Water, local civil society organizations, and volunteers have planned events all over the world with themes such as “Toilets and Nutrition”, “Toilets and Jobs”, and “Wastewater”. Narendra Modi, the prime minister of India who launched projects like the Swachh Bharat Mission (Clean India Mission) in 2014, forged ahead to eliminate open defecation with the goal of constructing toilets in every household in the country by 2019. India is

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making impressive headway with its comprehensive planning for achieving this goal (Liangyu, 2017). President Xi Jinping proposed a “toilet revolution” in China’s rural areas in 2015. Thereafter, the China National Tourism Administration (CNTA) quickly started a “toilet revolution in tourism”, and great efforts have been undertaken to promote better sanitation (Cheng et al., 2018). More than 68,000 public toilets have been refurbished in China (Wong, 2017). Global sanitation efforts have been undertaken by governments as well as non-governmental organizations, where there are additional resources and manpower. In 2011, the Bill and Melinda Gates Foundation (BMGF) launched a research program named “Reinvent the Toilet Challenge (RTTC)”, which aimed to build sustainable and financially-profitable sanitation services and businesses that operate in poor, urban settings in both developed and developing nations. The new toilet system that won the challenge is a truly aspirational next-generation product that operates “off the grid” without connections to centralized water, sewers, or electrical supplies, removes harmful organisms from human waste, and recovers valuable resources such as energy, clean water, and nutrients. The toilet also costs (consists of both fundamental investment and operation cost) < 5 cents (US) per user per day. In 2013, after the successful implementation of worldwide activity in 2011 and 2012, the BMGF expanded the project by supporting for regional programs, including “Reinvent the Toilet Challenge – India (RTTC-India)” and “Reinvent the Toilet Challenge – China (RTTC-China)”, encourages researchers and institutions to innovate and design new-generation toilets in the China and India locally, but the RTTC-China also accepted the proposal which was proposed by Chinese leading team cooperated with the foreign partners.

However, although the percentage of people gaining access to improved sanitation increased from 54% to 68% and the percentage for open defecation has fallen from 24% to 13%, the world still missed the MDG target (WHO, 2015). Currently, there are still 4.5 billion people lacking safely managed sanitation, and among them, 2.3 billion still do not have basic sanitation services. This number includes 600 million people who share a toilet or latrine with other households and 892 million people – primarily in rural areas – who defecate in the open, as reported by the World Health Organization (WHO) and the UN International Children’s Emergency Fund (UNICEF) on July 12th, 2017 (Osseiran et al., 2017). WHO defines sanitation as the provision of facilities or services that separates people from urine and feces. Safe access to sanitary toilets and the management of excreta are the basic targets for global sanitation, and these targets are important to realizing effective resource recycling. Resource recycling, generally called “sustainable sanitation”, should be economically viable, socially acceptable, and technically and institutionally appropriate. It should protect the environment and conserve natural resources. Developing economical, acceptable, technically flexible, and environmentally-friendly sanitation technology for the next generation requires research into sanitation technologies development.

Here we present a statistical analysis based on published research that appeared in journals between 1992 and 2016 intended to identify trends in publication, explore research patterns and hotspots, isolate the specific issues with global sanitation as well as the assessments of those issues. The results offer a comprehensive overview of current issues and perceptions in sanitation research. This work can also help researchers develop ideas concerning future research areas and make more informed decisions.

2. Materials and methods

2.1. Data sources

Information about scientific output was extracted from the Science Citation Index EXPANDED (SCI-EXPANDED), Social Sciences Citation Index (SSCI), and the 2017 Journal Citation Reports (JCR), Science Edition, from Clarivate Analytics on August 17, 2017. The 2017 JCR

covers 11,459 journals across 236 scientific disciplines spanning 81 countries. In this study, we searched for the keywords “sanitation” or “sanitary” in the period from 1900 to 2016.

2.2. Data analysis

We used bibliometric analysis, which has been adopted in other studies (Chiu et al., 2004, Fu et al., 2013, Zheng et al., 2018) to investigate sanitation research trends worldwide. We utilized numerous markers to help identify trends in publication, such as the document type, language, categories, and journals, as well as countries/territories, institutions, and the *h*-index. It has to be mentioned that *h*-index was regarded as the *h* of *N_p* articles were cited no less than *h* times each and the other (*N_p*-*h*) articles were cited no more than *h* times each (Hirsch, 2005). The document type, language, output, subject category, journal, country, institute, source title, abstract keywords, and *h*-index were all analyzed using Microsoft Excel 2010. The frequency analysis was conducted using BibExcel 1.0.0.0 (Persson et al., 2009). We used BibExcel for the co-occurrence analysis and Pajek 1.0.0.1 (Nooy et al., 2011) network diagrams for the cooperation analysis. By identifying the institution and country of at least one author, we were able to estimate the influence of a country and its research facility. Research from Hong Kong was grouped with that of China (Chuang et al., 2011), and works from England, Scotland, Northern Ireland, and Wales were included with research from the UK. We assigned the tag of “internationally collaborative publication” to works that had authors from multiple countries. We identified articles as being the “independent type” when the researchers were all from the same location. We used the tag “single institute publication” when the researchers’ addresses were all from the same research facility, and “inter-institutionally collaborative publications” identified works from the authors from different research facilities (Fu et al., 2012). We used data from the JCR, Science Edition, 2017 for the values of the journal impact factor (JIF). We also applied “word cluster analysis” (Mao et al., 2010) to explore the research patterns and hotspots. This analysis encompassed the distribution of author keywords, article title, article abstracts, and the KeyWords Plus during the time period, so that we were able to isolate the specific research trends with global sanitation as well as the assessments of those issues.

3. Sanitation activities in scientific research

3.1. Publication patterns

3.1.1. Characteristics of publication outputs

We identified 18,449 publications related to sanitation research in the SCI-Expanded and SSCI databases between 1900 and 2016, and we found a continual growth trend, as shown in Fig. 1. There were 15,615 (84.6%) papers indexed in the SCI-Expanded and 1450 (7.9%) papers indexed in the SSCI on sanitation; 1384 (7.5%) were indexed in both the SCI-Expanded and SSCI. Fig. 1 shows that after 1991, the number of publications rose significantly.

More than 90% of articles in Web of Science have, since 1991, included abstracts, compared with only 20% articles in 1990 (Ho et al., 2010), 14,645 papers from 1992 to 2016 were selected as study samples. We grouped these works into 17 types of documents. Articles comprised 81.6% (11,956) of the total number of works examined, making them the most common document type. The remaining publications consisted of proceedings (981), reviews (954), editorial material (262), meeting abstracts (176), book reviews (74), news items (73), letters (64), book chapters (44), corrections (19), notes (18), reprints (8), discussions (6), items about an individual (4), biographical items (3), retracted publications (2), and retractions (1). We did not use any other document types in this study because articles were the most common type of work. Of the 11,956 articles, 10,049 (84%) were published in English, followed by Portuguese (651), Spanish (508), French (315), German (134), Japanese (65), Italian (62), Polish (61),

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