Bibliometric trends of South African environmental health articles between 1998 and 2015: Making local research visible and retrievable

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Background. South Africa (SA) has to grapple with multiple burdens of disease for which environmental factors have a role to play in both causation and prevention. This article describes a bibliometric review of environmental health indexed literature for SA over an 18-year period.
Objectives. To provide an overview of the nature of SA-based published environmental health indexed research and to identify search challenges, frequently researched topics, and gaps and opportunities for future research.
Methods. The Web of Science, PubMed and Science Direct were used to search for original, peer-reviewed and review articles with the inclusion criteria 'environmental health' and 'South Africa' available online and published between 1998 and 2015, inclusively.
Results. A total of 230 journal articles were included in the bibliometric analysis. The highest number of articles (n=54) was published in 2015. The majority of the first authors were affiliated with SA institutions (n=160, 69.5%). For the articles where funding was explicitly declared (n=148), the three most frequently occurring agencies that funded the published research were the National Research Foundation in SA (n=17), the South African Medical Research Council (n=13) and the Water Research Commission (n=9). There was little inter-annual/environmental health category variation over time owing to the relatively small sample size. The largest number of retrieved journal articles was in the area of environmental pollution control (n=76), followed by environmental health lifestyle and behaviour-related topics (n=42) and then water monitoring (n=26).
Conclusions. Despite the research needed to solve large environmental health challenges in SA, environmental health was only used as a keyword in title, author keywords or abstract for 230 SA-based studies over an 18-year period. This makes it extremely difficult for environmental health research to be located and used to inform the profession as well as the research agenda. Several issues that environmental health practitioners are typically tasked to implement and monitor are not indexed as environmental health topics. The need for authors to use 'environmental health' as a keyword is emphasised, particularly if research is to inform decision-making and policy support, as well as guide future research in the country.

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Worldwide, an estimated 12.6 million deaths each year are attributed to an unhealthy environment.[1] Environmental risk factors (unsafe water, inadequate sanitation and hygiene, indoor air pollution from solid fuel use, urban outdoor air pollution, and lead exposure) were associated with 5% of all deaths in South Africa (SA) in 2000. The joint attributable burden was high in children aged ≤5 years, with nearly 11% of total deaths in this age group.[2] Many of these deaths could be prevented by appropriate public health interventions.

Despite the pressing environmental health problems in SA, no research has assessed the bibliometric characteristics of environmental health research in the country. Such studies have been done for other sciences[3] and for a specific topic[4] or disease,[5] but not for environmental health research as a whole in SA. A bibliometric assessment provides patterns of publications within a field of study or body of literature. It can help decipher overall patterns in research, indicate where and how to find the articles, and provide direction for future research. The World Health Organization defines environmental health as those aspects of human health and disease that are determined by factors in the environment. It also refers to the theory and practice of assessing and controlling factors in the environment that can potentially affect health.[6]

Objectives

To provide an overview of the nature of published SA environmental health indexed research over an 18-year period and to identify search challenges, frequently researched topics, and gaps and opportunities for future research.

Methods

Search procedures

We used an adapted version of the bibliometric analysis methodology applied by Pouris and Pouris[4] and Chuang *et al.*[3] The literature search was conducted in March 2016 in three electronic databases: the Institute for Scientific Information (ISI) Web of Science Citation Index Expanded (SCI-Expanded), the US National Library of Medicine/National Institutes of Health PubMed (https://www.ncbi.nlm.nih.gov/pubmed/), and Science Direct (www.sciencedirect.com). The search for published articles was limited to between the

years 1998 and 2015, inclusively. Search terms were 'environmental health' (the Medical Subject Headings (MeSH)) exact thesaurus term match for environmental health[7]) AND 'South Africa'. In Web of Science, limits were set for the search in *all databases* for article, other and review, in Science Direct, restrictions were set in *journals* for article, review article, short survey and discussion, and in PubMed, limits were set for the time period and for all fields and types of articles.

Inclusion criteria

Full-text articles that met inclusion criteria similar to those used by Chuang *et al.*,[3] available online through an open-access platform or via two of the authors' institutional libraries, were included in the dataset for review (Table 1). Both search terms needed to appear in the title or author keywords or abstract. First the article title, then the abstract of the article and the aim/hypothesis/objective(s) in the introduction were reviewed to determine relevance to the topic 'environmental health' and 'South Africa'. In addition, the article had to focus on an SA issue or an SA study site. The article was excluded if the study was only done by an SA institution and not at an SA study site. Review articles were included. For cross-checking purposes, an independent double check was made by two different researchers regarding whether or not to include an article in the study. Where the researchers did not agree, two additional researchers reviewed the article and a final decision was made whether to include or exclude the article based on the defined inclusion criteria.

Article processing and categorisation

Bibliometric characteristics of all retrieved articles were downloaded into a Microsoft Excel spreadsheet (Microsoft Office Professional Plus 2013, Microsoft, USA), and each article was given a unique identity number. Downloaded information, as suggested by Carpenter *et al.*,[8] included names of authors, title of article, year of publication, name of the journal in which the article was published, and, in accordance with the visibility metric applied by similar bibliometric studies in South Africa,[4,9] its 2016 ISI impact factor (extracted from the Journal Citation Reports Journal 2016 Impact Factor List), affiliation of first author, country of first author, and whether the article was a research article or a review. The articles were also allocated to one of the environmental health subcategories based on the scope of practice of environmental health practitioners in SA[10] (Table 2). A brief description of each subcategory is provided to illustrate the complexity of subcategories in this field of public health. We used these categories rather than the ISI Web of Science subject categories[3] because in SA environmental health research aims to serve the profession and the country, as well as contribute to international knowledge.

Four subcategories emerged during the article processing stage, namely lifestyle/behaviour, climate change, sustainable development and occupational health. The latter is probably an erroneous finding (occurring where occupational health and environmental health were mentioned), but we have included it for illustration purposes, and this will be explained in the discussion.

For completeness, an independent double allocation to the subcategories by two different researchers was conducted in April 2016. Again, when the two researchers did not agree on an article's topic allocation, the same two additional researchers who had already reviewed several articles for the final decision whether to include or exclude the article based on the defined inclusion criteria also reviewed the article for the appropriate category. Finally, a decision was made on the journal article's appropriate category.

Data processing and statistical analysis

After processing and categorisation, the articles spreadsheet was prepared for export into Stata 14 (StataCorp, USA) for further analysis. Descriptive statistics were explored regarding individual variables and relations between several variables. Variables included number of articles published per year, journal names and number of articles per journal, number of different main-author countries, number of articles per category of environmental health research, and number of review articles v. research articles. Comparisons of bibliometric characteristics are discussed and interpreted as numbers and percentages.

Results

Bibliometric description of the sample

A total of 1 182 articles were retrieved. After removing all duplicates (n=99), there were 1 083 articles remaining for critical review. These articles were scrutinised and 853 were excluded after reading the title, abstract, aim, hypothesis and objectives in the introduction showed that the focus of the article was not in fact environmental health related to an SA-specific (in-country) issue or an SA study site. The total number of articles remaining was 230 (Appendix 1).

The number of published articles by year and cumulatively during the 10-year period is shown in Fig. 1. No more than 30 relevant articles were retrieved per year, except for 2015. The highest number of retrieved articles was published in 2015 (n=54), followed by 2014 with 28 articles published. Of the total, 79.0% of retrieved articles were original research articles and the remaining 49 were review articles.

Ninety-one different institutions, including national and international institutions, were represented in the sample of first authors' first reported affiliation. The majority of the retrieved articles' first authors were affiliated with SA institutions (n=160, 69.5%). The highest-numbering first author's first affiliation was the University of Cape Town (n=50), followed by the University of KwaZulu-Natal (n=31), the South African Medical Research Council (SAMRC) (n=14) and Tshwane University of Technology (n=15). Across all years, the province with the most articles was the Western Cape (n=51), followed by Gauteng (n=49).

The USA was the country with the greatest number of first authors after SA, followed by the UK. Only three other sub-Saharan

Table 1. Four study inclusion criteria and their descriptions

Inclusion criterion	Description
1. Keywords	Returned from search for 'Environmental health' and 'South Africa'
	Evident in the title, author keywords or abstract
2. Date range	1998 - 2015, inclusive
3. Availability	Full article available online (free to download or through authors' institutional library where not open access)
4. Study site	South African

Note: Keywords could appear in the title or abstract or as keywords of the article. We also checked the aim, hypothesis and objectives in the introduction for clarification when it was not clear whether or not the article met the inclusion criteria.

Table 2. Classification subcategories for SA-focused environmental health research articles*

No.	Categories	Brief subcategory description†	Articles (*N*=230), *n* (%)
7	Environmental pollution control	Ensuring hygienic working, living and recreational environments Identifying the polluting agents and sources of water, air and soil pollution Taking the required preventive measures to ensure that the general environment is free from health risks	76 (33.0)
15	Lifestyle, behaviour	Environmental factors influencing lifestyle diseases, e.g. tobacco, alcohol, physical activity, sun exposure	42 (18.2)
1	Water monitoring	Monitoring and sampling of water intended for use for human consumption and for recreational and commercial use Monitoring of surface waters for waterborne diseases Ensuring the monitoring of effective waste water treatment and water pollution control, including the collection, treatment and safe disposal of sewage and other water-borne waste, and surveillance of the quality of surface water and ground water	26 (11.3)
2	Food control	Informal and formal sectors are monitored to ensure the safe handling of foodstuffs during their production, storage and delivery Licensing of food premises, condemnation of unsafe foods and ensuring the sale and supply of safe meat and milk	21 (9.0)
4	Health surveillance of premises	Residential, business and public premises are regularly monitored to identify, monitor and evaluate health risks and hazards and institute remedial and preventive measures Ensuring the abatement and prevention of any condition on any premises that is likely to constitute a nuisance or health hazard	17 (7.3)
3	Waste management and hygiene monitoring	Ensuring the proper refuse storage, collection, transportation, transfer and processing, materials recovery and final disposal Ensuring proper management of liquid waste, including sewage and industrial effluents	10 (4.3)
14	Control and monitoring of hazardous substances	Ensuring correct labelling and registration of hazardous substances	7 (3.0)
5	Surveillance and prevention of communicable diseases	Investigating environmental factors relating to the spread of notifiable infectious diseases and putting measures in place to prevent the spread thereof Implementation of education, health and hygiene promotion programmes	6 (2.6)
6	Vector control monitoring	Eradication and identification of vectors and their habitats and breeding places Conducting vector control in the interests of public health, including control of arthropods, molluscs, rodents and other alternative hosts of diseases	6 (2.6)
13	Malaria control	Implementation of a malaria control and surveillance programme Conducting continued health education and awareness programmes on malaria	6 (2.6)
19	Sustainable development	Environmental health and sustainable development, i.e. living conditions, financial and economic cost-benefit analysis	6 (2.6)
9	Chemical safety	Permitting, licensing and auditing premises that deal with chemicals Facilitating advice, education and training on pesticides and chemical safety	4 (1.7)
17	Climate change	Decadal effects of climate on environmental health risk factors and outcomes	2 (0.8)
20	Occupational health	Deals with the prevention and treatment of job-related injuries and illnesses. Includes all aspects of health and safety in the workplace, including environmental factors	1 (0.4)
11	Radiation (ionising and non-ionising) monitoring and control	Ensuring that ionising and non-ionising radiation sources are registered with the Department of Health and meet licence conditions Monitoring safe transportation of radioactive material to ensure compliance Ensuring that radioactive sources are registered and all radiation waste materials from hospitals are properly disposed Ensuring protection against any form or source of electromagnetic radiation	1 (0.4)
12	Port health	Monitoring, inspecting, sampling and labelling all imported foodstuffs, cosmetics and disinfectants at all ports of entry Sampling foodstuffs on aeroplanes and ships	1 (0.4)
10	Noise control	Controlling and preventing vibration and noise pollution	0
8	Disposal of the dead	Controlling, restricting or prohibiting the business of an undertaker or embalmer, mortuaries and other places or facilities for the storage of dead bodies	0

*Number of articles in this review by category is given in the right-hand column by descending order of the percentages. The number (No.) is the coding we used for environmental health subcategories.
†Descriptions were adapted from Pouris and Ho.[9]

African countries were represented by first authors, namely Tanzania, Zimbabwe and Egypt (Table 3). The London School of Hygiene and Tropical Medicine was the non-SA first author main affiliation with the highest number of retrieved articles (*n*=4) in the study.

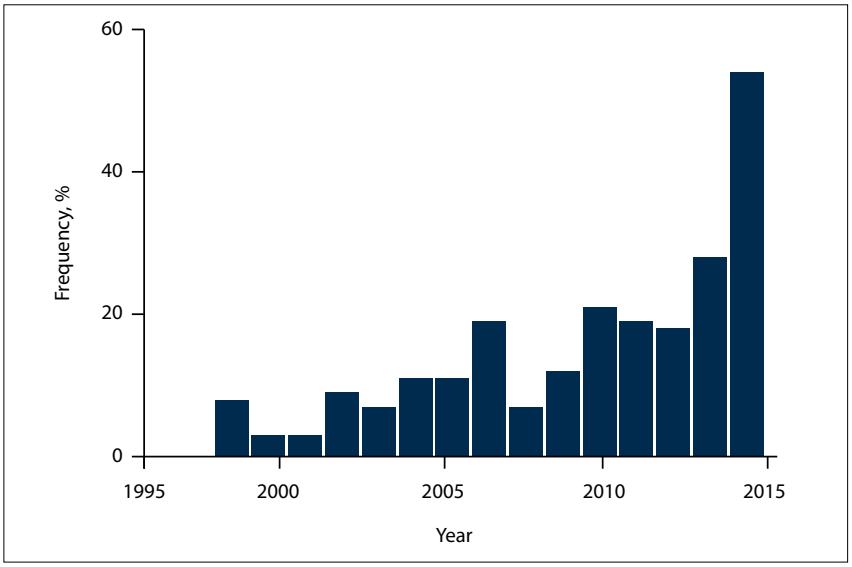

Fig. 1. Frequency of published articles by year over the period of study from 1998 to 2015.

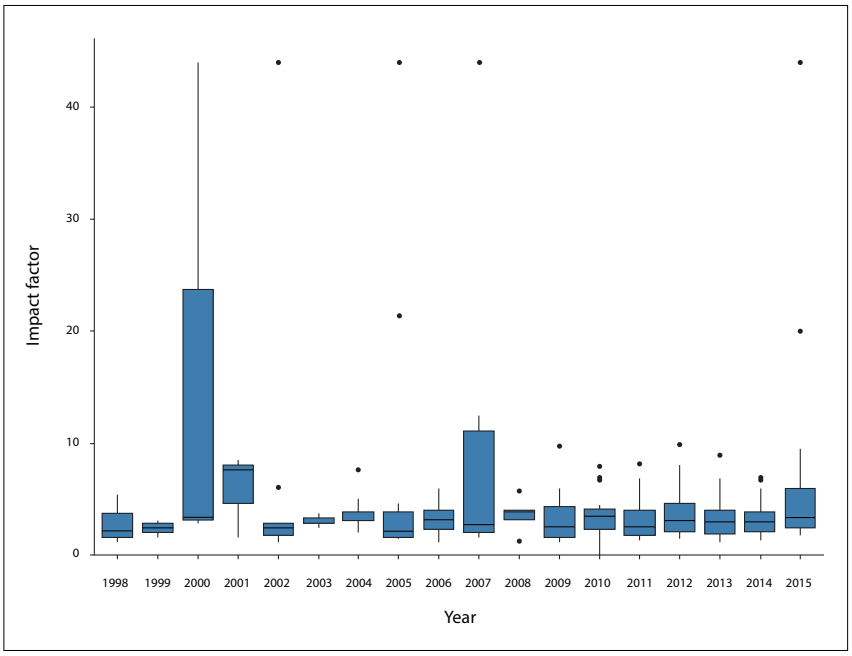

Fig. 2. Impact factors of the journals in which the retrieved articles were published, by year of publication from 1998 to 2015. The five anomalies are five articles published in The Lancet *(2016 impact factor 44.002).*

The 230 retrieved articles included in the study were published in 130 different journal titles. The journal with the most retrieved articles was *Environmental Research* (*n*=10), followed by *NeuroToxicology* (*n*=9), *Environment International* (*n*=7), *The Lancet* (*n*=6) and *Science of the Total Environment* (*n*=6). The Thomson Reuters 2016 impact factors of the journals ranged from 1.06 (*Journal of Occupational and Environmental Hygiene*) to 44.00 (*The Lancet*) (Fig. 2). The majority (*n*=185, 80.4%) of the journals had an impact factor of <4 and only 9 had impact factors of >10.

For the retrieved articles where funding was explicitly mentioned (*n*=148), the three most frequently mentioned agencies were the National Research Foundation in SA (*n*=17), the SAMRC (*n*=13) and the Water Research Commission (*n*=9).

Fig. 3 provides a description of the impact factors of the 230 articles by nationality. There was a smaller number of non-SA first authors (*n*=67) compared with SA first authors (*n*=163). However, the articles published by non-SA first authors were generally published in journals with higher impact factors.

Table 3. Number of retrieved articles according to country of first author affiliation between 1998 and 2015

Country	Frequency, *n* (%)
Australia	4 (1.7)
Bulgaria	1 (0.4)
Canada	3 (1.3)
China	2 (0.8)
Denmark	1 (0.4)
Egypt	1 (0.4)
France	2 (0.8)
Jamaica	1 (0.4)
Japan	1 (0.4)
Netherlands	2 (0.8)
Norway	2 (0.8)
Portugal	1 (0.4)
South Africa	160 (69.5)
Sweden	2 (0.8)
Switzerland	5 (2.1)
Tanzania	1 (0.4)
UK	15 (6.5)
USA	25 (10.8)
Zimbabwe	1 (0.4)
Total	230 (100)

Number of retrieved articles by environmental health subcategories

The review and analysis of the retrieved articles were based on the subcategories for environmental health as defined in the Scope of Practice for Environmental Health Practitioners[10] practising in SA. Fig. 4 is a count of the total number of publications in each of the 20 categories. Table 2 (right-hand column) shows that the largest number of retrieved journal articles was in the area of environmental pollution control (*n*=76, 33.0%), followed by the newly defined subcategory of lifestyle and behaviour-related topics (*n*=42, 18.2%), and then water monitoring (*n*=26, 11.3%). There was no trend in the pattern of article frequency within these (or any of the other) environmental health subcategories by year, except perhaps for a slight step change between 2009 and 2010 for articles retrieved and categorised in the lifestyle and behaviour category. Environmental pollution control (category 7) and lifestyle/behaviour (category 15) had the highest number of publications for the period 1998 - 2010 (Fig. 5).

Statistical analysis

Linear regression was run to assess the relationship between time (1998 - 2015) and the number of publications over that period. There was a strong positive correlation that

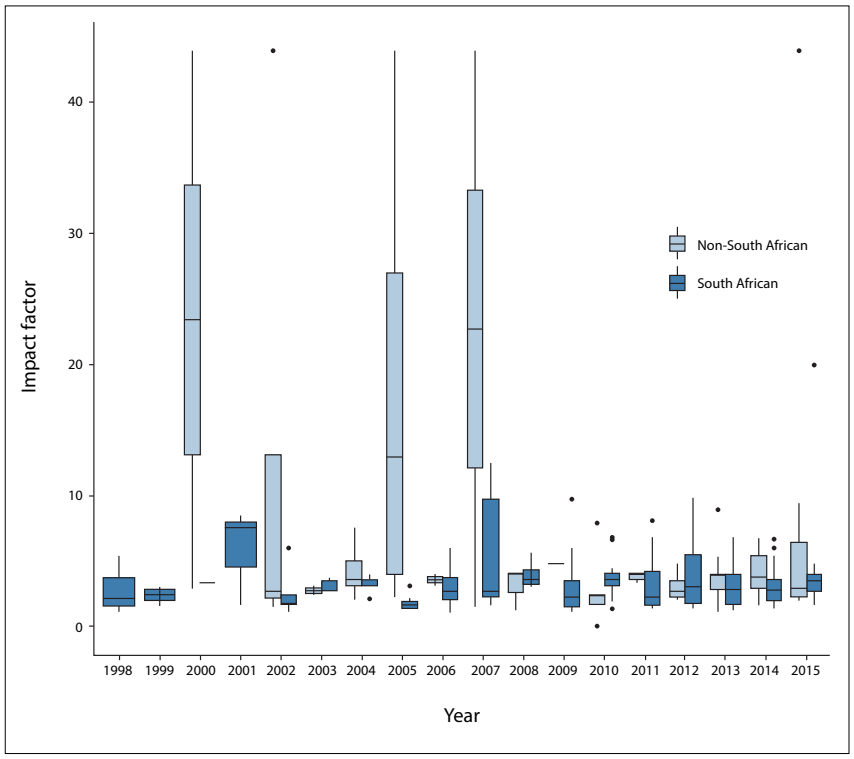

Fig. 3. Number of retrieved articles for the top four most frequently occurring environmental health categories by year from 1998 to 2015.

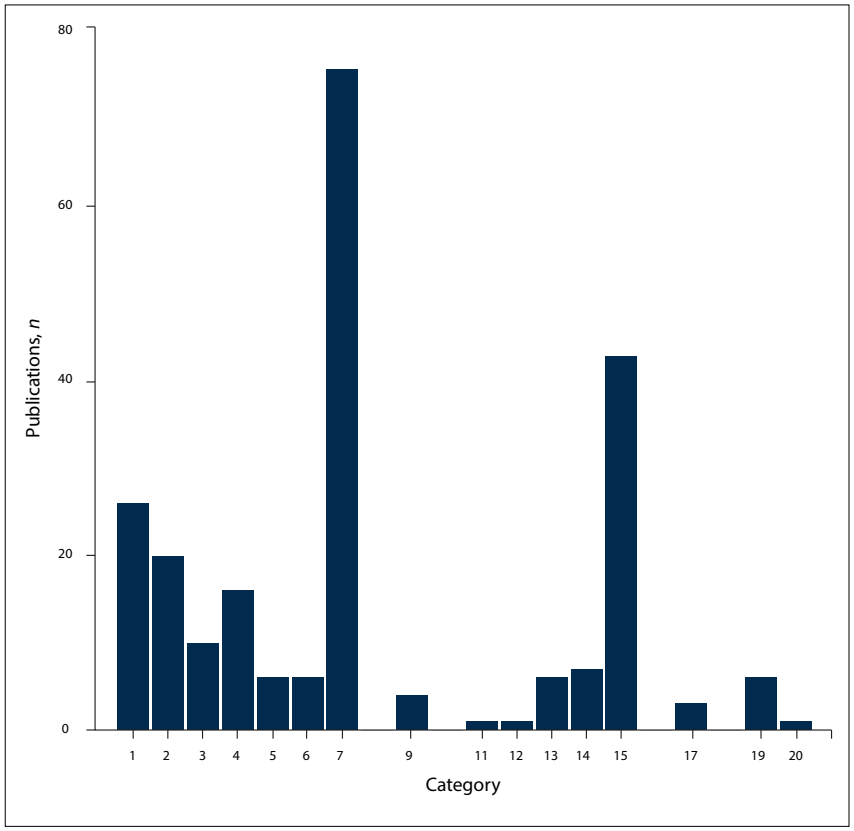

Fig. 4. Number of total publications per category from 1998 to 2015. There were no articles in categories 8, 10, 16 and 18.

was statistically significant (r^2 = 0.8319; p<0.001) between time and number of publications. A similar result was found when linear regression was run to access the relationship between time and impact factors; although r^2 was lower (0.5284), p was still <0.001, showing a statistically significant association (Table 4).

Discussion

This bibliometric exercise aimed to identify published research articles on SA-related environmental health issues and to identify research gaps and opportunities for future research. We set out to determine which environmental health themes are most often published, in which institutions the work is being carried out and by whom, and the suite of journals in which environmental health science related to SA is being published. Our goal was to identify the research gaps in the light of the current environmental health challenges facing SA and to highlight opportunities for future research, especially through the use of existing and big data that we hope will help environmental health surveillance and disease tracking. However, as we progressed through the interpretation of the study findings, it became clear that a number of important, non-research-related issues that pertained to aligning accessibility of science to the profession of the science were as important.

From the retrieved studies in our dataset, the annual number of environmental health/SA-related articles has increased over the past 18 years. Several factors may have contributed to this increasing trend. For example, availability of research funding to support environmental health projects may have increased, and there may have been more postgraduate students at local universities completing projects and publishing their findings. Interestingly, despite the pressing concern of climate change effects on human health, and the key role of environmental health in this research domain, only two studies were retrieved that considered long-term climatic impacts on environmental health. The absolute number of articles retrieved and that met our inclusion criteria seemed low (n=230) for an 18-year period. We compared our findings with a similar 10-year European bibliometric study[11] in which 6 329 articles were included and found that their total represented articles published by 29 countries, so when this figure is averaged by number of countries, on average each country produced 218 articles over 10 years, which is comparable to our findings (despite the European study using a set of MeSH terms including 'environmental health', 'environmental exposure', 'environmental illness' or 'environmental epidemiology').

Table 4. The relationship between time (1998 - 2015) and the number and impact factor of retrieved articles over that period and included in this assessment

	Time (1998 - 2015)	
	p-value	*F*-statistic
Number of publications	<0.001	79.19
Impact factor	<0.001	17.92

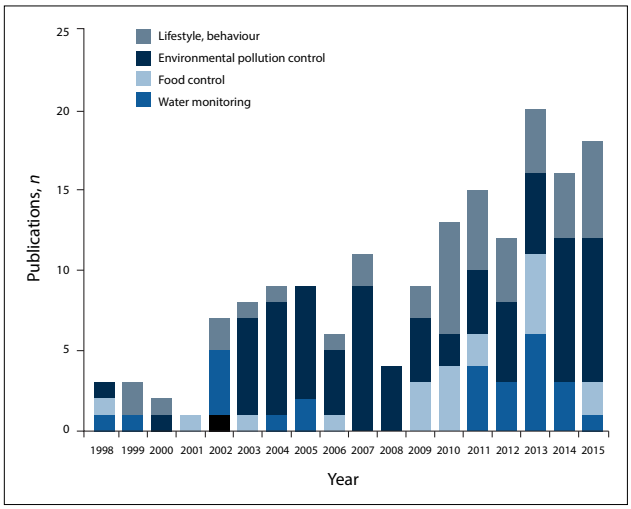

Fig. 5. Number of retrieved articles for the top three most frequently occurring environmental health categories by year from 1998 to 2015.

In our study, we used the MeSH exact thesaurus term match of 'environmental health'. There are nine phrase matches, and the MeSH tree for environmental health includes three terms, namely 'health physics', 'sanitation engineering' and 'sanitation'. Furthermore, the MeSH terms for 'environment and public health' closely follow the subtopics of environmental health, such as food inspection and environmental pollution, compared with those for environmental health. This poses a dilemma for researchers and others searching for the latest published environmental health topics, since the net of words one needs to apply in the search is large and complex. In bibliometric study of public health research in Africa, <5% of authors added the phrase 'public health' to the author keywords list, even though the subject or subcategory subject fell into public health.[3] Frequently authors referred to a specific disease in the keywords.

More than two-thirds of the retrieved articles were led by an author affiliated to an SA institution, with the University of Cape Town the most prolific. Similarly, the University of Cape Town was also the most prolific institution in Africa in terms of collaborating on article publication with other African countries between 2007 and 2011.[11] The majority of retrieved articles were published in international journals with an impact factor of <4 (and ~45% had impact factors of <2). While the impact factor is only one publication metric expressing the impact of research (other metrics exist, but in the present SA academic climate the impact factor holds as much weight as Department of Higher Education accreditation with regard to subsidy for article publication), these low figures do pose the question whether SA environmental health science is visible and accessible nationally and internationally. If this is not currently the case, researchers should consider ways in which to make it so, to ensure that local research can also have an influence in other low- and middle-income countries where environmental health issues are paramount.

Categorisation of the retrieved articles into environmental health subcategories research revealed that one-third of articles were related to environmental pollution and its control. Environmental pollution, i.e. water, air and soil pollution, is a challenging environmental health problem, particularly in countries with high levels of inequality and poverty such as SA. Relatively small numbers of articles were retrieved in the other subcategories, but this does not necessarily mean that they are under-researched. They may be, but it is more likely that they are indexed using different keywords, such as meat science for 'food control', and therefore do not appear in a search for environmental health. The example for occupational health was that one study with environmental and occupational health focus was included in our dataset. Occupational health is not a true subcategory of environmental health; it is its own field. In several studies where occupational health issues are concerned with environmental parameters, such as air pollution in an open-cast mine, environmental health concerns exist, but they fall under the jurisdiction of the mine safety, environment and health officer, and not the environmental health practitioner (EHP), who is tasked with community environmental health services. Nevertheless, the research may be relevant to the EHP and it would therefore be helpful if such articles were accessible when searching for pollution control as a subcategory of environmental health. Noise pollution, although a part of environmental health, did not appear in our dataset of retrieved studies, probably owing to lack of the words 'environmental health'. Such studies do exist for SA, such as a study that considered the environmental footprint of aircraft noise exposure at Cape Town International Airport.[12] Of all the environmental health subcategories, it seems that 'disposal of the dead' is possibly the least researched topic.

Study limitations

Our searches were made in three indices, which may not include several local SA journals that also publish articles on environmental health and its subcategories for SA sites. These articles would not have been included here.

An important limitation is that the use of the keyword 'environmental health' is likely not to include all articles related to environmental health. For example, if studies used 'prevention', 'intervention' or a specific disease name such as schistosomiasis, without mentioning 'environmental health' anywhere in the title, abstract or author keywords, the article would not have been retrieved. Studies on malaria control or noise pollution, which are highly relevant to environmental health, are unlikely to be indexed as such. Either all environmental health-related articles should be indexed with 'environmental health', or when someone searches for environmental health topics, the search should be targeted to a subcategory topic of environmental health without that term. If this bibliometric review for SA were to be repeated, it is recommended that all environmental health MeSH terms should be explored.

A local limitation may also relate to a change in government terminology from 'municipal health services' to 'environmental health services' in the 2000s. This could have affected the search return for articles published in the 1990s, when 'municipal health services' may have been used. Future research may also consider using the Social Science Citation Index, since environmental health perceptions and psychologies may be described in studies published by the social sciences in addition to the natural and health sciences.

Conclusions

Environmental health research in SA and beyond spans a range of complex subjects and fields. With the emphasis on multi- and interdisciplinary research to solve multifaceted problems, it is paramount that the research be retrievable and visible. This

bibliometric review highlights the importance of standardised keywords across the environmental health research sector. The steady growth in research output, particularly in the past 3 years, is promising. The most frequently published field from our findings was environmental pollution control, which remains high on the SA policy agenda. As evident by first author publishers, the interest of the USA and UK in SA environmental health issues should be encouraged further through research collaboration. However, this study also highlights environmental health research collaborations that need to be nurtured.

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Conflicts of interest. None.

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Appendix 1. Articles included in this review

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