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Environmental health research in Europe – bibliometric analysis

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Background: This article describes a bibliometric review of the environmental health research literature in Europe for a period of 10 years. The work, within the study *SPHERE* (Strengthening Public Health Research in Europe) aimed to provide an overview of the extent of published environmental health research in Europe and to assess recent output in this research field and future research direction. **Methods**: Medline was used via the PubMed online service of the US National Library of Medicine. Only original, peer-reviewed research journal articles were retrieved, which were published from mid-1995 to mid-2005 and by authors from the 28 (then) countries in Europe of the European Economic Area plus Switzerland. **Results**: In the PubMed database, 6329 references were located and were allocated to 11 pre-defined topic areas and 31 subtopic areas. The largest number of articles was in the topic area of work environment and health (2339) followed by environmental exposures (1314) and environmental illnesses (952) and these were the primary foci of 73% of the published articles. There were marked differences between countries in the number of published articles. Ten countries contributed 81% of all publications. It is apparent that economic factors have a major role for research outputs of countries in environmental health. **Conclusions**: Major advances have been made during recent years in the understanding of associations between health and environment, and of biological, environmental and social mechanisms involved in this association. More emphasis should be placed on investigations of complex environmental health problems such as complex exposures to different pollutants at different levels and their combined health impact in different populations.

Keywords: bibliometric analysis, environmental health, environmental health research, European Economic Area

This article describes a bibliometric analysis of environmental health research in Europe during 10 years between July 1995 and June 2005, undertaken as part of the public health literature review element of *SPHERE* (Strengthening Public Health research in Europe) project funded by the European Community Directorate General Research FP6 programme. The study was performed with the aim of providing an overview of the extent of published environmental health research in Europe, assessing recent output in this research field and future research directions. The results should also contribute to the overall objective of *SPHERE* to provide advice on the future development of public health research both to the EU and to individual European countries.

Public health research is based on an interdisciplinary approach to the identification and assessment of multiple health determinants and health hazards. The environment in which people live is one of these determinants which not only provides necessary life resources, but which also is a source of multiple health hazards. According to a recent report by the WHO,[1] nearly one quarter of all deaths and of the total disease burden globally can be attributed to the environment. In addition, environmental risk factors play a role in more than 80% of the burden of disease measured by the WHO.

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Methods

Study definitions

The study was based on two definitions. An overarching definition of public health research was established for *SPHERE*[2]:

> Public health research is undertaken at population level, in contrast to laboratory (cellular) or clinical (individual) health research. It addresses questions of policy relevance and may be published either in academic journals or as reports. Public health research uses a range of observational and comparative methods, including surveys, registers, analysis of routinely available data sets, case studies and statistical modelling and draws on disciplines including epidemiology, sociology, psychology and economics and interdisciplinary fields of environmental health, health promotion, disease prevention, health management, health services research and health systems research.

Secondly, the WHO definition of environmental health was applied:

> Environmental health comprises 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.[3]

Literature search and retrieval

The Medline bibliographic database was selected as the most suitable source of references to environmental health scientific, peer-reviewed publications. Medline was accessed using the PubMed online service of the US National Library of Medicine. Reference Manager Programme, version 11, was used as an online tool for searching the bibliographic database and retrieving literature references.

Table 1 Environmental health references search strategy

Connector	Field	Parameter
	Mesh Terms	[environmental health] OR [environmental exposure] OR [environmental illness] OR [environmental epidemiology]
AND	Publication date	July 1995: 30 June 2005
AND	Affiliation	[Austria] OR [Belgium] OR [Cyprus] OR [Czech Republic] OR [Denmark] OR [Estonia] OR [Finland] OR [France] OR [Germany] OR [Greece] OR [Hungary] OR [Ireland] OR [Italy] OR [Latvia] OR [Lithuania] OR [Luxembourg] OR [Malta] OR [Netherlands] OR [Poland] OR [Portugal] OR [Slovakia] OR [Slovenia] OR [Spain] OR [Sweden] OR [United Kingdom] OR [Norway] OR [Iceland] OR [Liechtenstein] OR [Switzerland]
AND	Publication type	Journal article
NOT	Publication type	Review
AND	All fields	Humans

Table 2 Display of the contents of the list of environmental health references (**'*SPHERE* database'**)

Header/ Current Labels	Ref. ID	Authors	Address	Title	A	B	C	D	E	F	G	H	I	J	K
Field type					Env. pollution	Env. health hazard	Env. exposures	Env. illnesses	Urban health	Rural health	Work env. health	Vulnarable. groups	Env. health risk assessment	Env. Health risk management	Env. health policy

Inclusion and exclusion criteria

Only original, peer-reviewed research journal articles, falling within the environmental health and public health research definitions, were retrieved. Retrieval was further limited to articles published during the period from July 1995 to June 2005 by authors from countries belonging to the European Economic Area (EEA).

Exclusion criteria included review articles, letters to editors, clinical case reports, animal and *in vitro* experimental studies, personal communications, conference abstracts. Articles published outside the established coverage time and outside the EEA were also excluded.

Search strategy

An initial stage identified the most suitable and effective search strategy by adjusting specific search criteria (fields, parameters and connectors). The final search strategy is presented in table 1. This search strategy was used to locate and retrieve references to environmental health publications falling within the strategy criteria and to set up a preliminary list of environmental health research references. Eleven main environmental health topics, each with several sub-topics, were identified. Each reference from the preliminary list was matched with a relevant main topic and sub-topic. Constructed in this way, the new list of environmental health research references was used as a '*SPHERE* database' for the objectives of this study. The contents of the *SPHERE* database are presented in table 2.

Results

Bibliometric analysis

In the Medline database, 6670 references were located and retrieved to the preliminary 'Reference Manager database'.

Subsequent review identified 343 references that did not meet inclusion criteria and which were removed, leaving a total of 6329 references.

Figure 1 shows the total and cumulative numbers of environmental health articles published during the 10-year study period and demonstrates an increase in publication outputs after the year 2000. These articles were published in 711 scientific journals.

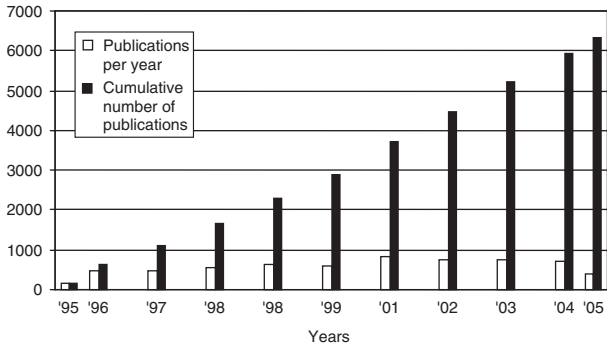

Figure 1 Annual publications rate during 1995–2005 (1 July 1995–30 June 2005)

Main environmental health research fields

The review and analysis of retrieved articles were based on the environmental health risk assessment and risk management paradigm, which includes basic elements such as identification of environmental health hazards, dose–response relationships, exposure assessment, health risk characterization and health risk management. This paradigm also takes into consideration specific environments and populations, specific exposure conditions and relevant health outcomes.

Table 3 shows that the largest number of retrieved journal articles was in the area of work environment and health (2339 articles) followed by environmental exposures (1314) and environmental illnesses (952). These three main topics were the primary focus of research in 73% of published articles. Research on the public health aspects of environmental pollution was presented in 7.8% publications. Less research effort was directed to topics such as vulnerable populations (4.7%), environmental health hazards (4.0%), environmental health risk management and risk assessment (3.5 and 3.1%, respectively). The least well represented in the review were rural environmental health (1.8%), urban environmental health (1.2%) and environmental health policy research (1.2%).

Table 3 Number of publications by main topic and subtopic areas

Main topics and subtopics	Number of publications	%
Environmental media pollution	485	7.8
Air (indoor, outdoor)	245	
Food	75	
Water (drinking, ground, surface)	110	
Wastes (hazardous, solid, liquid)	31	
Soil	24	
Environmental health hazards	252	4.0
Chemical	101	
Biological	67	
Physical	61	
Dust	14	
Climate	5	
Disasters	4	
Environmental exposures	1314	20.8
Assessment	967	
Monitoring	347	
Environmental illnesses (epidemiology)	952	15.0
Cardio-vascular diseases	33	
Cancer	307	
Immunology and allergy	207	
Neurological	106	
Respiratory	66	
Reproduction	52	
Birth defects and develop. diseases	48	
Organ diseases	43	
Others	91	
Urban environmental health	77	1.2
Rural environmental health	116	1.8
Work environment and health	2339	36.9
Occupational exposure	1681	
Occupational diseases	658	
Vulnerable groups	297	4.7
Children	288	
Elderly	9	
Disabled	–	
Socially deprived	–	
Environmental health risk assessment	190	3.1
Environmental health risk management	223	3.5
Risk prevention	34	
Control measures	173	
Risk communication	16	
Environmental health policy	82	1.2

Work environment and health

Within the work environment and health topic area the majority of published research (72%) focused on occupational exposures, addressing such aspects as assessment of exposure to occupational hazards, occupational exposure and related health risks, exposure–response analysis, biological monitoring for occupational exposure assessment, strategy of exposure assessment for specific exposure conditions and in epidemiological studies.

Research on occupational diseases concentrated mainly on occupational cancer and its aetiology and related risk assessment. Other areas of research were allergic diseases and neurological disorders.

Environmental exposures

Assessment of environmental exposure is a crucial element of environmental health risk assessment and essential tool in environmental epidemiology research. The focus of the studies reviewed in this topic area was on investigation of potential causal links between environmental exposures and health outcomes. Studies related to exposure monitoring concentrated on the assessment of levels of population exposures with a strong emphasis on the application of biological monitoring. Attempts were pursued to improve specificity and accuracy of exposure assessment. Much progress was made in modelling and assessment of the spatial distribution of environmental exposures.

Environmental pollution

Ambient outdoor and indoor air pollution was a major area of environmental pollution research (245 out of 485 references). The focus was mainly on the assessment of levels of pollution and their potential health implications. The studies concerned a variety of airborne pollutants and associated sources of emissions. The second largest area of research on this topic concerned water pollution (110 references). Most studies were focused on the assessment of contamination of ground and surface waters and identification of sources of pollution.

Food safety issue was the subject of 75 articles concentrating on identification and assessment of levels of food contamination and dietary intake. The most frequently examined groups of contaminants were heavy metals, persistent chlorinated pesticides, dioxins and polychlorobiphenyls, as well as microbiological contaminants.

A smaller number of studies was devoted to environmental pollution and the health impact of waste management (31 references). These studies dealt with various types of waste generation and disposal. Waste incineration and waste landfills were of concern.

Environmental illnesses

The literature search on environmental illnesses concentrated on locating and retrieving epidemiological studies carried out to investigate the aetiology of environmental illnesses, to establish causal relationship between environmental exposures and health outcomes and to assess health risks for populations exposed to environmental hazards from various environmental media. Under this topic, 952 references were retrieved in the *SPHERE* database.

Three groups of illnesses were the focus of research: cancer (307 references), allergic and immunology diseases (207) and neurological disorders (106 references). Most of the cancer studies were concerned with occupational exposures to chemicals, dusts (mainly asbestos) and physical hazards. Studies on environmental allergic diseases focused mainly on aetiology and risk of allergic skin diseases and respiratory allergy.

The aetiology of respiratory diseases was the subject of 66 studies, covering a variety of environmental and occupational exposures ranging from ambient and indoor air pollution, occupational exposure to chemicals and mineral and wood dusts and to infectious agents. Much evidence was produced (110 references) indicating that exposure to various organic chemicals, such as pesticides, generates risks of disorders in the process of reproduction, development of birth defects and risk of developmental diseases.

Urban and rural environmental health

Urban environmental health, was the subject of 77 identified studies pointing to various, related public health problems such as urbanization, housing and sick building syndrome, urban air pollution and sanitation.

Rural environmental health as a topic was the subject of research presented in 116 scientific articles focusing on health impact of specific agricultural occupations and related exposures. Health impact of exposure to pesticides was the most frequent focus of work in the area of rural environmental health. Particular attention was paid to exposure to pesticides among greenhouse workers and the risk of cancer and of allergic and respiratory diseases in pigs and cattle farmers.

Vulnerable groups

Children, elderly people, the chronically ill and socially deprived people face a higher risk to health when exposed to environmental hazards. Yet, although 288 retrieved articles related to research in this topic area, only nine were devoted to the health risks of environmental exposures of the elderly, and references concerning other vulnerable groups were neither located nor retrieved.

Environmental health risk assessment and management

Improvements in the methodology for environmental and occupational health risk assessment were the subject of a large number of publications out of 199 retrieved on the topic of health risk assessment. The remaining articles described studies on health risk assessment for specific exposed populations and exposure conditions. Results of health risk assessment in various studies were applied in risk management activities.

Research on health risk management was presented in 223 retrieved articles. They dealt with three main issues: prevention, control and communication. Prevention of environment and work-related diseases were the subject of intervention studies and of research aiming at preventive methodology. Established measures for air and water quality control were based on scientific criteria resulting from research described in a number of retrieved articles.

Communication of environmental health risks is an important tool in risk management. Reviewed articles examined the role of various professional groups, medical personnel in particular and training needs.

Environmental health policy

A relatively small number (82) of retrieved research papers focused on the development of environmental health policies. Papers concentrated on such issues as environmental health impact assessment, socio-economic factors of environment related exposures and diseases, legislative aspects of implementation of hygienic practices and application of the precautionary principle in the process of decision-making.

Publications by country

The review of environmental health research literature covered 29 European countries within the EEA for which 6329 references were located and retrieved. This number of publications accounted for 22% of the global publication output (28 713) during the same time and was 20% lower than that in USA. Online reference databases for each of 29 countries were developed. The number of retrieved references to the environmental health research publications during 1995–2005, by country, is presented in table 4, which demonstrates, that all except two countries produced publications on environmental health research.

There were marked differences between countries in the number of published papers. Three countries contributed 40.1% of all research papers published during the review period and 10 countries contributed 81%. These differences could only partly be explained by differences in population size. Economic factors seem to play an important role in environmental health research output as seen from differences between countries of comparable population size. Nordic countries, with their high GDP, had the highest population-adjusted publication index (number of publications per million population): Sweden: 89.4; Finland: 74.5; Denmark: 62.5; Norway: 57.0. Countries of similar population size, but with a low GDP, had the lowest population-based index of publications: Czech Republic: 9.2; Hungary: 4.1; Lithuania: 3.7; Greece: 1.3; Slovakia: 1.3; Latvia: 1.2.

Table 4 Number of environmental health publications in EEA countries

Country	Number of published papers	%	Population index*	GDP index**
Germany	979	15.4	11.9	0.51
Sweden	793	12.5	89.4	3.31
Italy	781	12.2	13.5	0.72
France	529	8.3	8.9	0.39
Netherlands	452	7.1	28.4	1.22
Finland	386	6.1	74.5	3.21
Spain	380	6.0	9.4	0.65
Denmark	334	5.2	62.5	2.11
Poland	305	4.8	8.3	1.83
United Kingdom*	303	4.7	5.1	0.21
Norway	256	4.0	57.0	1.53
Belgium	199	3.1	19.4	0.87
Switzerland	151	2.3	21.0	0.61
Greece	110	1.7	1.3	0.98
Czech Republic	95	1.5	9.2	0.87
Austria	94	1.4	11.7	0.48
Republic of Ireland	43	0.7	11.2	0.45
Hungary	42	0.7	4.1	0.90
Portugal	40	0.6	3.9	0.37
Slovenia	28	0.4	14.1	1.47
Estonia	17	0.3	12.4	3.10
Lithuania	13	0.2	3.7	1.15
Iceland	7	0.1	24.9	0.83
Slovakia	7	0.1	1.3	0.35
Latvia	4	0.06	1.2	0.52
Luxembourg	3	0.04	7.6	0.15
Malta	3	0.04	7.7	0.79
Cyprus	–	–	–	–
Liechtenstein	–	–	–	–

*number of publications per million of population
**number of publications per 1 billion US dollars of GDP

There were no significant differences between countries in the distribution of publications amongst the main topics of the environmental health research. The work environment and health topic achieved the largest publication output in all countries, amounting to between 27% and 47% of all publications. Four countries had the highest number of publications in specific research topics: Germany in environmental pollution, environmental health hazards, environmental exposures, vulnerable populations and environmental health risks; Sweden in environmental illnesses, urban environmental health, vulnerable groups and environmental health policy; Italy in work environment and health; and Netherlands in rural environment and health.

New areas of research in environmental health

Environmental health genomics

Progress in genomic research, observed during the last decade, resulted in a more comprehensive insight into the interaction between genes and environment. The discovery of variation in genes relevant to biological responses at the cellular level helps to enhance understanding of the development of diseases with environmental aetiology, inter-individual susceptibility to environmental exposures and associated health effects.[4]

A separate search in the '*SPHERE* environmental health database' set up for this project located 127 references to research on various aspects of environmental health genomics. The majority of the retrieved papers were published during the last few years. Research on this topic area has so far been undertaken only in 16 countries.

Environmental burden of diseases

Environmental health effects are a significant part of the total disease burden; according to the WHO[1] ~25–33% of this burden in developed countries can be attributed to environmental factors. Analysis of the environmental burden of disease is measured in terms of mortality and Disability Adjusted Life Years (DALYs)—a weighted measure of death, illness and disability.[5] Such estimates contribute to a better understanding of interactions between environment and health. They reflect how much death, illness and disability could be avoided due to reduction in exposures to environmental hazards. So far, very few such studies have been conducted.[6]

Health and environment information systems for exposure and disease mapping and risk assessment

Assessment of health risks associated with exposure to environmental health hazards is essential to protect people against the harmful impact of such exposures. Exposures to hazardous pollutants are usually unevenly distributed spatially and temporally. Disease occurrence also varies geographically. Geographic information systems (GIS) are used to produce maps of exposure and spatial distributions of diseases. Mapping of exposures facilitates assessment of population exposure and, together with disease mapping, helps to assess spatial distribution of risks to the health of the exposed population. GIS is also a valuable tool to explore changes in disease patterns potentially associated with changes in environmental exposures. Application of GIS to research on environmental health is a relatively recent development. A search of the '*SPHERE* environmental health database' created for this project located 13 references to studies conducted in 10 countries during 2000–05.

Discussion

After examining several online databases, PubMed was found to be the most suitable database for searching and retrieving references on environmental health research. In order to accomplish effective retrieval of references, an adequate search strategy had to be adopted. Environmental health is a multidisciplinary science and therefore a comprehensive search of the literature cannot be based on only one basic search term such as 'environmental health'. Several other basic Mesh Terms had to be used in addition to other parameters. These were 'environmental health' or 'environmental exposure' or 'environmental illnesses' or 'environmental epidemiology'. Using such a search strategy, 6329 original scientific papers in the field of environmental health research were identified and retrieved in the specially designed '*SPHERE* database'.

Environmental health research is an important area of science within the public health domain, with publications from a relatively large number of research units in all except two EEA countries. Although 6329 references were retrieved, this number of publications accounts for not more than 22% of the global output during the same time.

There were marked differences between countries in their environmental health research publications. Eight countries jointly contributed 81% of all the publications from EEA countries during 1995–2005. Economic factors seem to play a role in this differential publication outcome between countries. Scandinavian countries, with their high GDP, demonstrate a much higher population-based index of publications than countries with a similar population but lower GDP.

There were no significant differences between countries with regard to the main research focus. The greatest research effort in all countries was directed to the area of work environment and health. Scientific publications on occupational health in countries such as Poland and Norway accounted for 45 and 47%, respectively, of all the environmental health research outputs. Much less attention was given to issues such as urban and rural health (only 77 and 116 references, respectively), and environmental health policy (82 references). In the area of environmental illness, the main research focus was on cancer and on allergic and immunology diseases, followed by cardiovascular and respiratory diseases.

A number of disciplines contribute to environmental health impact assessment including various branches of bio-medical and environmental sciences. Major advances have been made in all of these areas during recent years. These have contributed to progress in the understanding of the association between health and the environment and of the biological, environmental and social mechanisms involved in this association. They also contributed to strengthening the concepts of evidence-based public health policy with regard to prevention of environmental health risks. Basic studies investigating individual environmental health hazards and causal associations between environmental exposures and health outcomes are still needed, but this overview suggests that there should be more emphasis on investigations of complex public health related problems such as exposures to different pollutants at different levels of pollution, durations and frequencies and their combined influence on health in different populations. Public health policy increasingly needs to be based on concepts of multi-causality and complexity.

Scientific data and knowledge are spread through different networks and databases. Clearly, a large number of research teams have been involved in environmental health research, the results of which have been published in a large number (711) of scientific journals. More collaborative research is needed in order to link these areas of data and knowledge in a more effective way and for a better use in planning future environmental health research.

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