World Health Organization

REGIONAL OFFICE FOR **Europe**

Setting research priorities in environment and health

Report of a meeting in Cascais, Portugal 27–28 April 2017

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ABSTRACT

Research in environment and health (EH) is of crucial strategic importance for contemporary society. This is becoming even more critical in light of the increasingly fast pace of environmental changes, opportunities and threats. It is essential to set the EH research agenda around key priorities, especially in consideration of diminishing public budgets in some areas; a focus on technological innovation and job creation; and the increasingly prominent role of the private sector. More clarity is needed, given the rapidly evolving global sustainability agenda, the ever-increasing sources of complexity and growing expectations of the public. This requires the identification of criteria to identify EH research priorities, with the ultimate goal of maximizing societal benefits. Often used implicitly, these criteria include: public health relevance (e.g. extent and severity of health impact, level of exposure, inequalities of effects); policy potential (e.g. availability of remedial action, feasibility); and innovation (i.e. production of new knowledge vs refinement of existing knowledge). Once fully developed, these criteria will facilitate an open consensus-based process of priority setting in EH research.

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Acknowledgements

Abbreviations

CAS	Chemical Abstract Service
EC	European Commission
EEA	European Environment Agency
EH	environment and health
HBM4EU	European Human Biomonitoring Initiative
IARC	International Agency for Research on Cancer
IPCHeM	Information Platform for Chemical Monitoring
JRC	Joint Research Centre
LDA	latent Dirichlet allocation
NGO	nongovernmental organization
SDG	sustainable development goal

Introduction

Research in environment and health (EH) is of crucial strategic importance for contemporary society. This is becoming even more critical in light of the increasingly fast pace of environmental changes, opportunities and threats. Research is also an essential ingredient for enabling WHO to fulfil its mandate on EH matters, as part of a commitment to strengthening the use of evidence, information and research for policy-making in WHO European Region *(1)*.

EH research involves the deployment of substantial human and financial resources, although these often appear to be insufficient. The overall agenda should be set through consultation between the expert community and multiple stakeholders to reflect a variety of viewpoints, interests and values. Potential difficulties, distortions and conflicts of interest arise from diminishing public budgets in some areas, the focus on innovation and job creation, and the increasingly prominent role of the private and third sectors in EH research. This raises the need to define adequate models for articulating private–public research, together with criteria for support to funding decisions, optimizing the possibility of joint ventures for societal and EH improvement.

The consultation approach has resulted in good progress but greater clarity and focus is needed, given the rapidly evolving global sustainability agenda, ever-increasing sources of complexity and growing expectations of the public. All of these add to the need to identify research priorities that can maximize societal benefits. Many questions remain as to whether and how current mechanisms for setting strategic and operational priorities ensure effective, equitable and sustainable allocation of efforts and resources in EH research, and whether they result in the greatest possible value.

The EH research community is highly specialized. Multiple research teams generate much knowledge on a variety of relevant issues, although often on very specific topics. It is not always easy to reconcile this rich and detailed information with the overall picture of the real needs and urgent priorities in EH.

Scope and purpose of the meeting

WHO Regional Office for Europe has undertaken a project to identify EH research needs and priorities, and the means to characterize them, in the light of evolving understanding of the complex nature of connections and interactions. This meeting was a key milestone of the project, with the aim to develop a conceptual framework and set of criteria and resources for screening, classifying and assessing EH research and its value in supporting evidence-informed policy response at local, national and supranational levels.

Specific objectives of the meeting included: (i) review and discussion of different approaches to establishing EH research priorities and agendas in different international and national organizations; and (ii) discussion of a draft proposal, developed by WHO, of criteria for setting priorities. By convening experts from the EH research community and involving relevant stakeholders, including funding agencies and national government agencies, the meeting aimed to seek a consensus-based view on these criteria.

The output of this meeting will be used in subsequent stages of the project as a basis for further negotiations and deliberations around a proposed EH research agenda in coming years. This meeting report will also be made available for the upcoming Sixth Ministerial Conference on Environment and Health, scheduled for 13–15 June 2017 in Ostrava, Czech Republic.

Setting the scene

Through evidence-informed guidance and recommendations, much of WHO's work is intended for supporting EH and other policies in its Member States. In developing policy advice, international guidelines, methods and tools to inform and support decision-making, WHO activities contribute to the development of healthy environments, well-being and strengthened community resilience to environmental impacts on health.

The policy needs are mostly location specific as are, in part, the research priorities, which may also differ from local to national and supranational level. There is marked heterogeneity across WHO European Region – not only in the environmental causes of disease but also in the potential for prevention and health promotion – with a frequent need to tailor research on global issues to the local context.

Political and economic agendas also often play important roles, which can be particularly challenging in some circumstances. With the broad range of EH challenges facing the European Region, there is a widely recognized need to develop methods and tools for priority setting to support funding and other decisions, and a more systematic approach appears desirable at this point.

The WHO European Centre for Environment and Health works as the interface between science and policy for the Member States with the aim of supporting and translating state-of-the-art science into policy advice. The region wide Health 2020 policy framework was adopted as a basis for improving health and reducing inequalities throughout the continent. More recently, WHO's work has also been driven by the 2030 Agenda for Sustainable Development and pursuit of its sustainable development goals (SDGs) across the European region. This is no small challenge as the SDGs cannot be addressed in isolation. They need a multisectoral approach that includes the research institutions, policy-makers and stakeholders (including citizens and their organizations) that may be directly affected. Further, research is becoming more complex with a recent shift toward a more holistic approach to EH, with a focus on distal health determinants (i.e. those further back in the causal chain and acting via one or more intermediary causes *(2)*) and integrated assessment, life course epidemiology , and with a larger planetary ecosystems-based perspective. A systematic approach for setting and maintaining up-to-date relevant priorities in EH research will be invaluable as we enter the Anthropocene.

Current approaches and needs

Building on the past while looking ahead

Adopted by the EU in 2004 *(3)*, the European Environment and Health Action Plan (2004–2010) is an important reference in this domain. Built on 13 action points, it aimed to reduce the disease burden caused by environmental factors through identifying and preventing new health threats

on the basis of available scientific evidence. The Action Plan contributed to formulating the following goals which have been pursued in European EH research and policy.

- Improve the information chain by developing integrated EH information repositories to shed light on the links between sources, pollutants and health effects (Actions 1–4). To this end, specific outputs include the publicly available Information Platform for Chemical Monitoring (IPCHeM) online repository, with over 23 million human biomonitoring and environmental measurement data records (https://ipchem.jrc.ec. europa.eu), and funding of the European Human Biomonitoring Initiative (HBM4EU). Further, several EH publications have been produced jointly by the European Environment Agency (EEA) and the EC's Joint Research Centre (JRC) *(4,5)*.
- Fill the knowledge gap by strengthening EH research and identifying emerging issues (Actions 5–8). Results from a 2017 review of EH support through the EU framework programmes highlights the recent trends and total investment of about €228 million. Table 1 presents the breakdown by research area and by health end-points *(6)*.
- Rigorously address the policy response component: review policies and improve communication by developing awareness raising, risk communication, training and education activities (Actions 9–13).

Table 1. European Commission funding for EH research

Research area	Allocation (%)
Nanomaterials safety and risks	19%
Chemical exposures and risks	18%
Environmental/lifestyle determinants and risk factors of health and disease/ageing	19%
Climate change	11%
Pollution/contamination monitoring and mitigation	10%
Environmental/public health policies and interventions, health impact assessment, foresight	9%
Ionizing radiation risks	8%
Air pollution risks	6%
Health end-points/outcomes	**Number of projects**
Toxicological end-points	20
Effects on brain	16
Respiratory effects/lung function	8
Well-being/quality of life	8
Asthma and allergy, immune effects	8
Cardiometabolic outcomes	8
Cancer	4
Healthy ageing	4

Source: adapted from Karjalainen et al. *(6)*.

Aside from these data (Table 1), few data are available to evaluate trends in EH research and most examples are limited to specific fields rather than EH as a whole. Approaches to evaluate trends have included network analysis *(7)*; citation analysis (i.e. scanning databases such as Scopus and PubMed); and latent Dirichlet allocation (LDA), a statistical model to uncover main themes for multinomial document-word observations. Using Chemical Abstract Service (CAS) numbers as reference, progress in coverage of specific substances in EH research has also been assessed. Prioritization techniques *(8)* such as Delphi panels or existing checklists (e.g. the previous checklist from WHO *(9)*, see Table 2) have been used to summarize proposed priorities. Beyond this trend analysis, foresight exercises have been used in some countries to discuss research programming and long-term needs *(10)*.

Table 2. Checklist for health research priority setting

1. Context	What resources are available for the exercise?
	What is the focus of the exercise?
	What are the underlying values and principles?
	What are the health, research and political environments?
2. Use of a comprehensive approach	Is it more appropriate to use a comprehensive approach or to develop own methods?
	Are different areas of expertise represented?
	Is gender balanced?
	Have important health sectors and other constituencies been included?
3. Information gathering	Choosing which information should be gathered (reviews, technical data, assessment of broader stakeholder views, reviews or impact analyses of previous priority setting exercises).
4. Planning for implementation	Establishing plans for translation of the priorities.
	Who will implement the research priorities?
	How will priorities be implemented?
Deciding on priorities	
5. Criteria	Selecting relevant criteria to focus discussion around setting priorities.
6. Methods for deciding on priorities	Choosing a method (consensus-based approach, metrics-based approach or combination).
After priorities have been set	
7. Evaluation	Deciding when and how evaluation of the established priorities will take place.
8. Transparency	Writing a report

Source: adapted from Viergever et al. *(9)*.

Heterogeneity of EH research

It is important to recognize that EH research is a heterogeneous entity. Many of the various types of research and study designs used in EH and public health research were mentioned explicitly or referred to implicitly and discussed during the meeting. For example, research may refer to:

- aetiological studies – focusing on elucidating environmental causes of disease;
- exposure assessment and exposure-related science;
- development of methods and tools for EH investigations;
- exploratory or hypothesis-generating studies – taking advantage of existing data to put forward novel suggestions on the environment's role in human health;
- descriptive studies – documenting occurrence, risk and distribution of disease and known health hazards;
- intervention research – studies to analyse the effectiveness of policy responses or formal randomized trials;
- opportunistic research – following specific large-scale events, so-called natural experiments; and
- different types of health impact assessment – a very broad family of EH research ranging from risk assessment to extended participatory prospective projects.

The merits and pitfalls of different types of research are dependent on circumstances. Some of these exercises can be regarded as pertaining more to monitoring, rather than generation of original knowledge, but it is difficult to classify work into mutually exclusive categories, let alone define what is and is not EH research.

The situation in WHO Member States outside the European Union is showing even more diversified, less streamlined approaches, so it is hard to analyse the state of the art in environment and health research in a coherent way.

Mainstream vs. high-risk research

A distinction between mainstream and so-called high-risk research refers to a certain inertia in EH research in which existing evidence tends to be replicated and refined, possibly at the expense of investigations that address newly formulated hypotheses. Both types of research are legitimate but some imbalance is frequently observed. For example, important EH research aimed at improving public health (including disease prevention and well-being promotion) is currently not strongly supported by available funding streams. This may reflect what is known as a silo culture – a recognized hurdle to innovative and cost-effective research with, for example, more resources typically directed to health care than to primary prevention and health promotion.

At the other end of the spectrum, more attention and more funding may also be desirable to support high-risk research. Such investigations explore novel grounds and address original innovative issues and are therefore less likely to succeed than established mainstream research. However, they have the potential to create invaluable new evidence and fill blank spots in general EH knowledge. Orienting research toward new priorities to improve public health takes time and may require specific actions (e.g. meetings and higher level funding to compensate entry costs). Emphasis is also placed on the need to orientate research toward informing policy - making and interventions more directly, though with the recognition that research funding and political cycles rarely align (e.g. 7–10 years to get full impact of a decided research action versus 3–4 year political terms).

"More research is needed"– or is it?

Many published studies indicate a need for further research but informative studies often require large investments or take a long time. There is often some level of burden on the study participants – when a community is faced with an urgent public health problem it can be undesirable, and even counterproductive, to wait for study results especially when available scientific evidence implies that there is an impact on human health. Extended epidemiological studies may shift the focus away from the community at risk or increase expectations, and uncertainty in the results can lead to controversy, potentially disrupting any necessary action and delaying it, which is unethical.

Decisions are often needed when only partial knowledge is available – arguably this is invariably the case in EH. When faced with an urgent decision, a sensible first step is thus to look to existing knowledge (e.g. in a comparable population or study area) to evaluate whether a new study is required. In such situations, the distinction between generalizability versus reproducibility of scientific results (and monitoring versus surveillance) is crucial in evaluating the specific research need at the time. Some relatively simple forms of risk assessment may be needed to inform such decisions, including framing efforts involving community engagement. Such activities could be given more priority by funding agencies, and opportunities to conduct intervention studies should not be missed.

In some situations it may be desirable or necessary to conduct a full epidemiological investigation – for example, a study to address specific concerns of high political interest within government. A study may also be mandated when a large population is exposed to an environmental risk, even a moderate entity.

It is also important to keep in mind the social and ethical responsibility of scientists – that is, their duty to answer important public health questions based on available evidence, in an honest and relevant way. In addition, scientists are best positioned to alert all society about emerging threats before they are established on the research agenda, playing the role of whistle-blowers.

Participatory approaches

Recent initiatives, such as the HBM4EU project, hinge on a participatory and transparent approach that requires researchers and policy-makers to work together. Such direct contact between the two not only helps to build trust, but also enables policy-makers to propose questions and take timely action where needed. Among others, nongovernmental organizations (NGOs) may also help to bridge this gap as they often operate in the area between research and policy. Researchers need to take note that NGOs and informal citizen groups can be valuable and skilled partners in enabling knowledge transfer and helping to tackle EH challenges.

Addressing the gap in EH research

European countries with less strong research, public health capacities and infrastructures face particular challenges as researchers may struggle to establish the links necessary for valuable international collaboration. This includes WHO European Region countries recovering from or facing economic, political and social transitions, intertwined with health and environmental change (e.g. from a legacy of past contamination or loose environmental policies, control and awareness). Hence there is a need to promote exchange and collaboration in order to avoid brain drain and to strengthen EH research in these countries. This may be partly addressed through innovative educational collaborations between academic research institutions and the private sector (e.g. industry-based PhD programmes) in which projects are co-designed to address real-life questions. Funding streams dedicated to coordination – for example, through the EC Horizon 2020 – COST scheme, or research infrastructures – are available to support large-scale and interdisciplinary collaborations as well as capacity building. They can also help to bridge the gap between European countries by enabling wider and more sustainable participation in research collaborations. These international networks can also counter the difficulty in getting reports on such initiatives accepted for publication in scholarly journals that are easily accessible to the public.

Challenges in EH research

When developing criteria for EH research priorities, it can help to identify challenges and barriers to undertaking effective EH research. Some of these are described in the following paragraphs.

- *Complexity*: as EH questions become more complex and far-reaching, research grows more specialized and inaccessible to many. This may widen the gulf between knowledge and public health practice.

- *Silos*: researchers are traditionally most comfortable within the specific area of science in which they were trained, and can face difficulties when crossing scientific borders (see next point). However, examples of truly trans/inter-disciplinary success do exist and should be communicated to (and part of the training of) young scientists.

- *Academic/institutional versus social needs*: professional advancement requires a positive feedback of grants and publications leading to recognition in the field. Similarly to the possible consequences of complexity, the tendency to dig deeper into specific issues may be at odds with societal needs, particularly in research laboratory work. Researchers in public health agencies work to their agency's mission and may face different barriers related to career advancement (e.g. through lack of innovation and thus fewer, or less novel, publications).

- *Communication*: the value of effective science communication is clear, but not always considered an important aspect of the job. Scientists should be prepared to correct misunderstandings and misconceptions and to manage unrealistic expectations related to their findings, but they are not necessarily trained in this. Academic focus has traditionally been on the citation impact of publications as the social impact is more difficult to characterize and highlight. Dissemination strategies should be an integral part of EH research projects, with efforts to communicate results to the lay public. Partnering with NGOs engaged in science translation may offer a mechanism to strengthen communication strategies. Multi/inter-disciplinary training and education across sectors and institutions (in different directions between researchers, policy-makers and the public) can help to make research a more effective tool for guiding EH policies.

- *Disagreement*: though often unavoidable in modern EH issues, lack of consensus amongst scientists is confusing and can slow or prevent EH policy decisions, especially when used instrumentally. Yet disagreement can also stimulate exploration of new angles and cross-disciplinary collaboration.

- *Partisanship*: interest groups, whether legitimate or not, often cherry-pick research to promote their agenda. Damage to the public health agenda is perpetuated by biased scepticism, poor science communication, lack of dedicated training and continued controversy. Many researchers are uncomfortable with, and/or lack the training, to engage effectively in public debates and therefore would rather avoid contributing to translating research into policy-relevant input.

- *Conflict of interest*: close working relationships between funders and researchers may be needed to meet project goals in some situations but there should be a clear separation between those deciding on research and those reporting research results. The problem is especially serious when funding comes from industry or other stakeholders with vested interests conflicting with public health needs. There are some historical examples of biases related to funding. This issue can be addressed via independent ethics review but experience shows that conflict of interest can be highly subtle and pervasive.

- *Evolving nature of EH challenges*: entering into the Anthropocene brings about radically different questions for the EH community. Investigation of future risks requires the use of projections and scenarios, besides and beyond the more familiar notion of counterfactuals (i.e. benchmarking against something that is contrary to the truth or did not actually occur). Advanced modelling and more flexible statistical methodologies for causal inference are needed to address questions of validity in epidemiological studies *(11)* and better address complex EH issues. Though at the root of EH research, these concepts are not necessarily easy to communicate.

- *Open data*: in EH research this term broadly relates to transparency, free access to published research (e.g. peer-reviewed publications, study summaries, reports) and public availability of data, platforms for analyses, tools and methodologies. While open data's benefits to the research community and beyond are widely recognized, a level of caution should be exercised to prevent malicious instrumental use of the data by groups with pre-set agendas. In particular, legal and ethical frameworks are needed if primary data (particularly individual health data) are to be included in the open-data paradigm.

- *Terminology*: bridging research domains will challenge researchers to achieve a common language of understanding between themselves (and stakeholders) to facilitate effective research and communication (e.g. definition of multi-, inter- and trans-disciplinary *(12)*). Building understanding across language, culture and research domains requires mutual respect, effort and time.

- *Socioeconomic and cultural diversity*: given the large heterogeneity in capacities, resources and tradition in EH research in Europe, investment in establishing fruitful and sustainable arrangements is needed to ensure information flow and promote collaboration between research teams.

Establishing criteria for priority setting in EH research

Given the challenges and shortcomings already described, a more systematic and transparent strategy for identifying priorities for EH research is desirable. As described in biomedical research by Chalmers and Glasziuo *(13)*, the term research waste has been used to indicate scientific production that, although of possible good quality, carries limited or no value to the advancement of knowledge and therefore to society at large. So what are the criteria for assessing which research should take priority?

Multiple criteria are typically considered when evaluating existing research and published (or would-be published) investigations. These criteria mostly refer to research quality (e.g. good design, validity, statistical power, completeness) but they also include originality, degree of innovation and contribution to expansion of available knowledge. These latter criteria are also of relevance for establishing research priorities.

In line with past work – for example, the IARC model for cancer research *(14)* – identifying and selecting a few simple categories for initial organization of such criteria seems to be the most promising way forward. Specifically, criteria would belong to the following domains.

- Public health relevance as expressed by the magnitude and severity of the health and/or environmental impacts involved; extent of the burden of disease; increasing trends in disease rates and avoidable disease; the level, extent and nature of exposures to single or

mixtures of agents; and potential for latent adverse effects, including on development, or through life-course mechanisms.

- Uneven distribution of exposures, effects and impacts, with inequalities and inequities across the population; and existence of particularly susceptible or vulnerable subgroups.

- Policy relevance and prevention; availability of remedial action or options for intervention, feasibility, needs of the community and society.

- Innovation and development: differentiating between the production of new knowledge and the refinement of existing knowledge.

- Novelty: identification of emerging risks, lesser-known hazards, or new disease aetiologies.

Once fully developed, these criteria can be displayed in a simple matrix with specific sub-criteria (Table 3). The items listed in Table 3 are examples only – expanding the criteria matrix to meet the broad range of needs in identifying EH research priorities is challenging and requires in-depth review and discussion. Rows in the matrix will refer to topical research areas; cells will need to be populated with some metric of relative weight, so as to enable a comparison of priorities.

These are no trivial steps and they require further discussion. It is necessary that the way forward is determined through transparent consultation with stakeholders – for example, using consensus-based approaches. In addition, some criteria may appear somewhat controversial. For example, what weight should be given to topics with high public or media interest, or to the role of research aimed at maintaining an issue in the political agenda but not necessarily based on solid scientific evidence?

Table 3. Criteria matrix

	Impact or EH relevance			Policy relevance		Innovation and development		Novelty	
	Burden of disease	*Inequity…*		*Options for intervention available*	*Public attention …*	*New knowledge…*	*xx*	*Emerging risk*	*New disease aetiology…*

EH research domains and thematic areas

Embracing complexity

Though it was beyond the scope of the meeting to identify specific priority research areas, several themes emerged (see subsequent section and Fig.1). Many of the issues that WHO and others identified as priorities in 2008 *(15)* and the 1990s *(16, 17)* appear still relevant in Europe today *(18, 19)*. However, the multidimensionality, complexity and fast pace of change of current EH challenges mean that research must widen its field of view and keep on top of emerging environmental hazards and evolving societies. It is now widely recognized that there is an urgent need to understand better the health implications of global change (e.g. environmental

degradation, loss of biodiversity) and explore opportunities for environmental stewardship. This is part of the growing aspiration to address distal health determinants and to inform intersectoral work – for example, evaluation of the health implications of policies on domains such as energy and waste production, urban and transport planning, agriculture and food security; or education calls for research that can integrate multiple pieces of evidence and embrace complexity.

Research efforts must therefore be able to recognize and deal with complex questions such as the role of potential co-benefits of, and adaptive response to, selected interventions such as biofuels, aquaculture and pest management. For example, the *Lancet Health and Climate Change Series* evaluated mitigation strategies in four domains (household energy; transport; food and agriculture; electricity generation) and found that actions to reduce greenhouse gas emissions can often, though not always, lead to net health benefits *(20)*.

Thematic areas

Comparing and contrasting different thematic areas can inform the development of criteria; some thematic areas that emerged during the meeting are depicted in Fig.1. Reflecting the vast spectrum of EH research, they include both traditional and emerging topics in EH ranging from risk factors to broad families of determinants, and from settings to analytical approaches. A few of these examples are elaborated below.
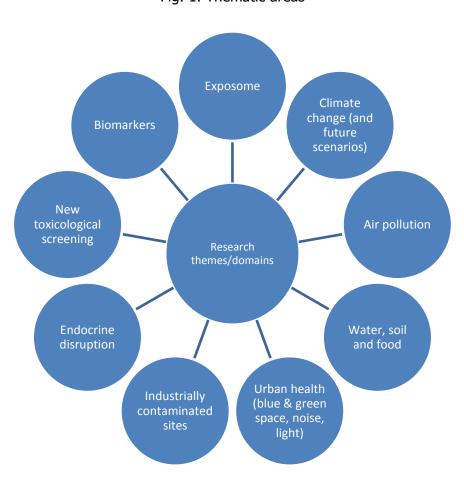
Fig. 1. Thematic areas

Climate change is a thematic area in which the emergence of new types of questions exposes important knowledge gaps and can inform the process of establishing EH research priorities. For example, there is a need for systematic reviews on long-term and multiple effects of global change (e.g. on agriculture, food security and promotion of sustainable diets). Better data are needed not only on the link between climate change and infectious disease, but also on evaluation of climate change's direct and indirect impacts on migration, population displacement and conflict. Rigorous and holistic approaches should also be developed further to evaluate co-benefits/co-harms of mitigation. Underpinning these issues is the need to better understand human behaviour, adaptation and willingness to pay in this time of global environmental change. To address such multidimensional global issues, funding agencies will be challenged to shift to multi/inter-disciplinary research that crosses traditional funding streams and agendas. Further, to achieve effective evidence-based public health policy, it is crucial to know and understand how translations of scientific evidence motivate policy-makers and trigger decisions on interventions. For this purpose, it is essential that the research agenda is set with the involvement of a wider expertise that includes political scientists, social scientists, anthropologists and economists.

Air pollution research is an area in which large investments and advancements have been made but more research is advocated to better understand the roles of individual behaviours and the full spectrum of mixtures of exposures and their health effects; and to assess the effectiveness of policies in different sectors. Despite the extensive knowledge base on the health effects of air pollution, there remains a lack of evidence-based clinical guidelines and advice for patients. Air pollution is declining (differentially) in some areas across Europe but it affects an ageing population and the burden of disease in Europe remains high. Additionally, continued research is important given the global nature of air pollution and the need to inform policies beyond European borders. Air pollution should also be viewed within the wider framework of the urban environment as continued research on sustainable, healthy and health promoting cities (e.g. energy efficient and resilient to climate change; accessible and quality recreational green and/or blue spaces; remediated industrially contaminated sites) is crucial for the well-being of a large fraction of the European population. Also, it is prudent to widen the focus on the mixture of environmental media as a whole (soil, water, air and biota) when considering industrial contamination. A more holistic view of health requires examination of not only environmental exposures, but also inequalities in the health burden, sociodemographic variables and nutrition that result in environmental injustice.

The plethora of research on specific toxicants (e.g. lead) has demonstrated their adverse effects and shaped the regulatory limits. Yet such knowledge is limited to a small number of substances with only few data for countless substances already on the market. There is also limited information about mixtures – for example, concerning commercial products or industrially contaminated sites. Such fragmentation makes it likely that estimates of the disease burden due to chemicals *(21)* or industrially contaminated sites are underestimated. New areas of research involving novel methods and technologies should be given priority over replication of studies on well-known agents that simply aim to refine what is already known. At the same time, new avenues of investigation of well-known substances can also be important for public health. Such new and more so-called high-risk science would help to address gaps in public health safety and knowledge related to chemicals in general and to chemical mixtures.

New methods and approaches

The complexity of contemporary EH questions has spawned a new breed of science and posed new questions and challenges, particularly in terms of the need to develop new methods and approaches. The exposome; systems or network medicine; co-morbidity; EH-related behaviours (either protecting or aggravating the interplay between environment and health); translational research; and uncertainty analysis are but a few examples of domains that should stimulate further transdisciplinary research. The life course perspective (i.e. the link between early-life exposures and health effects later in life) poses a particularly interesting challenge for future EH research. Use of tools currently being developed already enables preliminary explorations of the lifelong effects of environmental mixtures (e.g. including air, water and soil pollution). Mediation analyses and frameworks to integrate exposure measurements from various scales (i.e. personal/individual sensors through remote/satellite-based measurements) are also considered important for disentangling the effects of multiple exposures in the built environment. As mentioned earlier, work on mixtures and complex urban environments will require interdisciplinary research with a broader range of expertise (e.g. ecologists, physicists, psychologists, sociologists, anthropologists, urban planners). For example, an interdisciplinary one health approach involving veterinarians, agronomists or marine scientists is expected to be beneficial when considering vector-borne diseases, zoonoses or red tides. A similar approach could be used to investigate the possible impact on resistant strains of pathogens arising from less extensive use of antibiotics in food production. Use of interdisciplinary teams to address such complex EH questions implies the need for investment in training.

Policy uptake and public engagement

There appears to be consensus that strides must be taken to bridge the gap between research and policy uptake and that there is a need to act on factors that interfere with this dialogue. This has become even more relevant at a time when trust in science is being challenged. When defining research priorities, efforts should be made to ensure that citizens' concerns are heard so that directly relevant research hypotheses are considered, even if not deemed the most innovative of science. A shift from informing to involving and engaging the public in scientific enquiry seems to be underway and should be supported further – this is extremely important for consolidating a widespread public health culture and preserving the role of science and research within society.

Related to this is the need to improve risk governance in order to better address risk perception, assessment and communication in the different cultural settings and conditions across Europe *(22)*. In particular, it is desirable that social scientists are involved early in the research training and planning process. Opportunities and benefits for health promotion and environmental protection – achieved through new partnerships toward a focus across disciplines, institutions, sectors and stakeholders – should also be pursued and celebrated. A strong, engaged, informed and diverse community is necessary to tackle the major EH challenges currently facing the European Region.

Conclusion

The spirited discussions at this meeting, and the overall consensus on the need for more detailed guidance on prioritizing EH research, supports the notion that WHO should continue to engage in further stimulation of such discussions, with the aim of generating recommendations for priority setting in the EH field.

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Annex 1

MEETING PROGRAMME

Thursday 27 April 2017

08:30 – 09.00	*Registration*
09.00 – 10:45	Opening, introductions Welcome addresses Appointment of chairpersons and rapporteurs **Background, rationale and goals of the meeting** (WHO) **EH Research: current status and trends** R Bertollini: 25 years of EH Research in Europe S Ribeiro, Current trends in EH research
10.45 – 11.15	*Coffee break*
11.15 – 13:00	**Setting EH research priorities: Current approaches, practice, needs** Peeter Pärt, Environment and Health in Europe – what have we learned, where do we go? J Anto, Expanding research in environmental epidemiology from local to global issues A Haines (remotely), Global change and EH research L Laurent, Research for risk assessment. Specific questions
13.00 – 14.00	*Lunch break*
14.00 – 16:00	**Establishing criteria for EH research priority setting** C Portier, Proposed criteria for priority setting D Savitz (remotely), "More research may not be needed" M Kogevinas, Views from ISEE (and me) P Bulat, EH research in Serbia
16.00 – 16.30	*Coffee break*
16.30 – 18:00	**Establishing criteria for EH research priority setting, continued** F Reis, EH research in academia F Forastiere, Needs of modern epidemiology M Dewolf, The role and views of civil society G Schoeters, Twisting between science and policy
18:00 – 18:30	**Wrap-up day 1: discussion and close**
19.30	*Dinner*

Friday 28 April 2017

09.00 – 10:45	**EH Research domains and thematic areas: current status and priorities**
	P Grandjean (remotely), Is the desire for replication adding to the existing Matthew principle in research?
	M Kolossa-Gehring, Lessons from human biomonitoring projects
	S Medina, Complexity in Health and the Environment, For Whom? And How Should We Manage It?
	I Bukhtiyarov, EH Research priorities in the Russian Federation
10:45 – 11.15	*Coffee break*
11.15 – 13:00	**EH Research domains and thematic areas: current status and priorities, cont'd**
	L Trasande (remotely), Risks, impacts, costs
	L Fleming, Interdisciplinary Research in Environment and Human Health
	A Zeka, Research infrastructures for Environmental Public Health
	I Iavarone, Integrating evidence
13:00 – 14:00	*Lunch break*
14:00 – 16:00	**Way forward – next steps**
	Moderated discussion
16:00	*Closure of meeting*

Annex 2

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