Designing a Planetary Health Watch

A SYSTEM FOR INTEGRATED MONITORING OF THE HEALTH EFFECTS OF, AND RESPONSES TO, ENVIRONMENTAL CHANGE

TRANSDISCIPLINARY STAKEHOLDER ENGAGEMENT

WORKSHOP REPORT

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EXECUTIVE SUMMARY

In the new geological epoch of the Anthropocene impacts of human activity on the Earth's systems may pose major risks to human health. We propose the development of a Planetary Health Watch (PHW) system for integrated monitoring of health effects of, and responses to, global environmental changes. The PHW system will harness new capabilities emerging from the digital revolution to motivate and enable effective responses to threats posed by the transgression of planetary boundaries. It will build on the existing monitoring initiatives as a system aimed at integrated monitoring of environmental change, health effects, and intermediating factors along with the drivers of change and policy responses to protect health.

In July 2019, we held a two-day engagement workshop at the Wellcome Trust in London, UK. We convened 59 experts, representatives of existing monitoring initiatives, and potential users of the system to discuss and make recommendations on key aspects of the design of such a system, particularly its scope, opportunities for building on existing initiatives, target users and use cases, strategies for generating impact and key communities for engagement.

The scope of monitoring was defined by a framework integrating eight planetary boundaries (climate change, ocean acidification, atmospheric aerosol loading, novel entities, freshwater use, biogeochemical flows, land system change and biosphere integrity) with human health outcomes. (Discussion of the ninth boundary – ozone layer depletion – was omitted because the ozone hole is now healing as a result of the implementation of the Montreal protocol.) As the initial crosscutting areas for the prototype development of PHW, we selected cities, food systems, and links between land use change and human health (emerging diseases and air pollution) to act as foci for the discussion.

To build on the existing monitoring efforts, PHW will purse three levels of integration: (1) across health and environmental monitoring, (2) across top down and bottom up monitoring approaches, (3) between advancing knowledge and action that can be taken to protect planetary health. Existing data platforms, large-scale initiatives and networks such as the Multi-Country Multi-City Collaborative Research Network, INDEPTH network of health and demographic surveillance sites in low- and middle-income countries, Resource Watch, Global Burden of Disease project, C40, Global Covenant of Mayors, Sustainable Development Solutions Network and many others will be essential to this process.

PHW will aim to add to

- the evidence on the emerging risks for human health and the most effective solutions by engaging researchers as a key user community;

- awareness of the evidence on impacts and solutions by investing in an outreach strategy that includes clear messages, narratives, and strategically selected messengers;
- action to protect planetary health by motivating and enabling decision-makers who influence relevant policies and their implementation across sectors to incorporate planetary health as a priority.

The strategies for generating impact will include generation of clear messages comprised of both data and narratives compelling to the individual users, proposing solutions and engaging with those in power to implement them. Scientific oversight and inclusive governance processes will ensure the system's credibility and legitimacy. The next steps involve engagement with key stakeholders, facilitation of new partnerships, and development of a long-term funding strategy.

BACKGROUND

VISION FOR A PLANETARY HEALTH WATCH

We live in a new geological epoch – the Anthropocene – characterised by substantial impact of human activity on the Earth's systems. Transgression of planetary boundaries of these systems pose major but imperfectly understood risks to human health and well-being as well as future development (Rockström et al. 2013; Steffen and et al. 2018). Recent advances in computational, sensing and communication technologies have created the conditions for a revolution in global-scale planetary monitoring and early warning (German Advisory Council on Global Change 2019; Sachs et al. 2019).

We proposed the development of a Planetary Health Watch (PHW) to harness emerging technological opportunities to facilitate evidence-informed responses to threats posed by the transgression of planetary boundaries (Haines et al, 1993; Haines et al, 2018). In this context, we define *planetary health,* using the definition from the Rockefeller/Lancet Commission report, as 'the health of human civilisation and the natural systems on which it depends' (Whitmee et al. 2015). Our specific focus in PHW is on connections with human health rather than on the health of natural systems alone. Its scope includes effects on health arising from changes to the Earth's systems at planetary level (e.g., climate change) or from more local environmental impacts that occur in multiple locations and collectively add up to global scale concerns (e.g., air pollution). We exclude the impacts of purely local environmental changes and effects on the natural system without clear connection to human health.

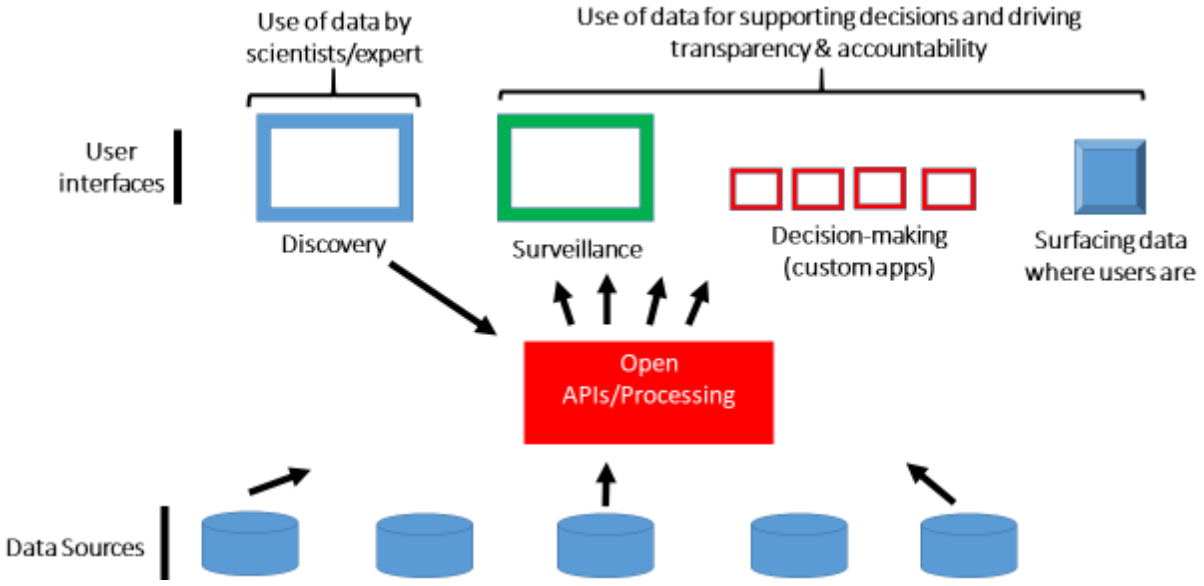

Figure 1. Schematic of the design of PHW system, illustrating its three core functions to support discovery, surveillance, and decision-making.

We envision PHW as a system aimed at integrated monitoring and action-oriented communication of factors relating to the health effects of environmental change, the drivers of change and policy responses to protect health (Figure 1). It will also harness

existing initiatives and facilitate closer integration between them and help identify/monitor:

1. Planetary drivers of changes to natural and social systems and associated **health effects**;
2. **Emerging 'hotspots'**, i.e., geographical areas where there are observable adverse effects of environmental stressors;
3. **'Opportunity sites'**, i.e., geographical areas where there are particular opportunities to achieve environment and health improvements through sustainable development policies or specific interventions.

Overall, we envision PHW as an investment in the health of the planet and the health of current and future generations. It will provide a platform for communities, researchers and decision-makers to collaborate, monitor progress and act to protect the health of people and the natural systems that we depend upon. It will assemble data for new research and support evidence-based decisions to adapt to and mitigate environmental change, helping to safeguard health in the age of the Anthropocene.

PROCESS OF DESIGNING A PLANETARY HEALTH WATCH

We first described the idea of PHW system in the journal Lancet Planetary Health (Haines et al, 2018) (Figure 2). We then started engaging with potential stakeholders, including the scientific community, data providers, prospective users and funders through our first event at the Annual Meeting of the Planetary Health Alliance (Edinburgh, 1st June 2018). The workshop led to defining the mission of PHW as a coordinating and harmonizing transdisciplinary initiative for monitoring the state and direction of travel of the major systems sustaining planetary health.

We then approached the Wellcome Trust with a proposal to continue and expand the stakeholder engagement process. They kindly agreed to provide support. The engagement process included: expert and stakeholder interviews and surveys, assembly of case studies of potential uses of PHW and its subcomponents, a webinar, and a two day transdisciplinary workshop, which we report here. The future steps in designing PHW would be refinement of the socio-technical architecture, development of prototypes of its components, testing their efficacy in driving action, and scaling.

Figure 2. Our engagement process and future steps for designing a PHW.

THE TRANSDISCIPLINARY WORKSHOP

The stakeholder engagement workshop was held on 9–10 July at the Wellcome Trust headquarters in London, UK. It was attended by 59 participants from 38 academic and non-academic institutions from four continents (Annex 1). The participants included practitioners, policy makers, and experts in planetary boundaries (Steffen and et al. 2018; Rockström et al. 2013) and their links to human health.

The workshop had eight sessions with presentations by the organisers and invited participants, panel and plenary discussions, as well as group exercises. The workshop programme and session summaries are available in the Annex 2.

AIM & OBJECTIVES

The aim of the workshop was to convene experts and stakeholders (Figure 3) to agree on the design of a PHW to monitor risks to planetary health and drive action for its protection. PHW would aim to gather data on planetary scale environmental changes and their impacts on human health, and to drive protective actions.

The workshop objectives were:

1. To identify initial target users and their information needs;
2. To refine the design, scope and theory of change of PHW;
3. To identify opportunities for building on existing initiatives and developing an integrated system;
4. To review options for hosting and governing PHW.

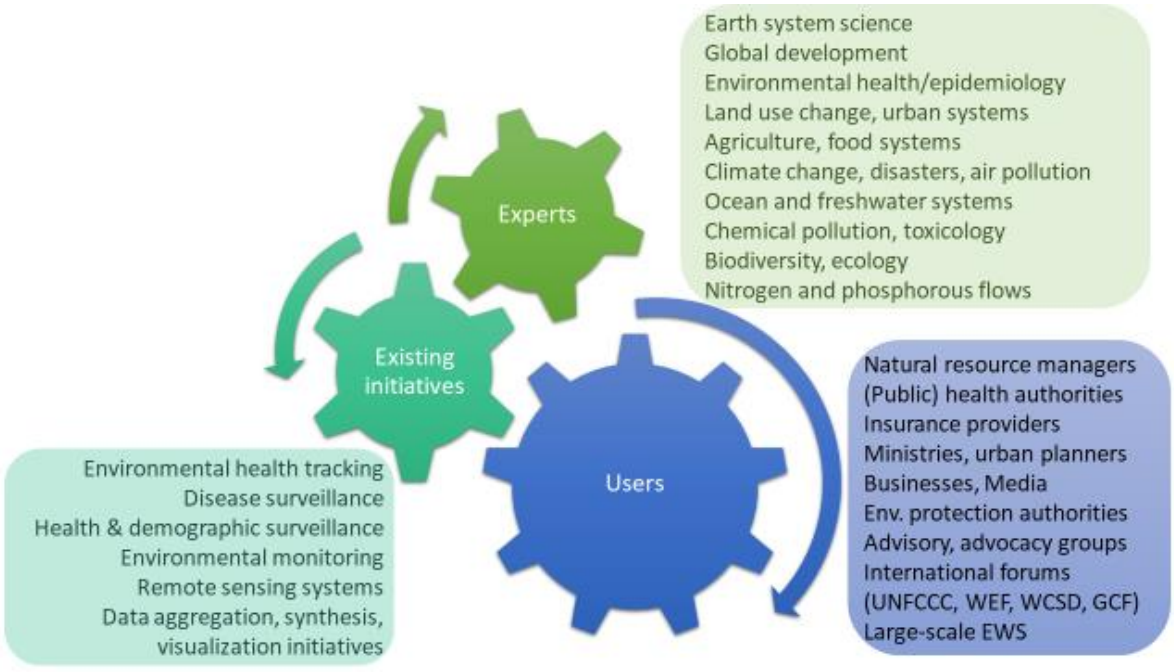

Figure 3. The expert and stakeholder groups convened at the workshop.

SUMMARY OF DISCUSSIONS

This section summarises the workshop discussions under three core themes:

(1) Scope and design: what should be the scope and design for monitoring in PHW,

(2) Integration: how existing environmental and health monitoring efforts can be effectively integrated into a PHW system,

(3) Impact: how would PHW drive impact on policy, decision-making, and management and what communities should be engaged in the PHW system.

Theme 1 addresses 1st and 2nd workshop objectives, themes 2 and 3 address 3rd objective. The 4th objective will be addressed by later discussions, based on the updated PHW design informed by the workshop.

SCOPE AND DESIGN OF MONITORING

To frame the scope of what a PHW should be monitoring, we proposed linking the Planetary Boundaries concept (Steffen and et al. 2018; Rockström et al. 2013) with human health outcomes (Figure 4). Guided by this framework, we explored what could be the key links connecting each of the nine planetary boundaries with human health by performing a rapid review of literature, expert surveys and interviews. A summary of our identified links is available as an electronic document through the following link. This is an evolving document open for further suggestions and comments, which you can enter directly into the document or by contacting PHW team.

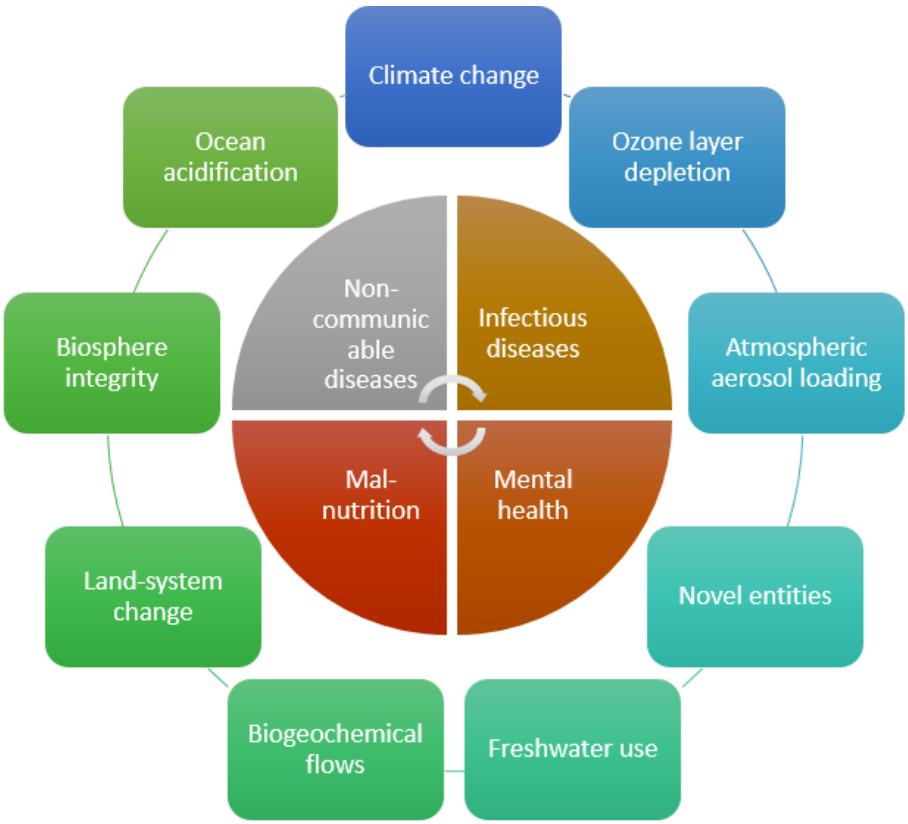

Figure 4. A framework linking planetary boundaries and human health outcomes.

We received the following expert suggestions to improve this framework:

- To de-prioritise focus on monitoring the health implications of the ozone layer depletion, as the situation is improving;
- To widen the scope of monitoring beyond ocean acidification to broader links of ocean ecosystem degradation and human health;
- To seek links between planetary changes and health by considering research: (1) that starts from environmental changes and investigates how they affect health and (2) that starts from changes in health outcomes and investigates how they are attributed to environmental factors.

It was also debated whether PHW should focus on planetary changes solely in relation to the health of human species or also monitor impacts on the health of other species. One point that was raised was that an instrumental approach to protecting biodiversity in the interest of contribution to human health (as an "ecosystem service") may be imprudent given our current imperfect understanding of the complex links between biodiversity and human health.

The links between planetary changes and health differ by the strength of attribution, potential burden of the attributable impact, sensitivity, likelihood of a tipping point, and data availability. An aim of a Planetary Health Watch system would be to assess potential pathways contributing greatest burden of environmentally-sensitive health outcomes and the potential for non-linear 'state shifts' which pose major risks to the viability of ecosystems with significant consequences for human societies. We proposed classifying environment-health links into three tiers:

Tier 1: those with strong evidence base and good data availability

Tier 2: those with strong evidence but limited data availability

Tier 3: those with emerging evidence and limited data availability

Discussions highlighted certain challenges with applying this classification for prioritization, as the relative importance of pathways is debatable. It would have more value to direct the use of monitoring information to the most appropriate form of action, e.g., further research/discovery, development of precautionary policies or immediate decision making.

Discussions also highlighted the interconnectedness and complexity of the links between planetary change and human health. For instance, the relationship between biodiversity and health can be characterized by a variety of direct and indirect pathways including disease regulation and provisioning of food and raw materials (Sandifer et al, 2015). There is also a lack of studies that identify specific mechanisms by which biodiversity affects health and more research is needed to examine the causal link between biodiversity and health. Therefore, a systems approach to conceptualising linkages between planetary changes and human health and precautionary thinking will be essential to selecting and organising indicators. To guide the indicator selection, we proposed using the Drivers-Pressures-States-Exposures-

Effects-Action (DPSEEA) framework (Figure 4), combined with systems mapping of interconnections between planetary change and human health.

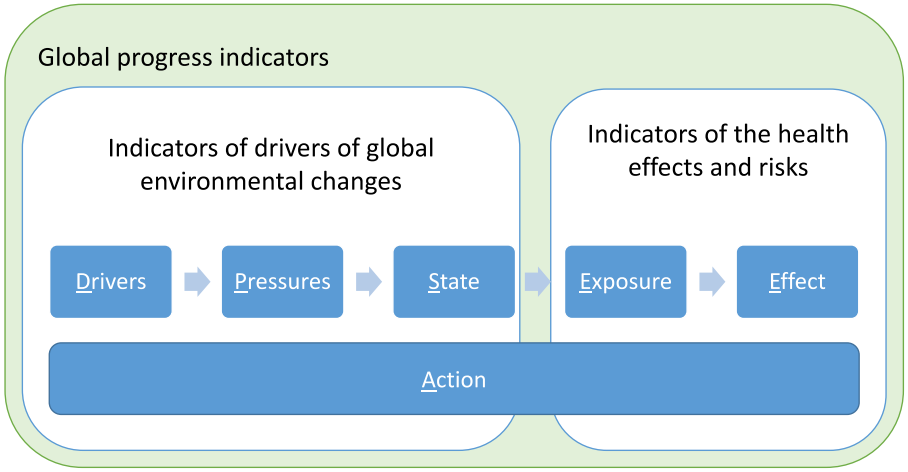

Figure 5. A framework for PHW indicator selection.

There was discussion that the initial focus of the PHW might be on indicators of health effects and risks of planetary changes, highlighting the unique focus of the system on tracking the attributable health outcomes. At later stages, PHW could be expanded to include indicators of drivers and pressures of the planetary changes. Additionally, the system could include indicators of global and national progress towards planetary health, tracking synergies between human health and sustainable use of natural resources. Workshop discussions highlighted opportunities for PHW to contribute to the monitoring of synergies across the Sustainable Development Goals and inform the post-2030 sustainable development agenda. PHW could also incorporate indicators for evaluating the effectiveness of actions taken to mitigate and adapt to planetary changes. To ensure scientific validity and political relevance, indicators would be developed as per the criteria proposed by Hambling, Weinstein and Slaney, 2011.

Box 1. Criteria for PHW indicator development (Hambling, Weinstein and Slaney, 2011).

Actionable — related to climate/environmental/health conditions that are amenable to adaptive actions
Sensitive – to environmental changes and less sensitive to alternative (non-climate) explanations
Relevant -- to an issue of policy or practical concern
Sustainable — able to provide data for the next 20–30 years
Consistent – and comparable over time and space
Scalable — capable of being used at different scales
Robust -- and unaffected by minor changes in methodology, scale or data
Unbiased – and representative of the conditions and area of concern
Explicit — identify specific adaptation responses
Accurate—based on data of a known and acceptable quality
Understandable – and applicable, and acceptable to stakeholders and potential users
Measurable — based on available data and manageable methods with retrospective data for assessing trend
Cost-effective — capable of being constructed and used at an acceptable cost-benefit ratio
Selective — in that they help to prioritize key issues in need of action
Timely – available in a timely manner

TOWARDS AN INTEGRATED MONITORING APPROACH

We envision the PHW as a coordinating and harmonising transdisciplinary initiative helping to fill in gaps between the existing initiatives and facilitate their coordination. In advance of the workshop we reviewed the landscape of existing global environmental and health monitoring efforts, identifying >150 monitoring initiatives. Most of our identified initiatives monitored either environmental changes or health outcomes separately, with little integration of the two (Table 1). Only a few of the existing initiatives are designed to link information between environment and health. Examples include the Multi-Country Multi-City Collaborative Research (MCC) Network, which currently monitors trends in temperature-related mortality in over 700 cities and is expanding its capability to monitor aspects of the urban environment such as green space and air pollution (Gasparrini et al. 2017). The Institute for Health Metrics and Evaluation (IHME) collects data on a wide range of exposures to risk factors for diseases and injuries across 197 countries (GBD 2018) but currently does not assess the impacts of global environmental change on health. To our knowledge, none of the existing initiatives currently links human health outcomes across all planetary boundaries.

Table 1. Examples of existing environmental and heath monitoring initiatives.

Planetary Boundaries	Monitoring Initiatives*
Climate change	NASA MODIS, World Meteorological Organization, Climate Watch, City Carbon Footprints
Ocean acidification	Ocean Health Index, World Ocean Database, FAO Fisheries, Global HAB (also related to nitrogen and phosphorus loading)
Biosphere integrity	Global Biodiversity Change Indicators, Biodiversity Indicators Partnership
Atmospheric aerosol loading	NASA Earth Data, NASA Air Quality Monitoring, OpenAQ
Novel entities	Global Alliance on Health and Pollution, US NHANES
Freshwater use	GEMS/Water, Aqueduct, WHO/UNICEF JMP for water supply, sanitation
Biogeochemical flows	International Nitrogen Management System, NASA ORNL DAAC
Land system change	Global Forest Watch, Copernicus Global Land Service
Health Outcomes	**Monitoring Initiatives***
Nutrition	Global Dietary Database, Vitamin and Mineral Nutrition Information System
Infectious disease	PREDICT, Global Virome Project, WHO outbreak information database, Malaria Atlas Project
Urban health	Observatories for urban health, Multi-City Multi-Country research network
Global health metrics	Global Burden of Disease, World Bank Health Data, WHO World Health Statistics
Migration	International Organization for Migration, WorldPop
Livelihoods	FAO Rural Livelihoods Information System
Wellbeing	OECD Regional Well-Being, European Social Survey on Wellbeing

* Not exhaustive

PHW calls for three levels of integration in monitoring efforts:

1. Integration of health outcome monitoring with environmental monitoring across all the planetary boundaries
2. Integration of top down and bottom up monitoring
3. Integration of monitoring with actions to adapt to and/or mitigate environmental change

The three levels of integration can be visually represented by superimposing the DPSEEA framework onto the framework of planetary changes and human health outcomes (Figure 6).

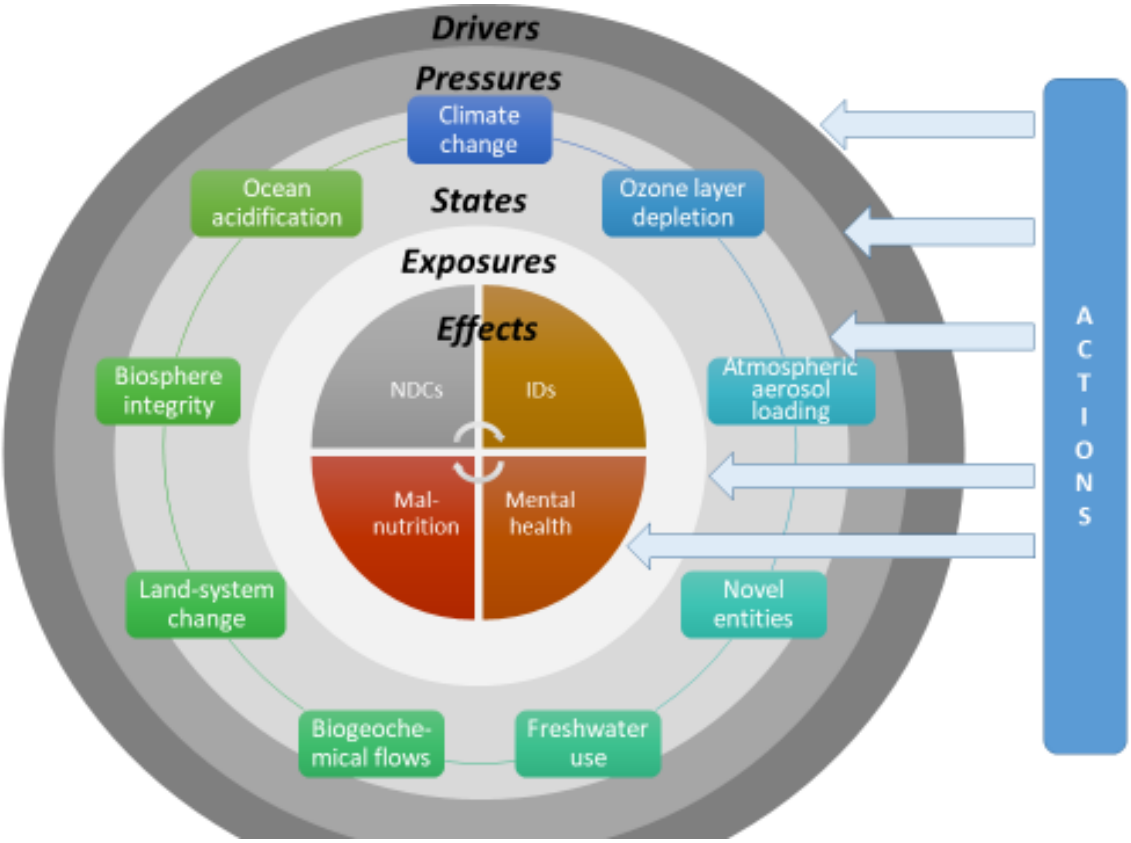

Figure 6. A framework illustrating the integration required for PHW.

The ***integration of health and environmental monitoring*** across all the planetary boundaries requires further systematic mapping of existing monitoring efforts against the pathways that link planetary changes with human health. Such integration would need to happen incrementally, alongside the advancement of the science of attribution in complex systems.

The ***integration of top down and bottom up monitoring*** can be achieved by using global satellite systems as well as on the ground monitoring at specific locations. This integration can happen on a "product" level, as in the Surface Particulate Matter Network (SPARTAN) (Snider et al. 2015) or other estimates of surface particulate matter that rely on ground observations as well as inferences from satellites, or at a dataset level. Resource Watch, for instance, is a platform that provides reliable data

on the state of the planet's resources and their links to people. The interactive platform allows users to explore more than 250 available datasets on topics covered ranging from climate change to human migration, deforestation to air quality, agriculture to energy. The web site also livestreams over 45 near-real time datasets including satellite-derived forest fire incidents.

The bottom-up monitoring can be achieved by monitoring trends in exposures and health outcomes in 'hotspots', or specific locations where vulnerable populations are heavily exposed to one or more environmental stressors. INDEPTH network collects longitudinal mortality data from 49 Health and Demographic Surveillance Sites (HDSS) in 19 low- and middle-income countries in Africa, Asia and Oceania. Such data can be linked to changes in environmental conditions (air pollution, temperature, precipitation, extreme events etc.) to monitor their effects on human health in the most vulnerable locations. An example is our research in Nouna HDSS, Burkina Faso where we established clear empirical relationships between changes in weather patterns, annual crop productivity levels, and child survival (Belesova et al. 2017a, 2017b). Our projections show that global warming of even 1.5°C above pre-industrial levels could result in doubling of the child mortality burden that is attributable to local crop production deficits (Belesova et al. 2019). This research can be expanded to look at other environmental drivers of undernutrition, such land use change and biodiversity loss.

The third level is ***integration of knowledge production with actions*** that mitigate risks to planetary health. PHW could track progress on mitigating drivers and pressures of planetary changes in the 'opportunity sites', i.e., geographical areas where there are particular opportunities to achieve environment and health improvements through sustainable development policies or specific interventions. These could be accessed through networks of cities (e.g., C40, Global Covenant of Mayors, Cities4Forests) where policies are being implemented to promote sustainable development.

Systems approaches might help identify actions leveraging greatest change in socio-economic systems in a manner that would address the key drivers and pressures of the planetary changes and their health impacts. Further, stakeholder mapping needs to be undertaken to identify actors in the position to most effectively influence such actions. The motivation and needs of such actors should be central to tailoring the information and manner its communication through the PHW system.

Before the workshop we surveyed existing monitoring initiatives and identified potential barriers to integration of data across initiatives (Table 2). These include coordination, governance, and technical challenges. For example, some of the existing data systems lack interoperability, partly due to a lack of common protocols and language across areas. At the workshop we discussed how PHW could help overcome such barriers and facilitate integration of existing initiatives under a common strategy.

Table 2. Potential barriers to the integration across existing monitoring initiatives.

Coordination	Governance	Technical
Integrating different priorities and objectives	Data ownership and exchange	Standardization
Duplication	Cooperation agreements	Data gaps
Availability and stability of funding	Ethics and equity	Technical and processing capacity
** Not exhaustive*		Linkage across scales
		Methodological differences

Representatives of existing monitoring initiatives introduced all workshop participants to their monitoring efforts, including

- **Belo Horizonte Observatory for Urban Health** – a local research–policy partnership that focuses on the acquisition of in-depth knowledge on urban health metrics
- **China CDC** – a governmental and national-level technical organization specialized on disease control and prevention and public health in China
- **EM-DAT International Disaster Database** that aims to assist with decision making for disaster preparedness and vulnerability assessment and priority setting
- **Global Observatory on Pollution and Health** tracking efforts to control pollution and prevent pollution-related diseases
- **INDEPTH** and **ANDLA** networks of HDSS sites that collect longitudinal health and demographic data in low- and middle-income countries, represented by the MEIRU Malawi Epidemiology and Intervention Research Unit that runs one of the sites
- **International Network on Public Health and Environment Tracking** (**INPHET**) that supports and advances the development, implementation, and evaluation of local, national, and international environmental public health tracking/surveillance initiatives
- **Lancet Countdown on Health and Climate Change** – an international research collaboration, dedicated to tracking the world's response to climate change, and the health benefits that emerge from this transition
- **International Nitrogen Initiative** that quantifies temporal and spatial changes in air concentrations and deposition of ammonia
- **PREDICT** and **PREVENT** projects that aim to identify new emerging infectious diseases that could become potential disease outbreaks and threat to human health
- **UN Environment World Conservation & Monitoring Centre** working with scientists and policy makers worldwide to place biodiversity at the heart of decision-making

They shared experiences in establishing and running the initiatives, integrating data across environmental factors and health outcomes, overcoming methodological challenges including scientific attribution and data interoperability. The workshop participants discussed existing strategies for engaging with stakeholders across sectors, building common understanding, making links with policy setting, co-developing transdisciplinary tools and programmes, building trust and ensuring data security, ensuring effective coordination, communication and engagement, as well as funding sustainability.

Overall, PHW could add value to the current landscape of monitoring efforts through

- Integrated approach with a focus on health outcomes, which is unique among existing efforts monitoring planetary changes
- Analytical attribution
- Promoting inter-operability/standardization
- Transdisciplinary design with expert and user input
- Trustworthiness and action-ability
- Tailored apps for specific decisions
- Open source, high quality data for future discovery
- User-centric approach

DRIVING IMPACT AND ENGAGEMENT

Key to the success of the PHW system is its ability to generate impact and drive action for the protection of planetary health. We presented two interconnected theories of change for PHW system (Figure 7).

Figure 7. The two interconnected theories of change proposed for PHW.

The two broad blocks presented in Figure 7 represent the two stages of driving action: motivating change, and supporting decisions to effect it. The precise pre-conditions for motivation vary by actor – whether an individual, an organization, or simply a collection of people – but generally require some kind of mutual recognition of a problem (transparency) as well as mutual understanding of responsibility and ability to solve the problem (accountability) (Figure 8). PHW can support improved decision-making processes and by expanding implementation options, e.g., through enabling market and policy instruments in response to trends identified, as well as leading to the development of new partnerships or contractual arrangements (Figure 8). Institutions, from peer pressure to contracts to regulatory protocols or impact bonds all require some way of measuring objectives and individuals' or organizations' contribution to those objective. Each of these routes does not only involve data but also the social and institutional context to use that data to shape incentives.

The workshop participants discussed the opportunities for the PHW system to motivate change and support decisions. PHW could both add to the description of the problems and address the implementation gaps. There are many global networks created to describe problems or health effects, but these often lack constructive links to the sources of those effects and actors in the position to mitigate them. Identifying the roots of a problem is the first step toward solving it.

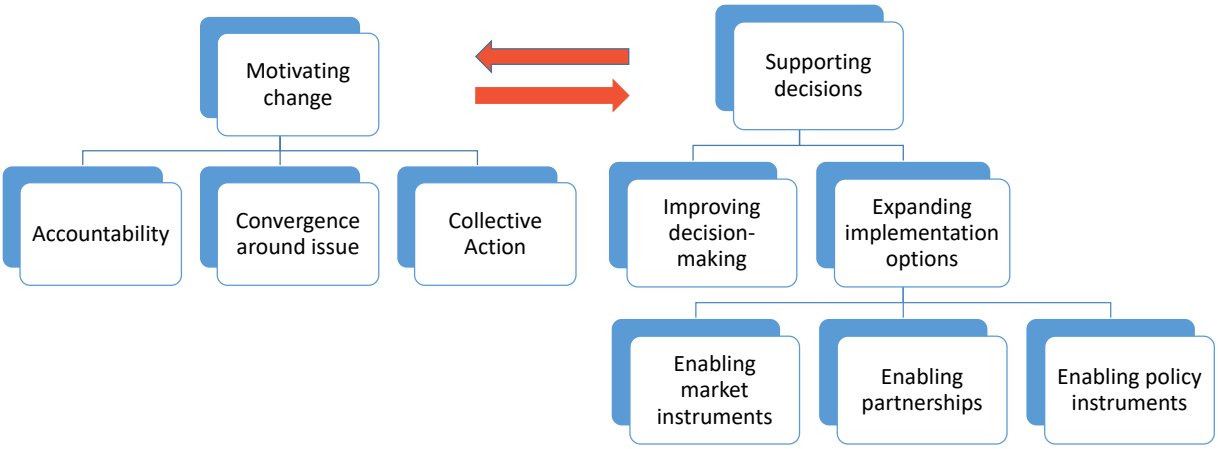

Figure 8. Potential pathways of the two interconnected theories of change.

Workshop participants also discussed the importance of the user group for ensuring that the provision of information leads to action. The first consideration is who is in a position to influence the environmental change and/or its impacts on health? The second, is what information they would need, in principle, to make better decisions for planetary health? The third is critical: what are their motivations – or motivators? What messages and messengers matter most?

Reliable and robust data are essential for decision-making and surveillance for PHW system and can generate substantial impact if they are designed to meet the needs of their target users – researchers, policy-makers, and managers. Data on their own may only provide a partial perspective on planetary health, therefore, they require compelling narratives, context and visualizations chosen accordingly for their intended audiences. Stories and case study collections should combine the best available data with narratives that speak to the emotions of decision makers and citizens. Resolution of data that matches the remit of its target audience can also facilitate action. It is often neither appropriate to base local decisions on global data, nor it is easy to relate global stories to the local context. Adjusting the definition of 'planetary health' can further help aligning with stakeholder needs and 'meeting them where they care'. Benchmarks, targets, backcasting, forecasting, as well as economic considerations are required to operationalise planetary health.

Clear recommendations of solutions need to supplement the messages about risks. Politicians and policy makers are less inclined to address problems which there are no clear solutions available. Planetary challenges require cumulative problem solving across multiple levels and sectors, including policy making, financial investments, community action, and public awareness. Solutions need to be guided by a common vision with an individually-tailored purpose. Capacity needs to be built for systemic responses to complex problems, taking into account their different and emergent manifestations. Effective transdisciplinary partnerships are essential to develop such capacity.

It is essential to identify who has the power to implement the required solutions, and what might drive them to exercise this power. In some cases, this requires identifying the key decisionmakers (individuals or organizations) and tracing back their accountability to taxpayers, voters, party leaders, or other groups who may be motivated to use their authority by narratives and a sense of solution. In other cases, there is a strategic void – an absence of an identifiable decisionmaker driving outcomes for planetary health. This is a particularly challenging situation, in which the dispersed systemic reasons for environmental impact and/or transmission to health effects need to be identified; then the actors who have the power to change the system, then their accountability and motivations.

Finding the right messengers is also critical. Sometimes the strongest organisations or individuals are do not have time or patience to engage in the instigating change. There could be strong benefits to working with the next generation, who are much more willing and energetic in embracing and advocating for change. Messengers need to be resilient to the political cycles and denialism. Media is a powerful force for further spreading the message to the masses.

The specific types of information that drive awareness, political pressure, effectiveness of response and implementation vary, as illustrated by the example from WRI's analysis of the stages of the political economy of air pollution and the role of particular types of science in driving action demonstrates (Figure 9).

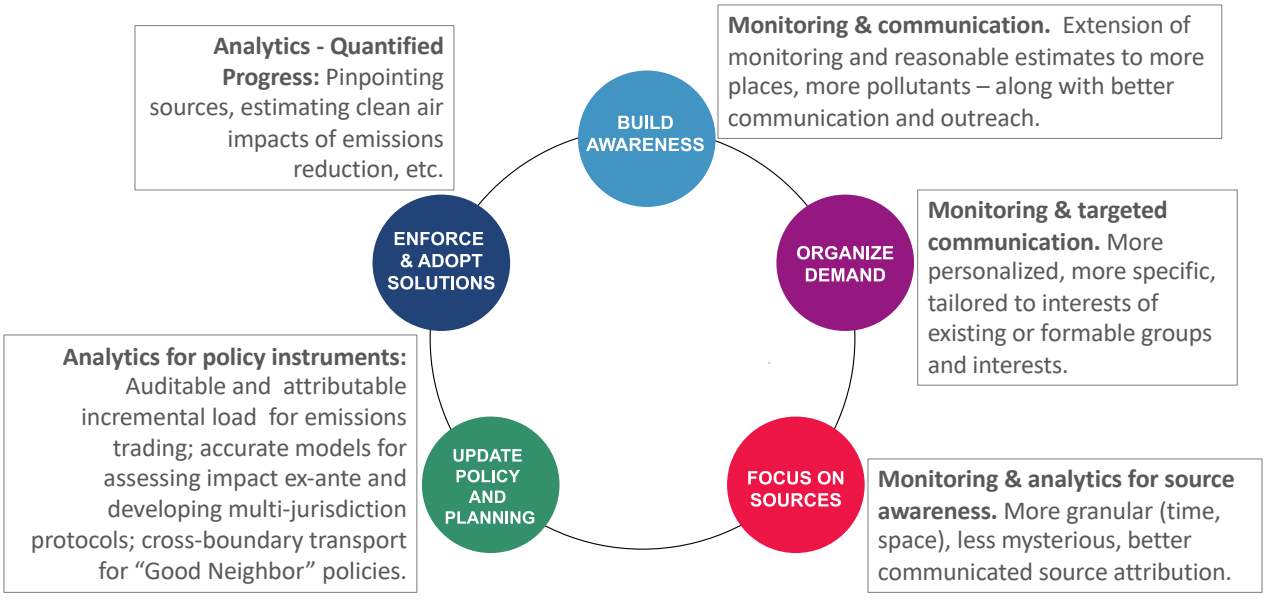

Figure 9. Example of the process by which science influenced action on air pollution.

Another important point of discussion was how the PHW system could be best configured to increase the uptake of its core functionalities of discovery, surveillance and decision-making. Some of the identified needs from the workshop and the preparatory scoping exercise are outlined in Table 3.

Table 3. Considerations suggested for the configuration of the PHW system for its discovery, surveillance, and decision-making functions.

Discovery	Surveillance/decision making
▪ Algorithms for data management	▪ Transdisciplinary capacity building to use data
▪ Translating confidential health data into easily accessible and open source data	▪ User engagement upfront to help sustain use
▪ Keeping up with the latest advances in data research	▪ Solution and demand driven
▪ Sharing lessons within an established community	▪ New partnerships and ambassadors/advocates to create change
▪ Sustainability of funding	▪ Bringing issues down to scale at which people can relate
▪ Data sharing and making data publicly available	▪ Communication of priorities to political leaders
▪ Demonstrating the need for data	▪ Use of diverse languages/media
▪ Identification of hotspots with multiple environmental stressors for monitoring	
▪ Understanding how research can target decision-maker needs	
▪ Managing quality of data from multiple sources	

Any data and evidence shared by PHW would need to be trustworthy. Therefore, scientific oversight, incl., data quality control/assurance, compliance with standards, peer-review, user feedback, external auditing, and an independent advisory board will be essential. Ongoing monitoring of the impact would also be essential to ensure that the system remains configured in a manner compatible with the user needs and is continuously improved to generate impact. User definitions of "better" data vary, and multiple dimensions can make a significant difference for impact (Figure 10). Lowering the cost of acceptably accurate data, for example, can activate new governance possibilities as community or private actors generate data that credibly competes with official measurements of pollution, heat, deforestation, or other indicators in courts or regulatory proceedings. Timeliness can make all the difference for enforcement, while scale matters for attributability to the actions of particular political leaders.

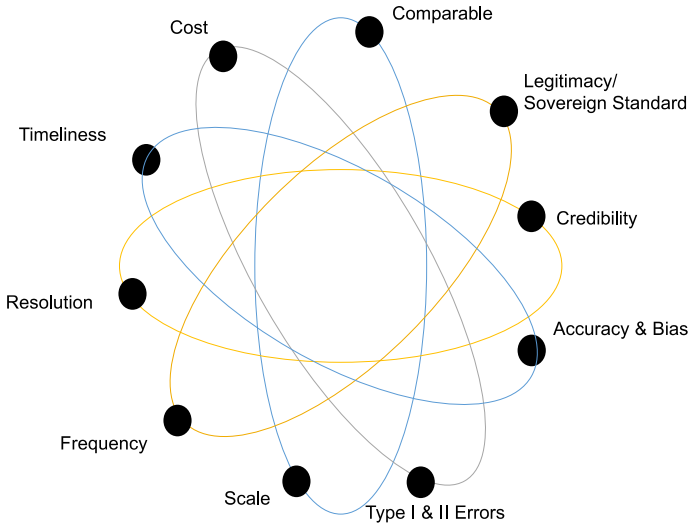

Figure 10. Data characteristics that are important for creating impact.

CONCLUSIONS & SUBSEQUENT DEVELOPMENTS

There was broad support from workshop participants for the concept of PHW and acknowledgement of the potential to address the fragmentation of current monitoring initiatives. There was also consensus that PHW requires three levels of integration:

1. Integration of health outcome monitoring with environmental monitoring across all the planetary boundaries
2. Integration of top down and bottom up monitoring
3. Integration of monitoring with actions to adapt to and/or mitigate environmental change.

Representatives of a diverse range of monitoring initiatives recognised that these integrative activities would add value to current activities and enable synergies between them. It was concluded that PHW should therefore aim to capitalise in existing initiatives rather than attempting to duplicate them. Development of coordinated transdisciplinary partnerships linking stakeholders and experts are essential for the creation of PHW system. Interoperability between different systems should be a priority to facilitate cross-sectoral analyses.

Following the workshop, the proposed PHW system was presented to a side event at the UN High Level Political Forum on Sustainable Development at which it triggered considerable interest and enthusiasm from UN agencies. Several examples of how linked environmental and health monitoring have influenced policy and could be further developed in future were discussed. For example i) assessing vulnerability to environmental change can inform targeted action to address the equity aspects of the environment-health link according to gender, age, location, and income, ii) quantifying impacts to health and natural systems can influence investment decisions to improve health and reduce environmental risks, iii) trend analysis, including forecasting and backcasting can help plan for preparedness and support attribution of health effects of environmental change iv) supporting existing monitoring efforts, such as for the SDGs to provide data for the annual Voluntary National Reviews for the UN High Level Political Forum on Sustainable Development.

Further information on the discussion is summarised in a manuscript recently submitted for publication. In the follow up, strategic links with the UN Statistics Division were established to explore opportunities for integration with PHW. Equally constructive discussions were held with the EAT-Lancet Commission offering support to the development of new Food System Observatory which could be linked to other data sources, for example Forest Watch https://www.wri.org/our-work/project/global-forest-watch to assess land use change and Aqueduct https://www.wri.org/aqueduct on freshwater resources. There is also an opportunity to discuss the potential role of the EU during a strategic event in December in the light of the upcoming Finnish Presidency which aims to include planetary health as one of its priorities.

To advance the development of the system, follow-on discussion groups with the workshop participants were set up around some of the key elements of the PHW system:

- Cities (as both hotspot and opportunity sites, capitalising on urban networks such as C40 and the Mayor's Global Covenant)
- Hotspots (particularly focusing on INDEPTH sites)
- Migration

The groups will have regular online meetings to discuss potential papers and proposals that will aim to clarify metrics and advance thinking on data sources (including interoperability) on the following topics for each of their respective areas:

- Environmental drivers and health outcomes that should be monitored
- Relevant data and initiatives for integration with PHW
- Proposals for specific indicators
- Methodological aspects of monitoring including attribution of changes in exposures and health outcomes to environmental change

Towards the end of 2019, we will convene coordinators of all groups to discuss the group progress, discussion outputs, and agree on the priority actions, metrics and quality assurance for the PHW. In the accompanying document (to follow) we outline the proposed next steps in terms of governance options, funding models and hosting. The long-term funding strategy for the overall system and its components will include support for:

- A data system and apps for the discovery, decision-making and surveillance functions of PHW
- An expert and researcher network
- An action-oriented policy, industry and public engagement programme

We will focus on a near term funding strategy for the next 3–5 years, aiming for self-financing in the longer term. Potential sources of funding for the initial 3–5 years will include foundations, national and regional governments and private sector sources.

In order to develop effective governance, an interim steering group composed of representatives of potential stakeholders and a scientific advisory group will be set up. The former will develop a governance framework and ensure accountability, the latter will develop priorities for 'proof of concept' linkages of data sets, mechanisms for ensuring quality standards are met and for developing interoperability between data sources.

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ANNEX 1: WORKSHOP PARTICIPANTS

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ANNEX 2: WORKSHOP SESSIONS

WORKSHOP SCHEDULE

Tuesday 9th July

08:30-09:00	*Registration and refreshments*
09:00-10:00	Welcome and introductions
10:00-10:40	Session 1: Connecting planetary change and human health
10:40-11:00	*Coffee break*
11:00-13:00	Session 2: Monitoring priorities
13:00-14:00	*Lunch*
14:00-15:30	Session 3: From monitoring to impact
15:30-16:00	*Coffee break*
16:00-17:30	Session 4: Building on existing initiatives
17:30-18:30	*Drinks reception*

Wednesday 10th July

08:30-09:00	*Refreshments*
09:00-09:15	Debrief from the previous day
09:15-10:45	Session 5: Theory of Change
10:45-11:15	*Coffee break*
11:15-13:00	Session 6: Engagement
13:00-14:00	*Lunch*
14:00-15:30	Session 7: Flexible session
15:30-16:00	*Coffee break*
16:00-17:00	Session 8: Closing

SESSION SUMMARY

WELCOME AND INTRODUCTIONS

The introductory session started with opening words by Prof Howie Frumkin, the head of Our Planet, Our Health team at the Wellcome Trust, and an introduction to the workshop objectives and structure by Dr Kristine Belesova, followed by three presentations.

(1) Planetary boundaries

Professor Johan Rockström, *Potsdam Institute for Climate Impact Research*

Explained the trajectories of the Earth System in the Anthropocene and the global trend for temperature rise since the last Ice Age. The concept of tipping points is illustrated by the effects of the Anthropocene on various Earth scale processes such as the El Niño-Southern Oscillation and the thermohaline circulation of the ocean. If humanity is serious about accomplishing the SDGs, it will occur within the safe operating space of the Planetary Boundaries. Radical transformation is needed to achieve a good future for all citizens on Earth.

(2) The need for a Planetary Health Watch in the Anthropocene

Professor Sir Andy Haines, *London School of Hygiene and Tropical Medicine*

Introduced the need for a PHW system in the Anthropocene, the concept of planetary health and key linkages from environmental change to human health effects. The DPSEEA framework was proposed for indicator selection and the idea of leverage points for PHW where a small shift in one area can produce big changes in everything within a complex system. The three initial focal areas for PHW, which include food systems, land use change and cities, examples of hotspot and opportunities sites were briefly introduced as well as how the integration of the top down and bottom up approach.

(3) Opportunity, vision, data driving action

Janet Ranganathan*, World Resources Institute*

Emphasized the importance of leveraging the opportunity for PHW through harnessing the current data revolution which is facilitated by open data, government and program interfaces. Mobile phones have become ubiquitous worldwide and are rapidly shaping the accessibility of data and contributing to the growing data deluge. The inspiration for PHW stems from allowing users to find signal in the noise created by all the data. The architecture of a simple schematic for a PHW system was introduced illustrating the three core functions of the PHW: enabling decision making, surveillance and discovery. Two interconnected theories of change for increasing transparency and accountability and decision making were also briefly introduced.

SESSION 1: CONNECTING PLANETARY CHANGE AND HUMAN HEALTH

Professor Paul Wilkinson*, London School of Hygiene and Tropical Medicine*

Prof Wilkinson presented an approach to conceptualising pathways linking planetary boundaries to human health as well as criteria for pathway prioritisation with regards to different functions of PHW system. He also introduced a group task for the workshop participants to identify priority indicators for the three focal areas of PHW.

SESSION 2: MONITORING PRIORITIES

Professor Andy Haines, *London School of Hygiene and Tropical Medicine*

The workshop participants split into groups to brainstorm about potential monitoring priorities and indicators for the PHW under its three focal areas: cities, land use change and food systems. Some participants felt that there are other important monitoring areas for PHW, and therefore, convened in a separate group to discuss such monitoring areas including air pollution, chemical pollution, and disaster-related mortality. The group leaders presented outcomes of the discussions. Expert discussants Prof Virginia Murray, Prof Philip Landrigan, Dr Enrique Montes, and Prof Gong Peng offered their perspectives on monitoring priorities for PHW beyond the initial focus areas.

SESSION 3: FROM MONITORING TO IMPACT

Dr. Jessica Seddon, *World Resources Institute*

Presented two interconnected theories of change about how data can influence action: (1) by increasing transparency and accountability and (2) by supporting decisions. The route through transparency and accountability is driven by three factors: accountability, convergence around problem and solution, and collective action. Supporting decisions involves market instruments, partnership and various policy instruments. Data plays a major role in all these elements and the consideration of certain institutional and social context to drive action. The relationships between data, platform and the relevant context are all necessary components to drive action and impact. Feedback and advice on user needs and the most useful ways to communicate data was solicited through a panel discussion with

- **Dr Guido Schmidt-Traub**, Executive Director of the Sustainable Development Solutions Network
- **Dr Beatriz Cárdenas,** Air Quality Manager at World Resources Institute and former Director-General of Air Quality Management for Mexico City
- **Gabriela Uchoa,** Head of Teresina 2030
- **Dr Joy Shumake-Guillemot**, Lead of WHO/WMO Climate and Health Joint Office

SESSION 4: BUILDING ON EXISTING INITIATIVES

Dr. Kristine Belesova, *London School of Hygiene and Tropical Medicine*
Janet Ranganathan*, World Resources Institute*

Gave examples of the range of existing monitoring initiatives that PHW had been engaging in the past few months. There is potential for integrated monitoring for both health and environment, however, there has been limited attempts at integration. Past progress on integration has been focused on the exposures and well known effects, outcomes with clear and simple attribution, thematic integration and less directly related factors to both environmental change and health. The approach for integrated monitoring for the PHW system will happen incrementally along with future progress being made in the science of attribution for complex systems. Janet Ranganathan presented Resource Watch as an example of an integrated monitoring system that brings together over 200 datasets on various topics including water, biodiversity, forests, food and climate change and allows users to explore and perform analysis to monitor trends using available data. Opportunities for integration and the value that PHW could bring to the existing efforts was discussed in a panel discussion with

- **Prof Waleska Caiaffa**, Director, Belo Horizonte Observatory for Urban Health
- **Prof Mia Crampin**, Director, MEIRU Malawi Epidemiology and Intervention Research Unit
- **Prof Liu Qiyong**, Director, Department of Vector Biology and Control, China CDC
- **Prof Mark Sutton**, NERC Centre for Ecology and Hydrology

SESSION 5: THEORY OF CHANGE

Dr. Jessica Seddon, *World Resources Institute*
Janet Ranganathan*, World Resources Institute*

Raised key questions regarding how PHW can accelerate discovery and verification of linkages between environment and health. Examples were given to illustrate ways to accelerate discovery, including General Transit Feed Specification (GTFS), OpenAQ, and Amazon Sustainability Initiative. GTFS standardized its metadata to allow more users to contribute to the data platform while OpenAQ's approach to openness of data increased its visibility on major search sites (e.g., Google Scholar) and publications in scientific journals. The Amazon Sustainability Data Initiative significantly reduced cost, time, and technical barriers for organizations and institutions interested in analysing large datasets to generate sustainability insights. Two broad theories of "motivate" and "enable" were subsequently explored for PHW to engage users and drive change to mitigate planetary changes and their impact on health. The session included a plenary discussion of what is needed to accelerate discovery and better motivate decision-making for the protection of planetary health.

SESSION 6: ENGAGEMENT

Dr. Jessica Seddon, *World Resources Institute*
Janet Ranganathan*, World Resources Institute*

Invited a discussion on what are the key communities that should be engaged in PHW. The best practices in engagement should take into consideration the concept of co-creation and incorporate various aspects of design, operations and strategy. The impact of PHW system can be enhanced by continuously monitoring and evaluating its performance. Scientific oversight would ensure data quality, compliance with standards and needs of its stakeholders, as well as help strengthening global strategic direction for the protection of planetary health. The communities for engagement and principles of engagement for PHW were explored in a panel discussion with

- **Tamara Lucas**, Executive Editor of the Lancet
- **Dr. Aleks Berditchevskaia**, Senior Researcher at the Centre for Collective Intelligence Design
- **Rachel Huxley**, Director of Knowledge and Learning, C40 Network
- **Dr. Nick Watts**, Executive Director of the Lancet Countdown

SESSION 7: FLEXIBLE SESSION

Professor Andy Haines, *London School of Hygiene and Tropical Medicine*
Janet Ranganathan*, World Resources Institute*

Focused on identifying the key users for PHW system, strategies for their engagement, and ways of catering monitoring data to their needs. The next steps for the development of PHW system were discussed and agreed.

ANNEX 3: GLOSSARY

Adaptation: adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities (IPCC 2014a).

Attribution: the process of evaluating the relative contributions of multiple causal factors to a change or event with a formal assessment of confidence.

DPSEEA framework (Driving Force–Pressure–State–Exposure–Effect–Action): framework adopts a linear approach to mapping environment and health issues, from high-level cultural and political drivers of environmental change to pressures which modify the physical environmental to produce an environment with defined characteristics or state.

Environmental change: a change or disturbance of the environment most often caused by human influences and natural ecological processes.

Exposure: contact with a substance which can occur over a short or long period of time.

Hotspots: geographical areas that are already experiencing adverse effects from multiple environmental stressors.

Indicators: provides measurement and summary of information regarding a given topic and provide comparable and actionable information across different boundaries and/or can track progress over time.

Mitigation (of climate change): human interventions to reduce the source of greenhouse gas emissions and to enhance the uptake of greenhouse gas emissions by natural and man-made sinks.

Monitoring initiatives: a commitment by a group to track and distribute data about a certain topic and can produce more than one products.

Monitoring: a systematic process of collecting and analyzing information to track the progress of indicators over a period of time.

Opportunity sites: areas that have demonstrated political will for major policy change or where there are resources earmarked for implementation of sustainable technologies or other interventions which have the potential to improve health and sustainability of an area with high environmental footprint and related negative ancillary health consequences as well as political will for major policy change.

Planetary boundaries (PBs): a framework represented by a set of nine processes regulated by the Earth system within which humans can continue to thrive and develop for generations to come (Steffen et al 2015).

Planetary Health Watch (PHW): a system aimed at the integrated monitoring of factors relating to the health impacts of environmental change at multiple geographical and temporal scales, the drivers of change, and policy responses to protect health.

Planetary health: the health of human civilisation and the state of the natural systems on which it depends (Whitmee et al 2015).

Surveillance: early identification and detection of health impacts resulting from global environmental change and monitoring of progress towards nationally and internationally agreed targets

Tipping points: point at which a series of small changes or incidents becomes significant enough to cause a larger, more important change.

Application Programming Interface (API): set of functions and procedures that allow for the creation of applications that access data and features of other applications, services or operating system**.**

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