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Addressing the global data imbalance of contaminants of emerging concern in the context of the United Nations sustainable development goals

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Contaminants of emerging concern (CEC) pose a significant global threat due to the ecotoxicological and human health risk they pose. Therefore, it is urgent that this pollution challenge is effectively addressed. Addressing CEC pollution is directly linked to several of the United Nations Sustainable Development Goals (UN SDGs), in particular SDG 6: Clean Water and Sanitation, SDG 11: Sustainable Cities and Communities, SDG 14: Life Below Water and SDG 15: Life on Land and SDG 3: Good Health and Well-being. However, tackling this global issue is hindered by the fact that there is considerably more CEC data available for the Global North than South. Utilising research on Global North situated pollutants and impacts may lead to strategies that are inappropriate and even detrimental to the Global South, with differing pollution profiles and/or environmental risk. In addition, to effectively address pollution, efforts must equitably include the views and knowledge of the diverse communities around the globe, given that pollution does not respect political borders. Therefore, it is essential to involve as many stakeholders as possible and to explicitly acknowledge the impact that global resource inequalities have on this data imbalance. While it may not be feasible to include everyone, prioritizing diversity and the representation of diverse perspectives helps to mitigate biases and address existing disparities more fairly. This paper examines the critical importance of meaningfully including Indigenous Peoples and local communities in CEC research and outlines specific actionable recommendations to facilitate their inclusion throughout the research process. Drawing on best practices in equity, diversity, and inclusion, the discussion emphasizes the necessity of collaborative approaches that respect indigenous and local communities' rights and self-determination. This is not only a matter of social justice but a necessity for acquiring representative global data and developing effective and equitable pollution governance frameworks. Specific recommendations to achieve this aim are made in four key areas for scientists and policy makers working on CECs: (1) Understanding the context and adapting sampling processing and analysis accordingly; (2) respectful and equitable collaborations, ensuring Indigenous Peoples and local communities views are respected; (3) funding and mechanisms for fair and equitable collaborations, recognition and transparency; and (4) sensitive language and narrative use, where we argue that the language used within CEC research and policy must be carefully considered to address the underpinning discourse based on capitalist and colonial ideals which sustains the global CEC data imbalance. This will lead to more globally comprehensive data that in turn informs more equitable global policy to address CEC pollution.

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Sustainability spotlight

Addressing pollution from contaminants of emerging concern (CECs) is directly linked to SDG3, SDG6, SDG11, SDG14 and SDG15. However, there is considerably more CEC data available for the Global North than South. To effectively address pollution, efforts must be truly global and equitable, given that pollution does not respect political borders. Therefore, it is key to include all stakeholders and their diverse knowledge systems and address the role that global resource inequalities has on this data imbalance. This paper examines the critical importance of including Indigenous Peoples and local communities in CEC research and provides specific recommendations to achieve this. This inclusion is not only a matter of social justice but a necessity for acquiring representative data and developing effective and equitable pollution governance frameworks.

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1 Introduction

The United Nations Environment Programme (UNEP) report 'Making Peace with Nature' highlights pollution as one of the world's most urgent challenges, as it drives biodiversity and ecosystem damage and presents human health risks.[1] Contaminants of emerging concern (CECs) are among one of the most pressing pollution issues currently affecting human and environmental health globally.[2] CECs include personal care products, human and veterinary pharmaceuticals, natural and synthetic hormones, synthetic polymer particles and natural fibres (including micro/nanoplastics), engineered nanomaterials, poly-and perfluroalkyl susbtances (PFAS), pesticides, antibiotic resistance genes and bacteria.[2,3] They are ubiquitously found in the environment, mainly due to treated and/or untreated wastewater discharge from municipal, agricultural, aquacultural, and industrial processes;[2,4,5] as well as the reuse of organic 'wastes', including wastewater sludge, animal manures and slurries, as soil amendments.[3,4,6] CECs represent a significant ecotoxicological threat, affecting food systems and the wider environment as well as the health of people.[2,3,5] Examples of ecotoxicological threats include the presence of microplastics in soils obstructing water and nutrient plant uptake[7] and bioaccumulation of the pharmaceutical diclofenac leading to the decline of vulture populations.[8] CECs have been linked to human health risks, for example the carcinogenic, metabolic, hepatotoxic, immune, and neurodevelopmental effects associated with PFAS exposure and the identification of pesticides such as glyphosate and malathion as probable or possible carcinogens.[3] In addition, the environmental presence of antibiotics and other CECs, such as preservatives, disinfectants and biocides have been shown to contribute to the development of antimicrobial resistance (AMR).[9] AMR is a rapidly escalating global health emergency that undermines the effectiveness of antibiotics, increases disease transmission, and is estimated to have contributed to approximately five million deaths in 2019.[10,11] The often indiscriminate use and improper disposal of antibiotics in human medicine, agriculture, and animal husbandry are major drivers of AMR.[12–14] Addressing CECs pollution is therefore directly linked to achieving several United Nations Sustainable Development Goals (UN SDGs), in particular SDG 6: Clean Water and Sanitation, SDG 11: Sustainable Cities and Communities, SDG 14: Life Below Water and SDG 15: Life on Land, SDG 3: Good Health and Well-being.

To address any challenge, it is first necessary to understand the system with data that is representative and global CECs pollution is no different. However, data availability is not representative of the global situation, with considerably more CECs data available for the Global North (GN) than the Global South (GS). In this article, pharmaceuticals are presented as the most frequent example of CECs, reflecting the greater availability of data on pharmaceuticals relative to other classes of chemicals. Nevertheless, the issues and recommendations discussed are broadly applicable to all CECs. For example, despite the majority of people living in Asia and Africa, most CECs research have focused on North America and Europe (≈75%).[15] In 2016 a key downloadable database of measured environmental pharmaceutical concentrations presented 100 times more entries for Western Europe, compared to Africa,[16] and nearly ten years later the situation remains similar, with considerably less GS data on CECs environmental presence.[17–22] In addition, the data that is available for the GS tends to focus on fewer CECs classes, namely pharmaceuticals, natural and synthetic hormones, PFAS and pesticides in water.[17–22] Utilising research on GN-situated pollutants and impacts may lead to strategies that are inappropriate and even detrimental to the GS, with differing pollution profile and/or environmental risk.[23] The detrimental effect to the GS when the voices from this region are underrepresented has been clearly defined in other environmental issues, such as electric vehicles (EVs), which reduce air pollution in affluent areas (mainly in the GN). However, the mining of metals for EV batteries has detrimental social and environmental effects elsewhere (mainly in the GS).[24,25] For CECs research, an example would be utilising global resources to address the presence of a pollutant measured in the GN and shown to have an effect in a GN species, which would reduce the capacity to effectively address pollutants that may remain undetected in the GS,[23] or have different effects on species key to a specific GS ecosystem. Therefore, to effectively address CEC pollution, efforts must not only remedy the existing data imbalance but also, as we argue herein, ensure the equitable inclusion of diverse knowledge systems. This requires coordinated action that actively incorporates the perspectives, expertise and knowledge of communities worldwide.

Recognizing this urgent need for coordinated action, the UNEP established the Expert Panel on Chemical Pollution in 2023.[26] This panel brings together leading scientists, policymakers, and stakeholders to assess the risk posed by chemical pollutants, and to provide evidence-based recommendations for global policy and intervention strategies.[27] However, to achieve more representative CECs global data, it is crucial we understand the reasons behind the current data imbalance. These can be traced back to capitalist and colonial practices. The relationships between capitalism and coloniality with pollution are multifaceted topics, which have been extensively covered elsewhere.[28–30] Capitalism can be understood as 'where growth and profit are put before environmental costs'[29] and coloniality can be simplified as 'control by a group of people over a different land, people and/or culture'.[30] These have led to the control and management of knowledge by "universals" of Western modernity, Eurocentrism and global capitalism on to non-Western peoples and territories.[31] It is important to note that colonial practices may occur within the same country by a more powerful group towards a more marginalised group.[30] In addition, colonialism is 'not a historical bad action', but a 'set of contemporary and evolving land relations that can be maintained by good intentions and even good deeds'.[29] For example, higher pollution profiles in the GS are frequently attributed to less stringent environmental regulations or weak enforcement in these regions. However, it is important to recognize that this is a global issue, since the demand for products associated with such pollution is often driven by countries with stricter environmental regulations.[32] Affluent areas mainly in the GN, have increased global consumer goods demand, with associated production and natural resource extraction frequently taking place in poorer areas of the GS, often with devastating local environmental and social consequences.[33] This phenomenon is referred to as distant environmental and socioeconomic interactions (Liu *et al.*, 2013). Within the CECs context, pharmaceuticals illustrate a notable paradox: while delivering health benefits in one location, they can simultaneously cause detrimental environmental effects elsewhere. To date, CECs research has largely neglected such distant environmental and socioeconomic interactions, as well as the underlying social inequalities and colonial legacies that shape them. This approach goes against the UN SDGs, in particular SDG 10 (Reduced Inequalities).

Pollution does not respect political borders and has been shown to disproportionally affect vulnerable groups globally. For example, in 2017 the Lancet Commission on Pollution and Health found pollution, especially in the GS, to be the largest environmental cause of death and disability in the world.[32] Colonial legacies often result in IP and local communities having the least negative environmental impact but suffering the most from environmental damage.[34] Colonisation has also resulted in Western culture and standards within academia to be considered superior to IP knowledge systems.[28] However, recent policies and scholarly works have recognised IP knowledge systems as a set of valuable skills, practices and custodial responsibilities passed down intergenerationally and which are key to address current environmental challenges.[35,36] IP have historically engaged in precise and accurate observations of natural phenomena, which allowed them to gain a deep understanding of earth systems, such as changes in climate and water quality.[37] However, this information remains an unexplored source of accurate, *in situ*, high-level data.[36] In addition, local communities often hold a wealth of knowledge about the local environmental problems which are key to effectively addressing pollution issues.[38] To address the global CEC data imbalance, it is key that efforts include all stakeholders and their knowledge and that the scientific community and policy makers working on CECs address the role that global resource inequalities and the bias towards Western-centric knowledge has on this data imbalance.

Country- or region-specific legislation on CECs environmental presence is limited to Europe, Japan, Australia, U.S.A., Canada, China, Brazil and India;[39] and global regulatory frameworks are based on the data available,[40] which is predominantly of the GN.[17–22] To truly achieve equitable sustainable development, IP and local communities' knowledge must be included from the onset of CECs research and policy-making through to implementation and long term regulation compliance.[1] It is important to note that inequality is interlinked throughout the UN SDGs, and without addressing this issue other interrelated pollution goals cannot be achieved. Therefore, this paper examines the critical importance of including IP and local communities' knowledge systems in CECs research, and provides specific recommendations to achieve this. We argue that this inclusion is not only a matter of social justice but a necessity for acquiring representative data and developing effective and equitable governance frameworks. This will lead to more globally comprehensive data that in turn informs more equitable global policy to address CECs environmental pollution.

2 Challenges in understanding and addressing global CEC pollution

To address the global data imbalance regarding CECs, it is essential to recognize the technical challenges associated with collecting CEC data in low-resource and/or challenging settings. For the purposes of this discussion, challenging settings refer to locations that are remote from cold storage facilities or from laboratories equipped with the analytical capacity required to detect CECs. The process of measuring and detecting CECs in environmental samples consists of two main stages: sample preparation and subsequent analysis. Sample preparation is the physical manipulation of the environmental samples to extract and concentrate the CECs and typically involves solid-phase extraction, liquid–liquid extraction, ultrasound-assisted extraction, microextraction techniques such as microextraction by packed sorbent, solid-phase microextraction[5] or digestion for the removal of organic matter.[41] Analysis refers to the measurement or detection of the CECs using an analytical instrument such as Liquid- or Gas-Chromatography Mass-Spectrometry, Nuclear Magnetic Resonance Spectroscopy, Enzyme-Linked ImmunoSorbent Assay, Fourier Transform Infrared Spectroscopy.[5] The required analytical equipment, such as Liquid- or Gas-Chromatography Mass-Spectrometers, are expensive to acquire and maintain and often geographically disparate to sampling, preparation and analysis locations. This has partly led to samples being collected and prepared in GS study locations and shipped to GN countries for analysis, sample preparation or both. This offers one explanation as to why many GS-based case studies are published with a GN collaborator. However, there are many instances where sample preparation and analysis location are not specified. This ambiguity has data interpretation implications such as consideration of analyte stability, due to the challenge of maintaining cold storage over long-distance shipping, but there is also a transparency issue. The transparency issue lies in there often being an ambiguity as to which part of the sample preparation and/or analysis was carried out in which location. Additionally, the higher analytical capacity of the GN leads to an imbalance, favouring GN collaborators in GS-based studies, in terms of GS studies often having a GN collaborator, but not the other way around. This may be due to reduced or not easily accessible analytical capacities in the GS, but without clarity and specificity on where samples are being prepared and analysed, this cannot be determined or addressed.

A GN collaborator is sometimes included in research projects due to language barriers and the necessity to publish in English; this often benefits GN academics by increasing their publication output. Interestingly, university theses, water body management and monitoring reports proved a valuable resource of GS monitoring data, yet are rarely incorporated into published CECs review articles.[16] Language barriers and the costs associated with publication are among the key factors contributing to this exclusion. At its core, the challenge is that research funding and publication processes are governed by the GN, which has standards that are not always possible to meet or even relevant elsewhere.

In addition, CEC research in the GS has predominantly focused on collecting and analyzing aqueous samples instead of solid samples, *i.e.* the presence of CECs in surface water samples, and groundwater, tap/drinking water is better documented than their presence in soils/sediments.[17–22] Consideration of regional specific exposure scenarios is urgently needed. For example, pit latrines, communal public sanitation, and septic tanks are common GS sanitation scenarios, however the occurrence, dissemination, fate, and human health risks of CECs in these environments are understudied.[42,43] In order to address this, it is fundamental that tools for detecting and quantifying CEC pollution are directly controlled by IP and local communities and that pollution monitoring efforts truly integrate their environmental understanding.[36] This calls for improved mechanisms to share knowledge, science, and data between IP and local communities and scientific research.

The path from environmental monitoring to remediating pollution, including regulation and good governance, presents a myriad of challenges, intersecting social interactions, environmental protection, and public health and involves varied stakeholders and knowledge holders, and the diverse knowledge systems they represent.[36,44] While existing frameworks provide some oversight, and despite many advances (for example the inclusion for the first time of the Indigenous and local knowledge systems in Global Environmental Outlook (GEO-7) report the UNEP-EAWAD), there is a growing recognition that a more holistic and inclusive approach is required. Yet, most policies are largely based on approaches and shaped by discourses from specific GN spheres excluding other's perspectives and knowledge systems, including IP and local communities knowledge, observations and practices.[36] These issues have been discussed in the context of environmental justice,[45] however this seems to have gone largely unacknowledged within the field of CECs where colonial practices which go against the principles of environmental justice often prevail.

3 Opportunities and recommendations for CEC research to address the data imbalance

3.1 Scientific community

3.1.1 Understanding the context and adapting sampling, processing and analysis accordingly. • Work alongside IP and local communities from the onset, from the identification of the pollution issue through to environmental monitoring and analysis,[38] to understand and address environmental issues they have observed and develop and implement sampling strategies which truly address local environmental issues.[36,38] Frameworks, such as co-creation of research and community-based participatory action to achieve this have been developed, and recent pollution case studies with practical advice are available in the literature.[38,46]

• System thinking is a way to understand patterns of change in terms of underlying, self-organising interrelationships.[47] This approach, alongside interdisciplinary and trans-disciplinary approaches, such as participatory methods often used in social sciences and humanities described in the previous point,[38,46] can help avoid linear thinking within the complex system of environmental pollution and more effectively include diverse knowledge systems,[36] including those of IP and local communities, in order to gain a richer, more nuanced understanding of pollution which in turn allows for more applicable solutions.[44,47]

• Evaluate which CECs should be analysed for each site. One approach is linking an understanding of physicochemical properties (*e.g.* volatility, degradability) to whether it is regionally used/prescribed, along with local knowledge of pharmaceutical consumption (which may differ from official sources) and which can be obtained through approaches such as community engagement.[48,49] Other complementary tools are untargeted analysis in understudied locations to avoid bias of looking for pollutants previously found in the GN[23] and modelling frameworks which can aid in prioritizing analytes.[50]

• Understand local waste/water flows, water use and reuse, treatment (if any) and natural attenuation, especially when analysing environmental risk and making recommendations for water use, reuse, mitigation or treatment. Again, local community input to understand this is essential and can be obtained through community engagement,[48,49] co-creation of research with key stakeholders[38,44] and valuing social sciences approaches equally to those from natural sciences.[44]

• Consider analytical innovations that limit/remove sample processing and/or enable on site analysis. For example, passive samplers and sensors are low-cost and rapid.[51]

• Use environmental quality standards (EQS) and predicted no effect concentrations (PNEC) that are site-specific or for species IP and local communities have observed to be key for the health of the local ecosystem or of particular sociocultural importance.[36] When there is little data on CECs presence and potential affected species, approaches to prioritise CECs based on their potential toxicity[52] as well as species sensitivity distribution[53] can be used to focus efforts.

• When samples are collected and/or prepared in one location and then analysed in another this must be clearly specified to address authorship transparency and to be able to identify and address the greater analytical capabilities in certain locations compared to others. In addition, when samples are transported for long periods of time there must be consideration of analyte stability to ensure the reliability of data from remote locations.[54] This can include the use of deuterated standards, however the high cost of these chemicals can be prohibitive. Therefore, other measures such as cold storage during transport and spiking a subset of samples with a known amount of the nondeuterated analytes to account for potential losses due to analyte degradation during transport can be employed.

3.1.2 Respectful and equitable collaborations, ensuring IP and local communities' views are respected. • Free Prior and Informed Consent (FPIC) must always be applied when working in lands belonging to IP. This is a human right under international law detailed in the UN Declaration on the Rights of Indigenous Peoples[55] and the Nagoya Protocol.[56] FPIC includes acknowledging their rights to control, manage, and benefit from their knowledge and resources and is not only a matter of social justice but a foundational principle for equitable and effective environmental governance.[36] Despite recognised challenges in achieving FPIC, it is certainly possible for anyone wishing to do so[57] and there are handbooks available detailing strategies which have worked in the past and things to be avoided.[58–60]

• Prioritise building trusting and mutually beneficial relationships between the scientific community and IP and local communities, valuing knowledge from both equitably.[36,57,61]

• Samples must be sourced with environmental respect, sensitivity and direct involvement of IP and local communities by following the principles of FPIC.[58–60]

• The holistic understanding of IP and local communities not only encompasses ecological shifts but also extends to chemical governance and environmental monitoring. Their observations and techniques, coupled with their knowledge, provide crucial insights than can enhance modern scientific approaches.[62] Thus, knowledge must flow both ways when working with IP and local communities, going beyond the idyllic concept of including indigenous knowledge, it is necessary to ensure the operationalization of their knowledge and human rights perspectives and environmental justice discourses.

• Communication must remain open longer term to understand and manage pollution presence and effects, including IP and local communities and scientific knowledge as equally valuable.

• Local people must be hired for as much of the sampling, sample preparation analysis of CECs environmental presence as possible. This will aid in understanding and respecting local values and customs, however efforts must be made to ensure this is the case beyond the hiring of local people.[63] In addition there must be recognition of IP and the local community when their knowledge or samples are used for the production of scientific outputs through authorship.[62,64,65]

• Where a GN country is involved with GS environmental monitoring, there must be clear recognition and benefit for the local researchers and wider community from where the samples originate.

3.2 Policy makers

3.2.1 Funding and mechanisms for fair and equitable collaborations, recognition and transparency. • Scientific papers and funding calls are often judged on 'novelty'. Much needed CECs data from the GS would not be acquired using novel techniques, however understanding the pollution profile of understudied GS locations would be of immense value and novelty in the pursuit of obtaining more representative global CECs data. It is important for funding and paper reviewers to understand this, as otherwise important work to address this knowledge gap does not get funded or outcomes disseminated.

• To reduce technical disparities, grants should consider supporting researcher training and set up/expand local laboratories to accommodate analysis (*i.e.* not only sample extraction and analysis elsewhere). Funding opportunities that are multi-country could include equipment in the country of focus and in the hands of IP and local communities,[36] however care must be taken to consider situations on a case-by-case basis to ensure funding is better aligned with local needs and capacities and should be designed in close consultation with local stakeholders.[66] In addition, training in the GS must encompass solving real-world pollution problems, rather than only focusing on pollution monitoring.[67–69]

• Funds should be available for translating research to English to ensure knowledge in other languages can impact the scientific community and policy.[62]

• Global mechanisms must actively foster the integration of IP's earth observations and understandings into environmental monitoring and mitigation strategies for CECs.[36]

3.3 Scientific community and policy makers

3.3.1 Sensitive language and narrative use. The following recommendations are not specific to addressing the global data imbalance in CECs research but are key considerations to address the underpinning discourse which sustains this imbalance.

• The terms 'developing' and 'developed' countries construct a false narrative where the concept of 'development' justifies actions and policies grounded on the assumption that pure economic growth leads to a reduction of human poverty; however 'development' has often led to the destruction of the natural environment and social relations.[70] In general, the assumption is that the GS needs 'modernisation' to become 'developed', aided by expertise from the GN.[70] This leads to an assumption that 'developed' countries have superior environmental practices, when IP and local communities are often more respectful of their environment.[35] Efforts have been made with terms such as 'GN and GS', however we must remain conscious of their binary nature. For example, IP and local communities are present in both GS and GN countries and the term GN often refers to the powerful spheres in this region without necessarily representing the views and interests of all its communities. Moving away from juxtaposing terms could lead to discourse enabling language that is better placed to recognise who is considered an expert, whose knowledge is valued, and who is looked at for solutions.[71]

• High pollution concentrations in the GS are often explained by limited regulation, poorer/lacking treatment infrastructures, and higher disease prevalence.[32] These statements neglect the root cause of these problems. It is necessary to put these issues in the context of historic and current global power and economic dynamics.[29,30] Otherwise, these statements are superficial and perpetuate colonial views, even when this is not the intention as there is an underlying assumption that the GS should 'follow in the path' of the GN.

The need to address pollution challenges with sensitivity and consideration towards IP and local communities has been highlighted previously,[1] yet within CECs research has rarely been addressed. We believe that if those working at the science–policy interface understand the historical legacies of colonisation and environmental harm in the name of 'development', it is possible that small actions within their fields will pave the way towards a more equitable tackling of global environmental pollution.

Data availability

Data sharing not applicable to this article as no datasets were generated or analysed during the current study.

Conflicts of interest

There are no conflicts to declare.

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