Utilising the critical zone concept in interdisciplinary research

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Background

Representing the interface between the atmosphere and the world's surface, governed by a complex and interweaving array of physical processes, biochemical processes and human activities on various scales, the critical zone is home to the vast majority of terrestrial life. It is a complex entity best comprehended by means of interdisciplinary research. Although various disciplines of earth sciences and life sciences have begun to join forces, interactions between environmental sciences and the human and social sciences are less advanced. Using the example of water management in El Alto, Bolivia, this study demonstrates how geosciences and social sciences can strike up a productive dialogue and generate new, useful knowledge, proposing solutions to mitigate the impact of climate disruption and human activities.

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Further reading

Hardy S., Robert J., 2021 – Entre grand système et alternatives d'approvisionnement en eau à Lima et La Paz. *Echogéo*, 57.

Archundia D., Duwig C., Spadini L. et al., 2017 – How uncontrolled urban expansion increases the contamination of the Titicaca lake basin (El Alto – La Paz, Bolivia). *Water, Air and Soil Pollution*, 228 : 44.

The critical zone of El Alto studied from a geoscientific perspective

Located in a semi-arid part of the Andes, El Alto is Bolivia's second most populous city. In this zone, the availability of water resources is at the heart of various challenges such as climate instability, tensions between different water uses and the pollution they cause. Within this context, and from a geophysical perspective, it is fundamental to quantify and qualify this essential resource by modelling the flows of water and contaminants, as well as the availability of surface and subterranean water. Utilising the critical zone concept, researchers are able to detect contaminants and track their migration through the waters and soils of the drainage basin, predicting their future impact on socio-ecosystems. For example, surface water flows are intermittent in this semi-arid, high-altitude climate, and some rivers contain exclusively treated and untreated waste water during the dry season. The hydrographic network downstream of human activities is contaminated with various nutrients (nitrogen, phosphorous, carbon), coliform bacteria and pharmaceutical

The task of securing the drinking water supply in the Katari drainage basin requires some major changes to the way waste water from human activities is managed, since it is often simply pumped out without being treated, sometimes in direct proximity to inflow valves.

residues. DNA sequences associated with antibiotic resistance (sulfamethoxazole) have been found across the entire basin, and even in Lake Titicaca. Furthermore, the city of El Alto sits atop a sizeable aquifer contained within Quaternary-era rock formations composed of fluvio-glacial sediments. This aquifer is replenished primarily during heavy rains in January and February. It is already being affected by contamination from the city, and downstream of El Alto we find greater concentrations of nitrates and chlorides, as well as sulfamethoxazole. However without a clear understanding of the sources of these contaminants or the different soil and water uses, it is impossible to determine the recommended management practices which are both environmentally sound and commensurate with socio-economic realities on the ground.

The need for a geographical perspective

For the geographers working in this zone, analysing the vulnerabilities in the water supply in order to plan ahead for future crises is first and foremost a matter of studying water availability and potential threats to this availability. Pollution generated by local people, particularly the release of largely untreated domestic, industrial and agricultural waste water, both upstream and downstream of El Alto, has a major impact on the water found in the aquifer beneath the drainage basin. Mapping this pollution also serves as a means of raising awareness among stakeholders, and considering potential solutions. Mapping begins with the creation of a geolocated database of activities, which are then sorted by criteria including source (heavy industry, pharmaceutical and chemical industry, mining, industrial agriculture etc.), size, location in relation to waterways and wells, aquifer replenishment points, or upstream/downstream of water resources. Although it does not include undeclared activities – which account for up to 80% of total activity in Bolivia – this census of formally-declared activities, compiled by the La Paz chamber of commerce and industry, constitutes a valuable base from which we can work, and which can be enriched with data gathered in the field. Undeclared activities tend to be influenced by spatial dynamics, springing up close to declared activities for reasons of complementarity and logistical synergy. Approximate though it is, this mapping exercise thus provides a broad outline of the location of polluting activities, which can be improved as stakeholders continue to use it and build on it.

Cross-pollination of knowledge: 1+1 = 3

The data and results generated by researchers in geosciences and social sciences regarding land usage and trends, the geolocation of pollution sources and their circulation within the aquifer, at different temporal and spatial scales, can now be shared and analysed using the critical zone as a conceptual framework. The advantage of this approach is that it allows for a more detailed understanding of vulnerabilities in the available water supply. The aim is no longer to ascertain the quantity of water in the aquifer, but rather to determine whether or not this water is available for use in human activities, based on the circulatory dynamics of the water and associated contaminants. Pooling results from different disciplines in this manner can help us to better understand and anticipate the feedback mechanisms at work in the water cycle, with creeping anthropogenic pressures on the one hand and climate change on the other (see illustration). It also allows us to create *scenarios* which better reflect the reality of societal interactions with the critical zone. Furthermore, cross-analysing these data enables us to provide stakeholders (ministries, water agencies, municipalities) with more finely-targeted, and thus more effective, solutions. This targeted approach makes it easier to achieve a fair compromise between resource exploitation and conservation in the long term, identifying milestones for a road map for future actions which will be acceptable to all. Examples might include: optimizing the aquifer's replenishment zones, introducing regulations to guarantee the quality of the water in these protected zones, identifying waste water categories which need to be treated etc. Actions conducted in a spirit of consensus may be more readily accepted, since they focus on the shared interests of the different users of the resource. Finally, involving stakeholders with results also provides a means of mobilising them to facilitate research work, for example by helping with population census operations and ensuring access to key measurement points (community wells), or even setting up observation networks and participatory management methods. This inter-disciplinary research raises a number of exciting questions still to be explored: how can the concept of the critical zone and its inclusive management help us to translate results produced by different scientific disciplines into a single, unified result? And by the same token, how can we transfer the benefits of these results to stakeholders with diverse interests, encouraging them to seek out solutions which are not only sustainable, but also acceptable to all? And in return, how can stakeholders facilitate the development of our understanding of the critical zone?

KEY POINTS

One of the strengths of the critical zone as a concept is its capacity to unite researchers from different disciplinary fields in pursuit of a shared objective, with a view to improving our understanding of this zone by taking full account of the multiple interactions between the environmental milieu and human society. It thus serves to bring various questions, results and solutions into focus, some of which may be directly pertinent to stakeholders. It falls to the latter to resolve the problems arising from environmental-societal interactions, which are starting to be felt severely in El Alto, in a high-altitude region with a semi-arid climate which is under pressure from multiple angles.

SUSTAINABILITY SCIENCE

UNDERSTAND, CO-CONSTRUCT, TRANSFORM

Volume 2

Collective thinking coordinated
by Olivier Dangles and Marie-Lise Sabrié

IRD Éditions

French National Research Institute for Sustainable Development
Marseille, 2023

D2S follow-up of the articles: Claire Fréour and Magali Laigne
Editorial coordination: Marie-Laure Portal-Cabanel
Cover: Charlotte Devanz
Design and layout: Aline Lugand

Cover photo: Rock painting, Cueva de las Manos, Argentina.
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PDF version ISBN: 978-2-7099-3003-1