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What is a successful environmental geochemical study?

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ABSTRACT

A successful piece of applied research will not only influence the related problem perception within the scientific community, but also lead to much better understanding of a complex challenge, including the delivery of solutions. Ideally it may contribute significantly to reducing possible risk situations for people and/or the natural environment. In short, a successful study will have a broader impact beyond the sphere of science. Planning, timing, funding, networking, communication, and interdisciplinarity are identified as key aspects for a successful project and are being examined in their scope and boundary conditions, while not neglecting the particular role of local and regional people and authorities.

Defining what makes a successful environmental geochemical study is clearly based upon experience and evidence found, and not upon any particular theoretical concept. Here, experience is drawn from the outcome of many projects and specifically first-hand from the complex ARSENEX project in Minas Gerais, Brazil. Against the backdrop of both perceived and real arsenic contamination of environmental compartments, including local people, all subsequent project steps and proposals were set up using a three-prong approach that sought to a) understand the processes, b) educate and inform the public and all other stakeholders and c) remediate the situation.

1. Introduction and thematic scope

Most, if not all, scientists are eager to present meaningful and successful research results and related stories. Yet, what makes a study become a success? And how should such accomplishment be defined? While many colleagues would certainly argue that scientific impact hinges on publishing in high-ranking journals and appreciable citation numbers, which hence denote achievement, we take a slightly different stance here without neglecting the previous argument. This approach to evaluate success is inapplicable to basic research in any science, but appears useful to any applied studies that need to directly deal with the interface to society, especially to environmental geochemical projects. A successful research work will influence not only the way the scientific community perceives an issue, but also lead to much better understanding of it. The study may provide improvement through paradigmatic examples or contribute significantly to reducing possible risk situations for people and/or the natural environment. In short, a successful study will have a broader and measurable positive impact.

Environmental studies often do touch at least several interfaces with society and human living conditions. More often than not (in cases where this applies), the people involved represent all levels of society. Yet the conditions of those that live in the study areas, often characterized by significant geochemical anomalies, may be subject to poverty and limited access to resources such as education, health care and other infrastructures (Fig. 1). When scientists work in such settings, the question arises whether there are wider implications of the study for the surrounding community or environment? The local people involved often perceive incoming scientists with a bias, similar to a company that wishes to invest in, to explore or to exploit and use natural resources – and accordingly, local people immediately develop expectations towards such scientific projects. The concept of scientific work as 'art for art's sake' is generally foreign to them. In consequence, they may even hinder or counter the effort of scientists, which can take even more radical forms such as destruction or theft of scientific infrastructure.

An environmental scientist and a chemical and environmental engineer have written this paper. The authors attempt to venture into the realm of meta-science – analysing the core question of this

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Fig. 1. Poverty can express itself in living conditions with limited access to resources such as education, health care and other infrastructures. The picture shows standard conditions in a rural house in Minas Gerais.

paper from the perspective of independent evaluators – with all inevitable bias. This contribution is based on roughly 30 years of work experience in various African (Cameroon, Ghana, Namibia, South Africa), Asian (India) and Latin American (Brazil, Chile, Peru) countries. This includes mostly areas where social contrasts have been rather high at the time and location of the studies. More importantly, the understanding gained in a ten-year project in Minas Gerais, Brazil (1998–2007) is exemplary for the understanding of favourable outcomes from environmental geochemical work (Deschamps and Matschullat, 2011a). Following a project description to deliver some specific insights, five key aspects will be critically discussed, namely planning and timing, funding, networking, communication, and interdisciplinarity. The discussion is clearly based on experience and evidence found, and does not claim to be based upon any particular theoretical concept. We found it hard to find publications that elucidate the topic (e.g., GIZ, 2015; Liverman et al., 2008, and references therein), making this contribution more of a discussion rather than a true review paper.

Considerable expertise has been gained from environmental geochemical studies and particularly arsenic-contamination-related cases in Brazil as well as examples in Argentina, Bangladesh, Chile (Ferreccio and Sancha, 2006), China (Sun et al., 2001), India (Caussy, 2003), Inner Mongolia, Taiwan, and the USA (Anderson et al., 1999) to name but a few. When reviewing the plethora of related activities and publications, Bangladesh appears to serve as a global icon of arsenic pollution. Yet, it is surprising how little success in respect to feasible solutions is visible, given the still ongoing studies (Davis, 2001; Hanchett et al., 2002). One of the lessons learnt in Bangladesh appears to be that the health sector should take the pivotal role and that community participation is necessary for any sustainable public health program (George et al., 2013; Milton et al., 2012). An expanded and improved public education programme is essential to ensure that the Bangladesh public, especially the less educated, will benefit from future technological improvements. The bottom line, however, appears to be that rather little is known about the set-up, philosophy, management and success of such projects and that generally speaking, hardly anyone seems to have investigated the success-and-failure factors of such projects. In this respect, everyone involved in the ARSENEX project in Brazil have all been through a steep learning curve largely due to the constellation of participating colleagues and their individual experience. While that was certainly more or less coincidental, very practical recommendations for successful future projects can be distilled from the knowledge gained.

2. The setting – evidence from the ARSENEX case study

Mining has a long history in Brazil; namely in the state of Minas Gerais, where gold mining on placer deposits commenced in the late 17th Century during the Portuguese rule. The exploitation of primary hydrothermal gold mineralization started in the mid 18th Century, strongly influenced by British know-how and interests. A growing array of mined minerals rapidly became the state's and Brazil's key export item and the base for modern Brazilian development (Meneses et al., 2011). Most of the early gold mining has been taking place in the Iron Quadrangle to the south of the state capital Belo Horizonte (Almeida et al., 2011, Fig. 2). The hydrothermal deposits are very rich in arsenic minerals and the arsenic concentration in the mined primary ore is between 0.8 and 8.0 mass-% As (Matschullat et al., 2000). Disquieting news about As-poisoning risks for people in Bangladesh, West Bengal, and various other places (Chappell et al., 1994; Smedley and Kinniburgh, 2002) further strengthened the interest in elucidating the situation in Minas Gerais and its underlying processes of possible As-pollution.

The idea for the research project, later named ARSENEX, was conceived in 1997. Due to the regional mining history and the many well-known boundary conditions, there was an obvious dispersion of mining residues that likely contained arsenic in various bonding forms that were perceived as a potential risk and a promising study object. Preliminary studies from the State University of Campinas (UNICAMP) under Prof. Dr. Bernardino Figueiredo and by the British Geological Survey (Rawlins et al., 1997) suggested As-related environmental problems near mining sites in the Nova Lima district (Fig. 2b,c). Their results motivated a "closer look" and posed the question as to whether any As-contamination might have consequences for human health in the vicinity.

From 1998 to 1999, UNICAMP developed a pilot-project in partnership with the Minas Gerais Environmental Agency (FEAM) and the Minas Gerais State Health Service (FUNED), as well as with two German partners, the Baden-Württemberg State Health Agency in Stuttgart, and the lead author, then Institute of Environmental Geochemistry at the University of Heidelberg. Three supposedly contrasting areas were selected, representing the oldest industrial Au-mining district in Brazil (Ouro Preto-Mariana; Fig. 2a,d), the more modern and until today intensive mining district of Nova Lima with already known contamination issues (Fig. 2a,b,c), and the supposedly barely influenced Santa Bárbara district as a baseline (Fig. 2e). The latter assumption was soon to be falsified. Different from most related projects, the team developed a multi-media, multi-element assessment and aimed from the beginning to quickly obtain data that should test the hypothesis of widespread environmental arsenic pollution.

The general objective of the ARSENEX project was to detect, understand and minimize As-emissions and fluxes into the environment and their impact on humans, resulting from multiple pathways into the food chain. Specific objectives were to evaluate As-contamination of environmental compartments and human exposure, to correlate the encountered As-anomalies in the environmental and biological samples (including human biomonitoring), to identify the As-liberating processes, to implement analytical methods to quantify different As-species, to identify, test and select regional mineral sorbents for As-immobilization, and to train personnel at all levels from the institutions involved (as well as from the village population) to better understand and combat environmental risks (even beyond the As-related issues;