Sustainable Water Resources Management (2024) 10:5
https://doi.org/10.1007/s40899-023-00983-3

ORIGINAL ARTICLE

Ethical reflections on groundwater in contaminated areas

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Received: 6 June 2023 / Accepted: 7 November 2023 / Published online: 11 December 2023

Abstract

Groundwater science has a well-known relationship with social issues when dealing with risk assessment, yet there is a lack of case studies on the topic. Here, we present reflections for dealing with two ethical challenges: (i) the access and use of public domain monitoring data and (ii) the dissemination of scientific research data and its controversial character. The case study is a long-term collaborative research project aiming to bridge the social and natural sciences to tackle ethical questions and their implications for technical reporting and scientific production in a highly contaminated area situated in Portugal. The method included comprehensive interviews with hydrogeologists within the common project, the consulting of documents and the collaborative analysis of situations in online meetings between sociologists and hydrogeologists. The interviews and formal discussions were recorded, transcribed and analysed. In the two cases related to groundwater assessment in contaminated areas we found that researchers refer to emotions and moral dilemmas when they come into regular contact with social actors. Results also show that a different kind of knowledge is produced in these cases and point to three types of researchers' positionality. The significance of this paper is to encourage reflection and action on ethical issues in the scientific community and specifically in geoethics. Bringing researchers together to share their practice will help to disentangle some of the negative emotions and moral dilemmas of scientific practice and increase the attention researchers pay to other people's points of view and interests so as to improve the robustness of scientific data.

Keywords Groundwater · Contamination · Ethics · Scientific practices · Geothics

> *It is not enough to wave the flag of water ethics through a newsletter, a conference paper, or even this book. For ethics to have a real impact on water decision-making, the field of water ethics needs to have an institutional home or multiple homes. And more than a home, water ethics needs to become a dynamic member of a larger ecosystem of related schools of thought such as environmental justice, resilience, water stewardship, and decolonization. The particular contribution of water ethics, it seems to me, lies in highlighting the value principles within these other normative frameworks, finding commonalities and revealing differences.*
> *Groenfeldt. 2019, p. ix.*

Introduction

In recent decades the scientific community - academics and practitioners - have been increasingly focused on the interlinkage of natural resources, science and ethics. This has been in response to growing tension between science and society and has led more researchers to concern themselves with these connections in their scientific practice. The quote above from Groenfeldt (2019) explains the complexity of the ethics issue since science and society are intrinsically articulated and embedded, and ethics belong to several areas of scientific work. However, the emphasis goes on the singularity of the ethics dimensions that must take into

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consideration social, cultural and historical aspects where the issue is being held, contrasting with a general approach.

Mitcham (2005), a philosopher and sociologist of science, differentiates 3 phases in the assumption of responsibility for science as a key dilemma for professionals. Between 1945 and 1965, during the post-war period, scientists recognised the possible negative effects of their research. In the atomic community, scientists were the first to acknowledge their responsibility for threats and destructive consequences for humans and the environment. The second phase emerged in the 1970s with environmental awareness. As severe damages, such as chemical contamination, desertification and degradation of soils, or the health impact of toxic substances, were acknowledged due to fast-evolving technoscience, scientists started questioning their responsibility. The third and last phase has culminated in the reinforcement of ethics in science and its relationship with society in a context where a lack of public trust became dominant and problematic for scientists, as in the development of biotechnologies. As Mitcham points out, the positive consequence of this is that the scientific community has been forced to examine itself and put its own utility into perspective.

This contextual framework illustrates that the interest in ethics is not neutral and has its own root and motive in a specific setting ruled by ideologies and aspirations that value progress and technology. In a more holistic framework, it is impossible to detach the social from the scientific practices. We will not discuss the many reasons for the complexity of the relationships between science, society and the environment in this paper. We shall rather address the effects of recent research policies referred to by Coutellec (2015) as the economy of knowledge and the pressure for scientific productivism, which takes diverse forms, like the race for papers and results ('publish or perish'), public-private partnerships, conflicts of interest or bibliometric evaluation.

Groundwater and surface water resources as scientific objects reflect the tension between the incentive to produce more, and faster, and engagement, responsibility and ethical concerns - which tend to require a change in research practices. The creation of an international association to promote geoethics in 2012 (IAPG) and the first international conference on geoethics and hydrogeology in 2020 (GEOETH & GWM'20) are two consistent efforts that demonstrate how academics are concerned with these issues. Geoethics is primarily interested in questioning environmental risks that have been identified and made more visible by scientists in recent decades related to climate change, the greenhouse effect, pollution and contamination on the planet (Peppoloni and Di Capua 2012). The movement of the geoethics association and the collaborative conference between geologists and hydrogeologists can be seen as a signal that academics have decided to work for their community and society in general, taking into account the values and interests that underpin behaviours and practices related to water issues (Abrunhosa et al. 2018, 2021). The Cape Town statement on geoethics of 2016 (Di Capua et al. 2017) points out two types of concern. On the one hand, there is the idea that scientists addressing geoscience issues should be aware of the social and ethical implications for society, economics and diverse communities. It is stated that geoscientists deal with the public good, which includes knowledge, rights, access and natural entities that must be preserved for the wellbeing of the Earth and humankind. On the other hand, there is a need for deontological guidelines for professional practice, where values of responsibility, integrity and intellectual honesty are key to responsible practice (Di Capua et al. 2017). Simultaneously, an increasing number of senior scientists are writing scientific papers on the topic of ethics (Bohle 2021). In the groundwater area, the close collaboration between sociologists and hydrogeologists that we have experienced has nurtured common concern regarding ethical issues (Bento and Condesso de Melo M 2021), which is also linked to the general concern of society and researchers for the effects of science on the environment and humans.

In recent decades we have found a considerable number of codes of ethics in science, which demonstrates a will to regulate the behaviour of researchers. Before this wider attention ethics had been a subject of concern and enquiry in sociology, philosophy and history. Merton (1938, 1942), for instance, is an important reference for understanding ethics in science. He explained how inner norms, promoted by academic institutions, constitute an ethos for scientists. They are internalised and regulate the researchers' practice. Specifically, he identifies four main norms: universalism (intellectual), communism (common ownership of scientific goods), disinterestedness and organised scepticism. Together these constitute what he called the 'ethos of science', i.e. institutional logic used by the scientific community to distinguish appropriate from inappropriate values, beliefs, attitudes and behaviours.

Today, in a period where science is expanding its influence in several areas of expertise in public bodies, ethical challenges are no longer restricted to laboratory work or scientific research. Rather they exist in many different aspects of science, including mentoring, education, collaborative research, data sharing, peer reviewing, technical writing and publication, as well as private and public consulting. In fact, we know that education and research activities depend a great deal on cooperation based on shared expectations and understandings (Shanoo A and Resnik 2015). Tensions appear when science is used for political decisions or in public policy. Ethical issues are raised when researchers conduct studies for others that

need their expertise or make discoveries that have direct or indirect - indeed sometimes unexpected - consequences for society and people. Researchers have responsibilities and can be held publicly accountable (Davis 1995). This pushes them to adopt more ethical approaches. Meanwhile, more and more ethical guidelines are recommended for researchers and when applying for international funding (Carvallo 2019).

Furthermore, groundwater research contains a practical side that requires contacts in the field when researchers collect data and need to interact with local institutions, companies, inhabitants and end-users. The purpose may be distant from academic research and urges the need for strong and lasting social relationships. More specifically, groundwater researchers may have an important contribution as consultants for companies with significant economic interests or as experts for the governmental departments with water management and monitoring public responsibilities. In countries like Portugal, where the number of groundwater professionals is limited, the market is often too small to justify a clear separation between public and private sectors of activity. Although these sectors operate from different standpoints, with different strategies and goals, collaboration between academia and the market is frequent. The duplication of roles between groundwater researchers and groundwater professionals leads to ethical dilemmas and for this reason also to geoethical issues. We would like to reflect on the practicalities of doing science in groundwater areas. The urgency of addressing ethics in practice is not new; nor does it concern only water issues; but there is a need to advance our collective consideration of these topics in the scientific community and to discuss them from a more bottom-up perspective. This requires engaged research defined by Coutellec (2015) (p. 19) as a science that 'fully acknowledges its responsibility, that is aware of the need to pay attention to consequences, and that opens up the possibility of questioning its aims'. In this paper, we follow the hypothesis that engaged scientific practices, which involve regular contact with social actors, generate more emotions and moral dilemmas for scientists, especially when the researchers are concerned with forge social relationships with essential partners in the field. These engaged scientific practices are precious experimentations of geoethics that we explore a specific case based in Portugal. The main goal of the paper is twofold: to elaborate on the tensions in contaminated groundwater research, where negative emotions and moral dilemmas are at stake and are reported by researchers themselves, and to discuss the need to reconnect with local actors who have experiential knowledge of contamination because it concerns the quality of data that cannot be produced totally cut off from local experiences if we target scientific and social robustness.

Settings of reflection

The chemical industry, the study area and the collaborative project

The regional and socio-economic background of our reflection is Estarreja (NW Portugal), which has become a pole of industrial development. The Estarreja Chemical Complex (ECC) was founded in the 1940s and started operating with two companies: Amoníaco Português, now integrated into Bondalti, now the largest Portuguese company in the field of industrial chemicals, and a Belgian company with experience in the Portuguese agro-business SAPEC Química, SA, which established industrial units in the region to produce fertilisers for the intensive agriculture promoted by Portugal's dictatorship (1933–1974). Since then, the chemical market grew rapidly and the number of companies increased: Air Liquide, Cires, Bondalti and Dow Portugal. The ECC is now the largest Iberian producer of chlorine and the European leader in aniline salts. The location of this industrial complex can be explained by access to: (1) raw materials; (2) water and energy resources; and (3) road, rail and boat transportation, disregarding the environmental suitability of the area.

The chemical industry produces an enormous range of synthetic compounds, such as PVC, that, while often toxic, are nonetheless widely used and indeed form part of our daily lives to the extent that their existence is generally taken for granted. Some of these compounds are final goods for consumers but most are intermediate products to be transformed by industries, including the chemical industry itself. Many of them are hazardous during their manufacture, transport and use and may affect living organisms, human health, and the environment. As a result of this industrial activity Estarreja has become highly contaminated (Reis et al. 2009; Inácio et al. 2014; Cabral Pinto et al. 2020). The area was vulnerable to contamination due to its position on a gently sloping coastal plain at the lower end of the Vouga River Basin drained by an intricate network of water ditches and with hundreds of wells. To the west, it is surrounded by the Aveiro Lagoon ('Ria de Aveiro'), a coastal lagoon classified as a Special Protection Area (SPA) under the EC Directive on the Conservation of Wild Birds. In terms of groundwater resources, the Estarreja region is part of the Aveiro Quaternary aquifer system (< 40 m) that is highly vulnerable to soil and groundwater contamination due to the shallow water level and lack of confinement of its surficial layers. According to the latest River Basin Management Plans the Aveiro Aquifer is in poor chemical status due to diffuse contamination from agriculture (APA 2022). The ECC is identified as a source of contamination with impacts on the soil and the surface and groundwater bodies.

Modernisation of the ECC over the last 20 years has improved its efficiency and reduced its environmental footprint as required by various environmental impact assessments. Contamination mitigation measures have been put in place (ERASE 2003, 2015), as well as detailed soil and groundwater monitoring programmes (IDAD 2007a, b). All data are regularly reported to the Portuguese Environmental Agency and are publicly available. Nevertheless, significant contamination persists and is a source of hazard for the local water resources and ecosystems, as well as for the health of nearby residents.

Regarding the context of the team of this paper, it is methodologically relevant to situate the analysis of this object of contamination and the nature of the implication that each author had in the study of contamination. Although there is a longer tradition of hydrogeological study to which the second author belongs (Hinsby et al. 2008; Brouwer et al. 2020), the background of the first and third authors is sociology. Their involvement is based mostly on various research projects. The Soiltakecare (INTERREG - SUDOE) project carried out in 2018–2020 aimed to improve the management and remediation of contaminated land in the southwestern European regions of Spain, Portugal and France. Coordinated by geochemists, the project invited sociologists to identify the strengths, weaknesses and driving forces of communities facing pollution. In the case of Estarreja, where the 3 authors were involved, qualitative interviews with stakeholders (about 30) and a quantitative study targeting households (around 300 in Estarreja and in a control group for comparison) made it possible to capture the socioeconomic and health issues of the territory (Levasseur et al. 2021). To be clear: we are talking about an area of contrasts where industrial infrastructure coexists with a rural landscape, and where environmental change only indirectly affects practices unlike contaminated areas in Spain and France where food consumption and water use are clearly linked to an awareness of contamination (Levasseur et al. 2022). Rarely in Estarreja will a citizen avoid local produce, and, even knowing that it is contaminated, farmers and locals use the water from boreholes for irrigation, and in some cases for showers and even cooking. Public debate in the area rarely includes any discussion of environmental risks or uncertainties (Wateau 2018; Bento et al. 2021).

Methodology

The method adopted in this article is primarily qualitative. In the stricter sense this means that it relies on discourses, photos, official reports, emails and media analysis. More broadly the term refers to a means of generating data based on interpretation, paying particular attention to how the social world is produced through discourse and action (Mason 2012). In this study, we collect evidence about how hydrogeologists conduct and interpret their research in contaminated areas involving other actors. Consequently, the qualitative approach provides a framework for a reflexive exercise undertaken by the authors, taking advantage of their scientific backgrounds, which are respectively sociology and hydrogeology in the context of water contamination.

Besides our qualitative approach, we elaborate on a large body of literature dedicated to the understanding of science. Constructivist social studies of science (Latour 1999) provided insight into hydrogeologists' interest in coordinating with sociologists to improve their knowledge of socio-hydrosystems, as well as reflecting on their own practice and the unequal outcomes it can have for the communities affected by their work (Lane 2014; Riaux et al. 2023). We also rely on researchers in geology who have emphasised the need to develop the area of geoethics as a scientific and humanistic discipline (Peppoloni and Di Capua 2012), allowing geoscientists 'to ask questions about themselves, the quality of their work, and their contribution to the healthy progress of humanity' Peppoloni and Di Capua (2012) (p. 335).

Thus, methodologically the paper gives space to a joint reflection between hydrogeologists and sociologists. We use the narratives of specialists — the hydrogeologists — and use their trajectory and story (biography) to reflect on the conditions of the profession, particularly in the ethical sense. In this specific case the method used included comprehensive conversations (interview to Maria Teresa Condesso de Melo was held on 2 September 2021, Instituto Superior Técnico, Lisboa; interview to José Castejón on 23 February 2018 in Cartagena), consulting documents (APA reports from 2015 and IDAD reports) and the collaborative analysis of situations that were held in online meetings between the sociologist and the hydrogeologist from Soiltakecare and Agorarisk (respectively Interreg Sudoe [SOE1/P4/F0023] and funding at International Observatory Hommes-Milieux Estarreja [OHMI Estarreja, Labex DRI-IHM-CNRS], France). The interviews and formal discussions were recorded, transcribed and analysed. We also refer to the ethnographic study of our colleague Gramaglia on chemical research in the Sierra Minera of Cartagena, Spain (Gramaglia 2020) since there were several points in common between the approach of the researcher she had examined and that of our colleague hydrogeologist — a comparison which we judged enlightening.

Results

In this section, we reflect critically on the importance of ethics in how groundwater researchers plan, carry out and disseminate their work, as well as how they limit the reach of science in terms of environmental and human health and societal protection goals. The main ethical question of this

paper does not involve fraudulent data in scientific research, since Merton (1942) referred to these as 'abnormal' situations. However, nowadays, with globalisation, the incentive of finding funding for research projects or the involvement of economic interests, several studies underline the complexity of scientific activity and the existence of strong dilemmas for researchers whenever they must choose to whom to disseminate their data.

Our subject is rather the pitfalls of scientific practices that think of themselves as neutral and detached. Feminist epistemologists (Haraway 1988) now call this weak objectivity, i.e. without an explicit standpoint or with a delusional point of view from nowhere, or a 'good trick'. It is as if researchers could extract themselves entirely from the world in which they are working to observe the proceedings from afar without any retroactive effect on the object of their attention (or responsibility or accountability). Stengers (2013) qualifies this kind of scientific practice, based on the distance between the scientific community, stakeholders and things, of an impoverished imagination and a trap for researchers themselves. This includes researchers being pushed by a paradigm of objectivity and rationality based on factual argumentation to maintain a distance from the inhabitants using the groundwater or soil despite the great potential of outsiders' input and objections to make the knowledge they produce more socially robust. This in turn would make it relevant and accepted by the social actors it concerns and affects. Socially robust knowledge can also be reached through dialogue or the co-construction of experiments, so the scientific data are consolidated collectively and prove useful to the relevant communities (Nowotny 2003).

How to deal with vulnerable humans in the field?

One of the greatest ethical challenges hydrogeologists face is when humans inhabit the area being studied because they must be contacted and asked for permission to access their facilities. Researchers need to interact with them. What does it mean to base research on human contact when you practise hydrogeology? Access to data for a hydrogeologist is much more difficult than for researchers of surface water. For groundwater research, it is necessary to access the borehole, and this implies entering private property with the total consent of the owner. This also means that the objects of analysis are intertwined with the lives of these inhabitants and barely separable from values, culture and uses, or the landscape and physical characteristics of water and soil.

We will anchor our interpretation in two cases of researchers working on contamination: one is related to our case study in Estarreja and includes the testimony of Maria Teresa Condesso de Melo, a hydrogeologist who has worked in the area since 2009 and is a co-author of this paper; the second is José Matias Peňas Castejón, a geochemist and researcher on the site of the Sierra Minera of Cartagena since 2002.

The story of José Matias Castejón is that of a researcher whose scientific career is linked to strong public controversies (Gramaglia 2020). His long-lasting relationships with the inhabitants of the Sierra Minera villages, near an old mining territory located in the region of Cartegena in the south of Spain, where intense exploration of silver, lead and zinc took place, are key to understanding his positioning. Before undertaking a doctoral thesis defended in 2017 (Castejón 2017), Castejón grew up in the area. He studied geochemical processes and for years mapped soils and their uses (Bisquert et al. 2017). His knowledge of the site made him question the circulation of metallic residues. He tracked them until he showed that they disseminate in places where people live, while most of the scientists working in the area preferred to study geochemical processes in tailings remote from dwellings (as they are the most concentrated and protected from too much interference). Realising that they could seep into the interiors of houses, sometimes in even more harmful chemical forms although lower in content, Castejón decided to alert the authorities.

It was only when he was confronted at best with silence, at worst with intimidation, that he realised that these tailings were not just a scientific or technical problem but a social and political one. While other experts would have preferred to continue to treat these residues as limited, he continued his investigation to trace their entire trajectory, from the tailings to the houses to the agricultural fields to inside the bodies of the inhabitants of the Sierra. He decided to test their hair and nails at his own expense. Castejón extended his sampling and built ongoing relationships with the inhabitants. He could then connect his data with their daily lives; the children of friends, whom he met in cafés, played in schoolyards or playgrounds where soil metal concentrations exceeded several thousand ppm. Therefore, he also tried to learn from them, asking about their habits regarding the consumption of wild plants and fruit picking, to gardening, eating and their health status. He took their stories and knowledge into account to adjust his measurements. The authorities' reservations towards his first results only served to exacerbate his indignation, motivating him to pursue his research further.

Analysing the position of the second author, Maria Teresa Condesso de Melo, in reference to the human side of fieldwork, we found that, for our colleague's practice, interacting with the local users and becoming someone to whom they could talk in confidence on matters linked to water issues or health knowledge is a normal procedure. Condesso de Melo has talked about this at various conferences and when teaching classes (Groundwatch Erasmus Mundus): the population's interests and questions are always taken into account in her research. When she describes the way she accesses

fieldwork she connects people to the contaminants in Estarreja — a similar attachment to that identified in the case of Castejón. Here it is the landscape and water from which Condesso de Melo gets clear insight into the spatial extent of contamination and its noxiousness:

> 'The presence of mercury in the Aveiro ria and the contamination issues associated with the Estarreja cisterns we have always heard about; I have no direct connection to Estarreja, but it is very much this connection through the ria. On the other hand, the landscape is similar from Estarreja to Mira. These sand dunes, lagoons, the fact that the groundwater is just a few metres deep, the fact that it's easily accessible - you look in the wells and you see the water - after all the land is very open; you don't find that easily in other parts of the country; you almost don't need to ask permission to access the wells because they are there, everywhere [...] This creates an easy relationship with the population...' (Estarreja, Feb. 2023, Escola Estarreja)

In an interview (2 September 2021, Instituto Superior Técnico, Lisboa) Condesso de Melo referred to two phases of her contact with local inhabitants. The first corresponded to the period when she was a consultant. At that time, she was dealing with a huge amount of information that she could not disseminate for deontological reasons vis-à-vis the company that had requested the study. This was clearly experienced with a negative emotion, giving way to a moral dilemma between the information available and its dissemination to the population.

> 'It's not that I'm very given to protest, but, somehow, I was aware that I could encourage the increased awareness of this population, and I think I was trying to keep a safe distance and that was something that I felt constrained too at the end of the day.' (Lisbon, September 2023, Instituto Superior Técnico)

A second phase began once she had decided to leave her role as a consultant and could connect her knowledge and data with evidence obtained from inhabitants without fear of being unprofessional or breaking a rule of confidentiality. Now she could simply spend time with them, listening to their concerns, answering their questions, even relocating her samplings based on their indications. On some occasions she was moved by what people told her about their bad health status, making her willing to engage in more responsible and accountable research practices as she could not remain indifferent or act unemotionally.

The two cases analysed here reflect the positionality of the researchers regarding the way they face inhabitants in line with the engaged science described by Coutellec (2015). Both researchers deal with the inhabitants in a humanistic manner, whether in Estarreja or Sierra Minera. Condesso de Melo has developed social relationships with certain farmers and local people with whom she has been in contact for over 10 years. This implies spending time in discussion and accepting invitations for a meal. We think that doing research on pollution, particularly, requires social interaction to learn about social practices and uses of potentially risky resources like groundwater. By contrast usual risk assessment is based on estimates and assumptions. In the attitudes we describe about facing social actors while doing fieldwork, we suggest that social relations bring in new, more locally accurate perspectives about how inhabitants understand data. This means a different kind of knowledge can be produced.

How to communicate data from the sampling activity to the inhabitants?

In the previous section, we wanted to highlight the status that researchers of soil and water may assume in relation to other human beings. In this part, we want to deepen this relationship by including the data that field sampling provides to researchers. When taking samples of groundwater, researchers, and sometimes consultants, need to access private wells and boreholes. Analytical results should be provided and explained to the owners, yet the research is not always compatible with this practice. If the results have adverse health effects, it is important that researchers communicate them to the local environmental and health authorities, discuss with them the potential sources and help them to mitigate contamination. In fact, these are the guidelines we can find in a classical handbook. In practice, contaminated areas contain very sensitive information, and this communication raises ethical concerns.

In Estarreja the contamination and its effects have been studied and analysed extensively by the scientific community (Ordens 2007; Reis et al. 2009; Neves 2015; Olowoselu 2018). According to our search on Science Direct webpage (accessed April 2020) the keyword Estarreja leads to more than 181 research papers, 9 review articles and 5 book chapters. If we narrow this to the keywords Estarreja, soil and water, a total number of 95 contributions is reached. Together these research papers provide a huge amount of data that is difficult to integrate because of the different methodologies, objectives and time spans. This is to say that scientific production on contamination is also embedded in uncertainties which are normal in science but critical for communication. As a Unesco (2004) report indicates: 'professional hydrogeologists should transfer the awareness of these uncertainties to decision-makers and the general public'.

However, Condesso de Melo's discourse repeatedly points out the lack of open dialogue about contamination that made her feel uneasy.

> 'You have monitoring data and it indicates contamination, and for me the next step would be that the company helped to identify the potential sources of soil and groundwater contamination. Where, why this is happening? maybe there was a leak there, or there was an accident, and this information is never given. On the contrary, the first reaction was always to try to mitigate the episodes of contamination that we saw indirectly from the results. We never had an open dialogue' (Lisbon, September 2023, Instituto Superior Técnico).

She argues that this open dialogue should exist between the researchers, the consultants and the companies from the chemical complex. Yet many researchers skip this process because they are afraid of facing limitations to their research in the future. In Gramaglia's article (Gramaglia 2020), we can see how Castejón invented new ways to talk about the analyses he carried out on soils. Not only did he write his thesis, but he also organised public demonstrations in his lab and at schools. He showed the presence of lead residues on the hands of younger children at one the primary schools he sampled. He staged an experiment at a junior school to explain the effects of the same residues in an acidic environment such as a stomach (simulating digestion and uncovering bioaccessibility processes that facilitate toxic contamination). He invited parents and families to the university to witness the same. This approach differed from that of his colleagues who had preceded him in the field. They had preferred to avoid contact with local populations for fear of generating social unrest, seeing the provision of information to be outside their remit according to the principle of the strict division of tasks between scientists and risk managers — even if the authorities were failing in their responsibilities in this matter.

In Estarreja, the Citaqua project, funded by OHM Estarreja in 2016 and directed by Daniela Figueiredo (Figueiredo 2016), involved an analogous process to that used by Castejón in schools - with explicit reference to participatory science methods. The sampling of boreholes was carried out by pupils, who brought the samples to school, and their teachers, whose laboratory classes allowed the young people to discover the water's contamination level. A documentary by Giongo and Wateau (2021) (10 mn–10:05 mn; 10:26–12:33; 12:45–13:10 mn) follows the receptivity of the school community to this initiative. Unlike Castejón's experimental sessions, however, it lacks the status of demonstrating the political visibility of the contamination, perhaps because it was not aimed at parents who would be able to mobilise to get the issue on the authorities' agendas. The results remained within the confines of the schools, without any further efforts to make them public.

Concluding remarks

Our paper argues that qualitative approaches can contribute to the study of ethical issues in geological and groundwater studies through the reflection of scientific situations by the researchers themselves. The examples analysed here relate to the access and use of scientific and technical data, and they are based on personal experiences that were considered relevant for ethical reflections. The purpose here was beyond highlighting their capacity to express responsible stories about science, in particular groundwater, without functioning as normative models or ethical principles. The main objective is that those stories work as cases for reflection - one that questions the way science relates to society when potential health risks are at stake and when authorities are not intervening.

In this sense, these case studies surpass an anecdotal perspective; instead, they seek to describe more attentively the conditions and the context of the scientific knowledge production, and they aim to demonstrate the relevance of reflexivity and emotion in science involving direct relations with lay persons. These are questions that researchers and consultants reveal in conversations yet very rarely in papers or documents about scientific outputs. They are mostly experienced away from collective and institutional structures - sometimes in solitude and suffering.

We also observed different ways of practising scientific research. In both examples, science is deeply related to ethics in the sense that each of the researchers we followed here has a precise notion of ethics in their practice. Finally, if we extend our cases (Castejón and Condesso de Melo) to other institutional practices, we might distinguish at least three possibilities. We can identify Castejón as a whistleblower, as defined by Chateauraynaud and Torny (1999): a person, researcher or not, who calls the public authorities to report a risk or a danger. We observe Condesso de Melo with a concern to integrate a social dimension into her research, making the scientific practice more concerned with the social impact of knowledge. A third possibility could exist within an institutional configuration that would allocate time and resources to practise this concern, to include and mobilise other persons in the research. This last configuration could be an invitation to bring together researchers, who, like Castejón and Condesso de Melo, have ethical concerns. If the researchers were to meet each other, they could develop more reflexive and responsible approaches.

Research institutions and funding bodies now request ethical statements from scientists, which include declarations of potential conflicts of interest, equal opportunities for

minority researchers, consent from concerned populations and public access to the results, but we think this should be pushed further. The idea would be that geoethics compel scientists to pay attention to other people's points of view and interests and that these not be treated as obstacles to objectivity. Rather they should be a guide in addressing questions and problems in their full complexity, taking into account all possible and unexpected consequences for parts of the affected populations. This is exactly what Castejón and Condesso de Melo did — accepting that the relations they established with populations as field research partners committed them to reviewing their sampling practices and dissemination strategy. In fact, they could not avoid thinking that their data were particularly meaningful and had direct implications for the continuation of the lives of the people they interacted with. It was a matter of empathy as well as responsibility but also a potential epistemological breakthrough: producing knowledge with others (Haraway 1988), especially those outside the field of academic research and professional expertise, brings to light other dimensions of the phenomena being studied.

Acknowledgements The present manuscript is an updated and more detailed revision of the authors' chapter in 'Rethinking the Role of Science in Society? Groundwater Science, Critical Reflections and Learnt Lessons' (ASTI Springer, pp 503-506) as presented at the first Geoethics and Groundwater Management Congress (GEOETH & GWM '20), Porto, Portugal 2020. The paper is dedicated to the memory of Luís Ribeiro and Bruno Latour - two inspiring intellectual figures whose research and engagement in the dialogue between science and society informed this article.

Author contributions All authors contributed to the conception and design of the study. Material preparation, data collection and analysis were performed by SB, MT, CM and CG. The first draft of the manuscript was written by SB and added to by all the authors. They read and approved the final manuscript together.

Funding Open access funding provided by FCT|FCCN (b-on). The research has been developed under the AGORARISK project - Dialogue on risks and the environment in Estarreja-, financed by the CNRS through the LabEx DRIIHM (https://www.driihm.fr/projets/projets-2020/details/149/2303). The work was also supported by FCT, I.P., the Portuguese national funding agency for science, research and technology, under the Project UIDB/04521/2020.

Data availability The datasets generated and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Conflict of interest On behalf of all authors, the corresponding author states that there is no conflict of interest

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