Sustain Sci (2017) 12:333–343
DOI 10.1007/s11625-016-0413-1

ORIGINAL ARTICLE

The political ecology of water metabolism: the case of the Cobre las Cruces copper mine, southern Spain

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Received: 19 September 2015 / Accepted: 8 November 2016 / Published online: 17 November 2016

Abstract Access to extractive resources relies as much on technology and prices as it does on the power to designate ecological and economic meanings to water and other environmental goods. This paper examines the ways in which the mining industry uses scientific models to create meanings for water that in turn legitimizes their access to and control over it. To do so, this paper explores the relevance of combining biophysical analyses—in this case water metabolism—with an examination of those power relations and social constructions that coexist with and affect the flows of water. Based on empirical research, this paper analyzes the evolution of water management in the process of copper production at the Cobre las Cruces mine in southern Spain to identify present contradictions in the strategies adopted by the mining company to avoid water degradation. These contradictions are revealed by examining how water has been framed as a resource not susceptible to being used for purposes other than mining processes. We argue that those framing this environmental explanation—the regional government and the mining industry—are promoting net subtractions of water from an aquifer against current regulations.

Handled by Rimjhim Aggarwal, Arizona State University, USA.

Electronic supplementary material The online version of this article (doi:10.1007/s11625-016-0413-1) contains supplementary material, which is available to authorized users.

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Keywords Political ecology · Water metabolism · Copper mining · Mine water

Introduction

The mining sector enjoys a prominent role in today's global economy. The growth in consumption and production has escalated the need for energy and raw materials, with the use of resources reaching exceptionally high levels worldwide (Özkaynak and Labajos 2012). The expansion in copper extraction contradicts the idea that the global economy will decouple from natural resources and environmental impacts due to the "dematerialization" of the economy (Martínez-Alier 2001). On the contrary, during the twentieth century, global copper consumption reached 18,000 million tons and this figure is expected to double in the next 30 years, driven up by increasing per capita consumption in high-demand economies like China, the United States, and the European Union (International Copper Study Group 2012; Rogich and Matos 2008). The mining of copper has a high environmental impact as most copper mines are open pits. One of the biggest impacts of open-pit mining is a high consumption of water, as well as the acidification of water running from the crater and the tailing piles (known as acid mine drainage). Water, therefore, is one of the most critical sustainability issues facing the mining industry (Moran 2006). As mining activities have generated conflicts over water around the world (Martínez-Alier et al. 2010) studies have addressed a diversity of issues, including the conflicts generated by water pollution due to mining activities and the different valuation languages of water in these activities (Kemp et al. 2010; Bebbington and Bury 2014; Molina

2012). The social nature of water (Bakker 2012; Linton and Budds 2014) involves meanings, concepts, and values that frame the different discourses associated with the different stakeholders involved in mining activities. As a result, water, therefore, becomes a turbulent discourse terrain of competing approaches with multiple normative conceptions of how water should be managed, and distinctive criteria determining who has a legitimate right to access it and for what purposes. As mining expands, access to extractive resources increasingly relies on the power to designate ecological and economic meanings to water and other environmental goods. An analysis of the competing environmental narratives on mining-related conflicts shows how scientific knowledge and scientific experts—presented as neutral and objective—play a central role in granting legitimacy, which ultimately reinforces the entitlement of certain actors to gain control over socio-natures (Herrero A 2013 Anatomía de un conflicto socioecológico. El caso de la minería a cielo abierto en el Valle del Laciana. Unpublished thesis http://www.tdx.cat/handle/10803/116202 Accessed 13 March 2016). Consequently, what is needed are studies that examine the ways the mining industry uses scientific models to attach meanings to water that legitimize their access to and control over the resource. Hence, this article explores the relevance of combining biophysical analyses—in this case water metabolism—with an examination of power relations and social constructions that both coexist with and affect the flows of water.

Following previous works (Martínez-Alier et al. 2010, 2014; Delgado 2015; among others), this paper combines a "materialist" understanding of the notion of social metabolism with that of Political Ecology—as the latter pays greater attention to the dimensions of power and conflict in the study of social metabolism—and then applies this combined understanding to a case study on the copper mining project of Cobre las Cruces (CLC) in Seville, Spain. Through an analysis of the water metabolism[1] at the CLC project, we examine from a political ecology perspective how the exercise of power dialectics, which in this case means the power to designate water as a resource not susceptible to being used for purposes other than mining processes, affects the competing discourses on environmental sustainability associated with the use of water resources in mining projects. We unravel how the underlying legal context and the techno-institutional "rules of the game" (sensu Cardenas and Ostrom 2004, 309) enable the mining industry to use scientific models to discursively create new meanings for water; in this case, mine water.[2] With regard to the CLC project, this effectively allowed the mining company to access and control water resources in a way that would otherwise be considered unjustifiable. This insight is particularly important because the global expansion of mining and extraction has led to new forms of extractive processes that target deposits previously deemed too expensive—both economically and environmentally—to exploit (Bridge 2004).

This paper is structured as follows. Following this introduction, the second section describes the theoretical framework of analysis, and the methodology used to analyze water metabolism from a political ecology approach. The third section introduces the case study, while the fourth section presents the analysis carried out, by first classifying the water flows of the copper production process and then examining the underlying legal context and the techno-institutional rules of the game determining, conditioning, and explaining the water flows involved in it. The work is brought to an end with a number of conclusions drawn from the study.

Water and water metabolism from the political ecology perspective

Contemporary political ecology scholars have been dismantling the veil that often conceals the political aspects in human–environment interactions, and have ultimately overcome the very dichotomy between the social and the natural (Latour 1987; Swyngedouw 1996, 2006; Bakker and Bridge 2006; among others). Moreover, there is a consensus within political ecology scholarship that water management is more than a mere technical field requiring scientific expertise only, because what is at stake is not just society's relationship with water but the social nature of water itself, which involves human values, behavior, and organization (Budds 2009). Thus, water is framed as biopolitical (Bakker 2012), highlighting the link between the constitution and consolidation of political and economic power, on the one hand, and the control of socio-natures, on the other. This in turn "implies a shift from regarding water as the object of social processes, to a nature that is both shaped by, and shapes, social relations, structures and subjectivities" (Linton and Budds 2014, 170).

[1] It is important to note that we focus the study on the quantitative aspect of water flows. A deeper analysis of water quality issues, although also relevant to the conflict, is beyond the scope of the present study.

[2] This concept refers to the water from the bottom of the pit that emerges naturally as the pit is dug deeper (Cobre Las Cruces 2008). As shown next in the analysis, this concept "appeared" in the technical documents of the water management global plan to justify the identification of mine water as part of the water flows.

In mining projects, water is needed in large quantities for mineral production and processing, and is considered one of the most critical sustainability issues facing the mining industry (Moran 2006). The multiple meanings of water shape the competing discourses associated with the different stakeholders involved in mining activities, which in turn are embedded within particular institutional configurations of power, knowledge, and authority (Bakker 2010). For instance, Herrero A (2013) Anatomía de un conflicto socioecológico. El caso de la minería a cielo abierto en el Valle del Laciana. Unpublished thesis http://www.tdx.cat/handle/10803/116202 Accessed 13 March 2016 analysis of environmental narratives and discursive regulation in mining conflicts shows how the characterization of a neutral and objective scientific knowledge obscures the politics that shape both scientific production as well as the powerful interests that are served by their practical implementation. Hence, much debate in political ecology has focused on the centrality of science in environmental conflicts, analyzing how scientific knowledge is rooted in social and power relations (Robbins 2004; Forsyth 2003; Wynne 1992). Building on these previous studies this article explores how scientific knowledge is discursively employed in mining conflicts to serve certain interests. To that end this paper unveils the connection between the discursive, the social, and the material dimensions of environmental conflicts.

The quantification of physical flows in the economy, in other words, a material understanding of the notion of social metabolism, sheds light on the physical dimension of environmental conflicts and studies carried out under this approach support ongoing discussions on sustainability. Haberl et al. (2011) argue that the growth in consumption and production has escalated the need for energy and raw materials, thus limiting the ability of the natural system to support economic activities. Similarly, Martínez-Alier et al. (2010) use the frame of social metabolism studies to discuss the expansion of extractive activities and their justice implications. The quantification of physical flows directly confronts the optimistic view of technological modernization and economic dematerialization with the increase of energy and material inputs feeding social metabolism and the resulting rise in waste products (Haberl et al. 2011). From the political ecology approach, "processual metabolism" (Swyngedouw 2006, 109) describes the material and socio-physical metabolic relationship embedded in particular power relations associated with the circulation of physical flows. The deepening entanglement of socio-physical metabolic flows and power relations makes the connection between social metabolism and political ecology studies particularly noteworthy. This relationship becomes clear when studying water metabolism, because the politicized nature of water management makes it impossible to "abstract water from the social context that gives it meaning and from the socio-political processes that shape its material flows and its discursive representations" (Budds et al. 2014, 167).

Though social metabolism—and by extension water metabolism studies[3]—has undoubtedly flourished academically when focused on analyzing physical flows, and despite becoming a metric for biophysical growth and degrowth (Fischer-Kowalski and Haberl 2015), it has done so by focusing on the quantitative analysis of resource flows without referring to the power relations associated with the circulation of these physical flows (González de Molina and Toledo 2011; Beltrán and Velázquez 2011).

Society shapes and is shaped by water, both materially and discursively, and water flows are embedded in all institutional and political processes that both coexist with them and affect them (Budds 2008; Swyngedouw 2009; Kaika 2004). Hence why water cannot be understood as an isolated element, as a factor of production only, or as a physical flow disaggregated from its environmental, institutional, technological, and social context. Therefore, we highlight the relevance of considering water metabolism not just as a resource flow, but as the manifestation of dialectical social relations that are themselves organized around the appropriation and transformation of nature (Swyngedouw 2006).

The most difficult and controversial issue in the assessment of sustainability goals is the metrics used to measure the state of a system and to evaluate its progress towards these ends (Hermanowicz 2008). The CLC case exemplifies that considering water metabolism as just a resource flow undermines its potential usefulness as a sustainability metric for water resources management. By utilizing a political ecology approach, our analysis of the water flows at the CLC mining project reveals the underlying contradictions in the discourse on environmental sustainability that the mining company deploys.

The analysis below is based on information from different sources that corroborate findings and allow a process of triangulation. It relies on both primary and secondary data sources. Firstly, the fieldwork (conducted over several months, though spread across 2009, 2012, and 2014) consisted of 20 in-depth interviews with key stakeholders (see Annex 1; Beltrán 2009; Beltrán 2012). The interviews were

[3] Water, although undeniably important as a material flow within the economic processes, has been difficult to integrate into other material flows (Fischer-Kowalski and Hüttler 1999). Nevertheless, many authors have studied water flows separately from the rest of the material flows involved in an industrial activity (Hubacek and Sun 2005; Arpke and Hutzler 2006; among others). The recent work by Madrid et al. (2013), in which the MuSIASEM methodology (multi-scale integrated analysis of societal and ecosystem metabolism) developed by Giampietro (2004) is extended and applied to the study of water, is also noteworthy.

semi structured with an unstandardized format and a predominance of open-ended questions. These open-ended, qualitative interviews were a means of hypothesis building, as opposed to standardized, closed, qualitative interviews that allow for formal hypothesis testing (Bakker 2010). We selected a range of stakeholders affected by and involved in the project: Four local inhabitants from the villages where the project is located, two representatives from the council of these villages, three actors from other economic sectors (agriculture and local and regional tourism), two representatives from the mining company, four representatives from the Andalusian Regional Government and other bodies related to the project ([Guadalquivir Hydrographical Confederation (GHC)], Spanish Geology, and Mining Institute), and two representatives from Ecologistas en Acción (the main NGO in the area) and two independent experts. Secondly, we conducted a systematic review of documentary data, including background scientific studies on the case, policy and legal documents, journal articles, administrative documents, licenses and permits, and NGO allegations. Thirdly, direct anthropological observations were employed during the fieldwork and interview stages, as well as when documents were being analyzed. We collected and analyzed the data in three ways: Firstly, observations were recorded narratively in a researcher's diary; secondly, data were collected and analyzed simultaneously, and an inductive approach was used to group the data and then look for relationships; finally, a narrative analysis allowed for the examination of the discursive practices presented by the different groups of stakeholders.

Case study: the Cobre las Cruces mine (Seville, Spain)

The Cobre las Cruces copper mining project is owned by the Cobre las Cruces S.A. (CLC) mining company, which was a subsidiary of the Canadian Inmet Mining Corporation until March 2013 when Inmet Mining was absorbed by First Quantum Minerals (also Canadian). The project has been fully operational since 2009. The approval of the new water management system (called the Water Management Global Plan (WMGP) was essential for the CLC project to begin its operations, although it took several years to construct the different infrastructures of the project and obtain the necessary permits. The project is located in the south of Spain (see Fig. 1), in the province of Seville (Andalusia). The area has a semi-arid, Mediterranean climate with regular periods of drought (FRASA and AIA Consult 2006). This fact, coupled with the location of the copper deposit beneath an aquifer, makes water management a particularly sensitive issue.

As mentioned above, the project is located in the easternmost area of the Iberian Pyrite. The CLC deposit is a

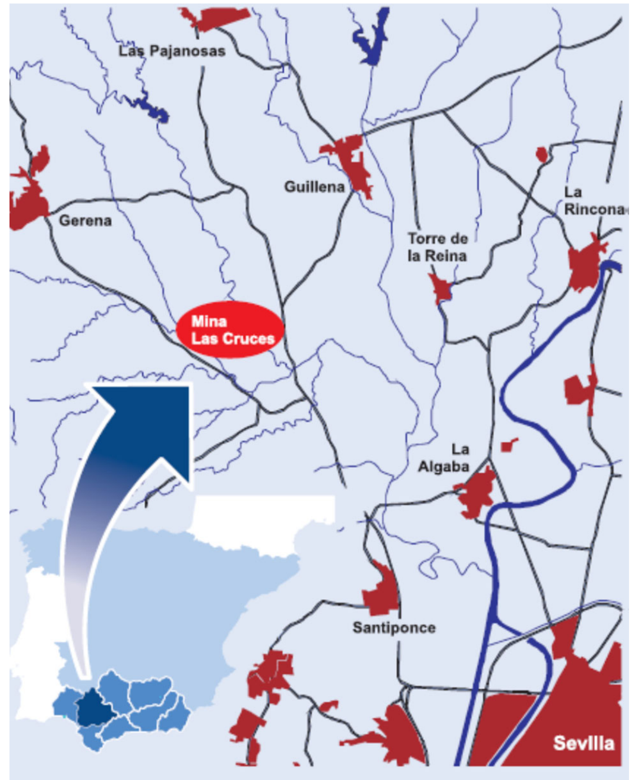

Fig. 1 Location of the Cobre las Cruces mining exploitation Source: Andalusian Regional Government 2009b

volcanogenic massive sulfide deposit, including the associated stockwork (copper and zinc), the supergene cementation zone (copper), and overlying gossan (gold and silver) (Miguelez et al. 2011). The minable ore reserves are estimated at 16,000,000 tons with an average copper grade of 6.2%. The deposit is very profitable since average copper grade deposits are considered profitable when their grade is over 2.5%. In 2012, ore processed was 1,082,000 tons, with a 7.1% copper ore grade processed and an 88% recovery, while copper cathode production was 67,700 tons (First Quantum Minerals 2013). The estimated mine life is 15 years (CLC 2011).

The mining activity of the CLC project includes the mining of the ore from the deposit (the process of extraction, according to the above-presented conceptual scheme) in the open-pit mine (mine pit), followed by the extraction of the metal from its ore and its processing at the hydrometallurgical plant. Both actions—the extraction of metal and its processing to obtain copper—constitute the process of transformation. The CLC plant was designed to process 72,000 tons of copper cathodes per year. Despite the company's forecasts, however, the failure of the Drainage and Reinjection System (water balance is shown in Fig. 3) gravely affected the plant's production, where only 5600 tons of copper cathodes were produced in 2008 (7% of its total capacity). Nevertheless, through the implementation of the WMGP (water balance is shown in Fig. 4), production increased from 28,500 to 42,100 tons during 2011 (Inmet Mining Corporation 2012). Thus, the approval of the WMGP was essential to the increased profitability of the plant.

Water is an indispensable requirement for hydrometallurgical treatment and needs to be managed throughout the whole mining process. Consequently, the project includes various actions that affect surface and underground water. Regarding surface water, drainage and supply pipes (19 and 15 km long) were built to channel the treated water to where it is dumped into the Guadalquivir River, in the basin of which the mining complex is located. The original water management system (before its 2008 failure) included sewage water from the nearby Sewage Treatment Plant (STP), a part of which, once treated, was pumped to the hydrometallurgical plant to be reused at the mine site. The mine was allowed to pump water from the STP for only 7 months per year (avoiding summer). As will be explained, this water source is no longer used for the hydrometallurgical plant.

Regarding underground water, the most relevant action was the implementation of the Drainage and Reinjection System (DRS). The DRS (see Fig. 2) is a system of water wells located near the CLC open pit, which extracts water from the surrounding aquifer and reinjects it back into the same aquifer through adjacent wells in order to prevent water from flowing into the pit, as this might result in acid mine drainage.

The permit (2003) and the water concession (2004) related to the DRS specified that the system should not affect the quantity or the quality of the underground water (GHC 2003). Immediately after its implementation phase in 2008 the DRS failed, affecting the quality and quantity of the aquifer's water (GHC 2008). The specific failures of the DRS were that some of the extraction wells in the open pit were faulty. As a result, these wells were not extracting enough water and the pit flooded with underground water from the aquifer. The resulting environmental damage prompted the government to initiate legal proceedings. The mining company was accused of the non-authorized detraction of 75,000 m^3 of water from the aquifer and creating 20 unauthorized boreholes. In relation to the quality of water, the discharge of arsenic and other AMD polluting substances into the river basin were detected (GHC 2008). The trial was held in September 2016 and the three executives of the company accused pleaded guilty to the charges. The result was the imposition of sactions against the three executives and the CLC company being fined euros 300,000.

The WMGP, approved in 2009 by the Andalusian Regional Government, introduced a mandatory modification to the mining project's water management to repair the environmental damage (described below). In 2013, the Guadalquivir Hydrographical Confederation approved a new permit for the DRS, providing further legal legitimacy to the water plan approved in 2009 (GHC 2013).

While the company defends the environmental performance of the project along with its economic benefits for the region, the mine has been criticized by Ecologistas en Acción (a local NGO). Since the beginning of the project, the strategy of Ecologistas en Acción has been to research and closely follow up on any developments related to the copper deposit́s exploitation. To have access to the legal proceedings, they successfully requested to be legally recognized as an affected party. This legal strategy resulted in access to crucial information and thus their continued monitoring of the mining activity. Their allegations, pointing out the contradictions in the WMGP, are the main contention in the controversy. They claim that through the WMGP the mine is extracting underground water in vast amounts without the authorization required by the water concession (as shown in the next section). These claims are based on scientific, technical, and legal arguments posed by Ecologistas en Acción in numerous allegations, legal actions,

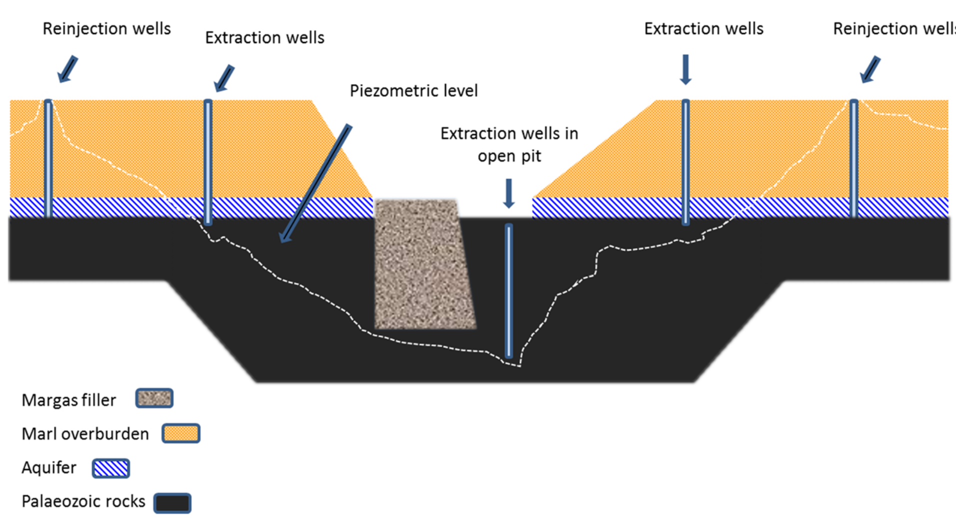

Fig. 2 The Drainage and Reinjection System of the Cobre las Cruces mining complex Source: Authors' elaboration in accordance with FRASA 2000

and reports (see Ramos n.d. Discrepancia científica con los informes del Instituto Geológico y minero sobre la masa de agua subterránea 05-49 subunidad Gerena-Cantillana. Unpublished document; Ecologistas en Acción 2008, Ecologistas en Acción 2009 Alegaciones al plan global de agua de Cobre las Cruces. Unpublished document, Ecologistas en Acción n.d. Queja al defensor del pueblo andaluz. Unpublished document) with the aim of halting the exploitation and forcing the mining company to develop a new water management system. The regional administration has ignored these arguments and, therefore, has not imposed new measures to protect the aquifer. Why does the scientific knowledge mobilized by Ecologistas en Acción have less credibility and legitimacy than that mobilized by the mining company? The issue remains one of power, which reshuffles authority and truth according to adherence to political and economic projects.

The following analysis of the water metabolism of the CLC mining project unveils the underlying contradictions associated with the mining company's environmental narratives through a quantitative analysis of the water flows and an examination of the underlying legal context and techno-institutional rules of the game that determine, condition, and explain the flows.

Water metabolism of the Cobre las Cruces mine

This section presents an analysis of the water flows involved in the mine's transformation process before the DRS failed and after the WMGP was implemented, providing a dynamic perspective of the problem at hand. The water balance shown in Fig. 3 was based on the DRS model approved in 2003, which once employed, immediately failed (in 2008). Therefore, the water balance before the DRS failed—and the related quantities associated with it—was never effective. The current water balance is represented in Fig. 4. Comparing the respective water balances shown in Figs. 3 and 4 demonstrates the reduction in total water usage achieved by the mining company with the WMGP. This reduction was achieved, however, at the expense of increasing underground water extraction. It is important to note that an analysis of water quality issues, while also relevant to the conflict, is beyond the scope of the present study.

The water flows of the mining project: the water balance of the transformation process

Before the implementation and subsequent failure of the DRS, the water concession granted to the project by the GHC in 2004 authorized the STP to use a maximum of 296.8 m^3/h of treated surface water, together with 18.3 m^3/h of surplus underground water derived from the mining activity (GHC 2004). The water flows are described in Fig. 3.

The water inputs are surface water (I1), derived from the STP, underground water (I3), and to a lesser degree water from the bottom of the mining pit that accumulates from rain or surface run-off not intercepted by the capture and draining systems. Another source of water is the humidity contained in the mineral (I4), which is to say the humidity that is naturally contained in the soil from which the mineral is extracted. Since the water requirements of the

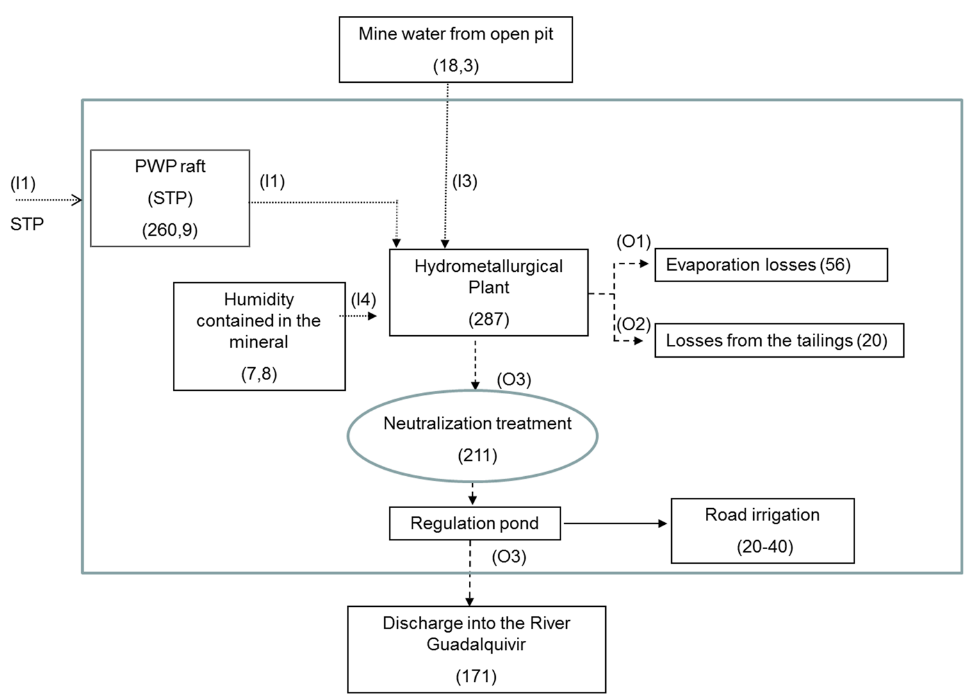

Fig. 3 Water balance of the hydrometallurgical plant at the Cobre las Cruces mine before the DRS failure (m^3/h) Source: Authors' elaboration based on Guadalquivir Hydrographical Confederation (2004) and Andalusian Regional Government (2009b)

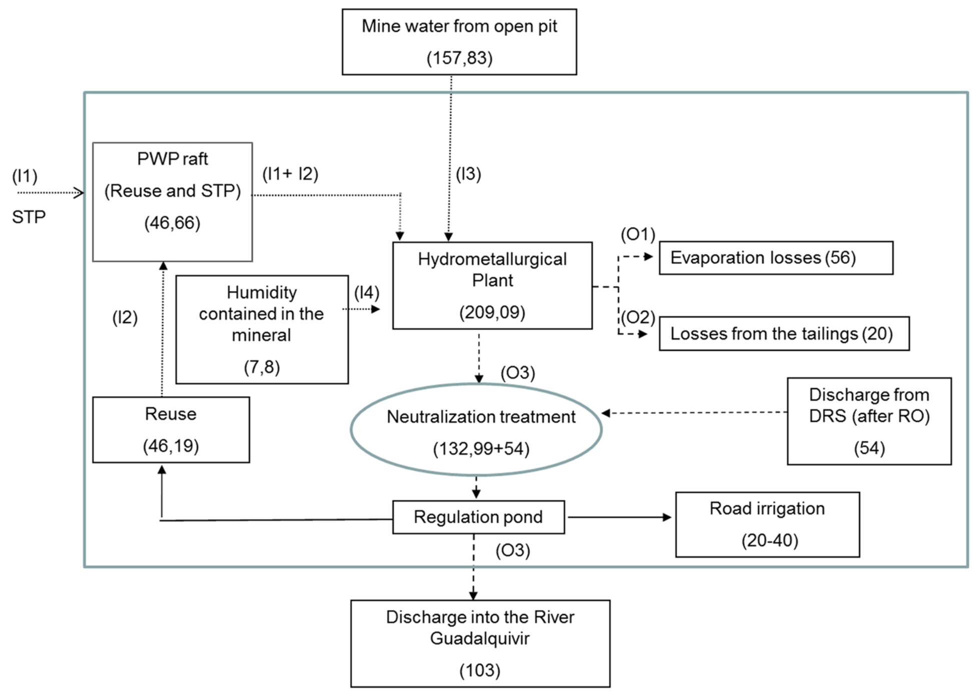

Fig. 4 Water balance of the hydrometallurgical plant at the Cobre las Cruces mine after the implementation of the Global Water Management Plan (m^3/h) Source: Authors' elaboration based on Andalusian Regional Government (2009b)

plant may vary depending on the development of the project and the amount of mineral to be processed, we assume that the amount of surface water derived from the STP (I1) is 260.9 m^3/h (Andalusian Regional Government 2009b).

Similarly, the output flows from the hydrometallurgical process are:

(a) losses due to the evaporation of water generated during the hydrometallurgical process (O1);
(b) losses of the water contained in the mining tailings resulting from the processing of copper ore (O2);
(c) water discharged back into the environment and accumulating, after being treated by neutralization, in the regulation pond (O3).

The existing discharge regulation to the Guadalquivir river (Andalusian Regional Government 2005) allowed a discharge of 171 m^3/h. After the DRS failure this was modified by the Andalusian Regional Government and reduced to 103 m^3/h (Andalusian Regional Government 2009a). The WMGP introduced relevant changes to the volume of water stipulated in the 2004 water concession (see Fig. 4).

Following the approval of the WMGP, the plant's estimated water requirements measure 209.09 m^3/h. This water could be from three different sources (see Fig. 4).[4] The main differences from the Fig. 3 are that in the present scheme the underground water (I3) is conceived of as "mine water". As already mentioned, this concept refers to the water from the bottom of the pit that emerges naturally as the pit is dug deeper (CLC 2008). It is important to note that this concept was not shown in the project's technical documents before the DRS failed. It will be used after the DRS failure as a criterion in the WMGP's decision-making processes of approval, as shown below. In addition, differing from Fig. 3, reused water (I2) derives from the neutralization process and is stored in the PWP raft. This modification contributes to the total reduction in surface water usage coming from the STP, which helps to reduce total water usage.[5] Furthermore, the neutralization process is applied to the water rejected from the reverse osmosis (RO) process. While going through the DRS, the aquifer water is polluted by coming into contact with the copper mineral, so RO is necessary before the water is reinjected back into the aquifer. Therefore, it is assumed that the DRS is producing AMD polluted water.[6]

To understand the implications of the WMGP, we need to consider the concept of the opportunity cost[7] of water when analyzing the water flows shown in Fig. 4. By

[4] The water requirements of the plant may vary depending on the amount of mineral to be processed. Thus quantities shall be taken as approximate. Indeed the source of the data consider that the amount of reused water may vary from 46.19 to 66.9 m^3/h(Andalusian Regional Government 2009b).

[5] "Water needs of the hydrometallurgical plant will be supplied with mine water and reused water…in case of need water from the STP it could be use only with prior permission" (GHC 2013, 35).

[6] The authors have not accessed data of the amount of water polluted through the DRS, only the resulting amount rejected after the RO.

[7] The opportunity cost refers to the "monetary value" of the best, unchosen alternative use when the water is taken for a specific purpose.

introducing the concept of "mine water", the WMGP explicitly classifies underground water as water without an economic opportunity cost. This means that this water input of 157.83 m^3/h may not have different uses, according to the interests of potential users. Water from the aquifer is also required in the region for agricultural irrigation during the summer, for industrial supply, and for emergency supplies to the nearby city of Seville during periods of drought (FRASA and AIA Consult 2006).

Therefore, the total opportunity cost of the mine's water usage would increase if "mine water" had been considered as water with an economic opportunity cost. Since "mine water" comes from the aquifer, the concept of mine water and its related opportunity costs are open to argument, as will be shown in next section.

The quantitative analysis of the water flows involved in Cobre las Cruces' production process shows that the implementation of the WMGP reduced both the amount of water from the STP and the total amount of water used in the transformation process (as shown in Fig. 4). Nevertheless, the study of the water metabolism should not focus just on the flow of the resource. Indeed, merely quantifying the water flows may lead to incorrect conclusions, which, in turn, can be used to legitimize certain decision-making processes and result in severe and sometimes irreversible damage.

The legal and techno-institutional context

As we have already seen, the current management of water at the CLC mining project (WMGP) was implemented after the DRS failed to comply with the authorization granted by the GHC in 2003, which led to the suspension of the system and work at the mine pit. The authorized model (GHC 2003), which was ineffective, was based on the need to return all extracted water from the aquifer. Why? The Guadalquivir River Basin Hydrological Plan in force at that time qualified the aquifer as at risk of becoming overexploited. This means that although the aquifer is not officially overexploited, only extractions that substitute the existing ones are allowed so that net extraction is zero. The legal proceedings to decide on the overexploitation of the aquifer began in 2008.

The water concession presently in force, granted by the GHC to the mining company in 2004, allows 18.3 m^3/h of underground "mine water" to be extracted by the mining company (GHC 2004) (Fig. 3). Considering the obligation not to implement any net subtraction of water from the aquifer, the WMGP included two relevant changes in the management of underground water: (1) a modification of the volume of water stipulated in the 2004 water concession by allowing the use of 157.83 m^3/h of "mine water" from the mining exploitation (see Fig. 4), some 876% higher than the amount originally authorized; and (2) in order to guarantee the quality of the aquifer water, any water from the DRS that comes into contact with the mineral will be treated by RO. This means that 54 m^3/h of water extracted from the aquifer will not be reinjected into the groundwater and will instead be rejected and subjected to a neutralization process, as indicated in Fig. 4.

How can a water management plan that allows for a modification of water usage be implemented without the authorization required by the water concession, especially when it affects an aquifer from which exploitation norms prevent any net water subtractions? An analysis of the institutional framework, based on the results of our interviews, helps to answer this question. Firstly, as regards the impact on the aquifer, the authorization issued for the WMGP states: according to the hydrogeological study (Spanish Geology and Mining Institute 2010), the volume of water considered as "mine water" does not actually come from the aquifer. The argument put forward by the study is that "mine water" and "aquifer water" are contained in different materials (the former in margas filler and the latter in Palaeozoic rocks, as described in Fig. 2), and are, therefore, themselves different. On the contrary, the WMGP states that both materials are fractured and "can be integrated as part of the same aquifer" (CLC 2008, 14). Consequently, there is no difference between "mine water" and "aquifer water" under this classification (Ramos n.d. Discrepancia científica con los informes del Instituto Geológico y minero sobre la masa de agua subterránea 05-49 subunidad Gerena-Cantillana. Unpublished document).

At this juncture, it is important to point out that the concept of "mine water", which is affected by the uncertainty regarding the aquifer's dynamics, is the result of a social negotiation between the regional administration and the mining company. As explained by Aguilera et al. (2000), two types of data influence this process of negotiation: (1) allegedly objective data (such as reduction of the phreatic level, estimated natural recharge, and so on) and (2) subjective data (such as those values and interests at play). A conflict of interests clearly appears in the present case study, since mine water, if considered water without an opportunity cost, cannot have different uses. On the contrary, should that water be considered aquifer water, it would automatically be classified as water with an opportunity cost, susceptible to being used for other purposes in the arid area surrounding the project's location. The regional administration, by approving the WMGP, established an institutional link between the concepts of mine water and water without an opportunity cost, despite the above-mentioned contradictions.

Secondly, our results point out that the WMGP was approved without the mandatory modification of the water concession. Instead, the plan included a clause explaining that the water concession granted to the mining company in 2004 is in the process of being amended. The proceedings, started in 2009, are being executed in parallel to the proceedings for the declaration of overexploitation started in December 2008. When the administrative proceedings for the declaration of overexploitation are resolved, the GHC may impose any limitations deemed necessary on water extraction as preventive measures. In this paradoxical situation, the actual modification of the water concession depends on the non-declaration of the aquifer as effectively overexploited before the modification is implemented, because, should the overexploitation be acknowledged, those preventive measures could hinder the extraction of more water from the aquifer, thus rendering the WMGP unfeasible.

The techno-institutional system is understood here as the rules of the game that, aiming to protect the aquifer after the DRS failure, have allowed the mining process to modifying the amounts and the sources of water involved in the process. The examination of the intricate nexus between the rules of the game, the technical model, and the power dialectic deployed by the mining company to identify "mine water" as water without an opportunity cost, reveals how the rights to water usage have been given to the mining project and legitimized by this scientific explanation.

Conclusion

Long-term global change trends drive the continuing expansion of mining, presenting serious challenges to sustainability (Bebbington and Bury 2014). In this vein, the CLC case speaks to a key hypothesis on the sustainability of water resources in mining activities. This paper shows that access to mineral resources depends on the power to attach ecological and economic meanings to water that ultimately legitimize certain actors to access and control the resource. Bakker (2012) argues that there is a link between the constitution and consolidation of political and economic power, on the one hand, and the control of socio-natures, on the other. Based on this idea, we argue that the power to frame water as a resource not susceptible to being used for purposes other than mining processes consolidates the political and economic position of mining activities because it has allowed the CLC mining company to develop its activity without complying with current environmental regulation. In contrast, the technical and legal arguments of Ecologistas en Acción were not powerful enough to influence the decision taken by the regional authorities, and therefore remained politically inaudible. These arguments reveal the underlying contradictions of the environmental sustainability discourse deployed by the mining company.

Because socio-natures are permeated by social relations, structures, and subjectivities, water can neither be understood as an isolated element, a factor of production only, nor as a physical flow disaggregated from its environmental, institutional, technological, and social context. Building on previous works, this paper shows the importance of considering water metabolism not just as a resource flow, but as the material manifestation of dialectical social relations that are themselves organized around the appropriation and transformation of nature (Swyngedouw 2006). The CLC case exemplifies that approaching water metabolism as just a resource flow undermines the potential use of this tool as a sustainability metric for water resources management. The study of the water flows involved in the CLC production process shows that the WMGP reduced the total amount of water used in the transformation process. However, analyzing the water metabolism of the CLC mining project from a political ecology approach highlights the power relations and social constructs that determine, condition, and ultimately explain these water flows.

The study of the techno-institutional "rules of the game", as political ecologists have argued, reveals that "powerful interests can strategically use and manipulate discourses—language, stories, images, models, concepts, terms—to serve their goals" (Otero et al. 2011, 1307). The institutionalization of the concept of "mine water" as water without an opportunity cost enabled the mining company to access and control a water resource in a way that would otherwise be considered unjustified. In this sense, this paper adopts a more politically sensitive understanding of the context within which environmental explanations emerge (Forsyth 2003).

Acknowledgements The authors would like to thank Isidoro Albarreal and Antonio Ramos of *Ecologistas en Acción* for sharing their relevant information. We also thank Vanesa Castan, Sara Latorre, the editor and the anonymous reviewer for their very useful comments. The corresponding author acknowledges support from the Marie Curie Actions—Initial Training Networks—FP7—PEOPLE—2011; contract No. 289374—ENTITLE, European Network of Political Ecology, and from the Spanish National Plan for R+D+I 2008–2011. *Sistemas agrarios sustentables y transiciones en el metabolismo agrario: desigualdad social y cambios institucionales en España* (1750–2010) (sustainable agricultural systems and transitions in agricultural metabolism: social inequality and institutional changes in Spain). HAR2012-38920-C02-01.

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