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Community perceptions on the health risks of acid mine drainage: the environmental justice struggles of communities near mining fields

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Abstract Environmental and social research studies have debated the impact of acid mine drainage (AMD). Solutions to the problems caused by AMD have tended towards a technocratic investment in temporary to long-term solutions. However, the health effects of AMD remain neglected in research and policy arenas because of the lack of documented evidence. As a result, this renders the problem invisible, while the impact is deleterious for poor communities. Such communities suffer the effects of AMD principally through a perpetual risk posed by water pollution. Moreover, they are voiceless and excluded from matters affecting their well-being. This study was carried out with a community in Carolina, near the Mpumalanga coal mining fields. It tested their understanding and perceptions of health risks associated with AMD. The goal was to uncover the knowledge of the research participants of the existence of AMD and of its impact on their physical health and well-being. Qualitative methods were employed to measure knowledge, attitudes, and perceptions and to analyse the diseases inventory of the study population. Findings suggest that communities located near mines are affected by mining externalities that pose a threat to their health. It was also discovered that such communities are excluded from any planning and decision-making by local mining authorities. This case study presents strong evidence in favour of empowering marginalised communities by including them in decision-making, actively facilitating their participation, and exposing them to environmental health education to increase their awareness and reduce the risks caused by mining externalities.

Keywords Acid mine drainage · Mining-affected communities · Health risks · Environmental justice · Participation

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1 Introduction

Environmental impact analyses and sustainable development research studies have increasingly demonstrated that, despite the inherent benefits of development, it carries both benefits and costs. Mining is crucial to the economy and, consequently, the development of many nations; however, due to its earth-destructive nature, it also has serious deleterious effects on the biophysical and socio-economic environments. Impact analyses of South Africa's mining fields, which have existed for hundreds of years, show many cases of such effects. These include contamination of water resources in the Witwatersrand mining fields, public health issues resulting from the uranium tailings in the Witwatersrand, the contamination of the Vaal River system and the Olifants River Catchment, and the displacement of poor communities, as well as other unrecorded socio-economic effects.

Mining commonly pollutes water bodies through sediment and salt loading, which increases the heavy metal contents and changes the pH levels of the water (Department of Environmental Affairs and Tourism 2006). The largest water quality problem associated with mining is acid mine drainage (AMD). It is an environmental problem of high concern, primarily in coal and gold mining, because of the pollution incurred in surface and underground water resources (Munnik et al. 2010; The World Wide Fund (WWF) 2011). AMD has gained significance in the field of environmental management and development studies because of the nature and extent of the threat it poses to the natural environment and social welfare.

AMD entails highly acidic water, usually containing high concentrations of metals, sulphides, and salts as a consequence of mining activity. The major sources of AMD include drainage from underground mine shafts, and runoff and discharges from open pits, mine waste dumps, tailings and ore stockpiles (Council for Scientific and Industrial Research (CSIR) 2009). Furthermore, there are often potential long-term pollution threats that may arise from the production of AMD, which often continue for many years after the mines have been closed and tailing dams have been decommissioned (Johnson and Hallberg, cited in Bussiere 2009). Sams and Beer (2000) also maintain that discharges of effluents, such as iron, manganese, aluminium, and sulphate from abandoned mines, have great potentiality for severely degrading water quality. The quality of water in the Mpumalanga coalfields has been severely compromised, with sulphate concentrations exceeding the recommended metal concentration levels for human consumption, and contamination continuously rising (McCarthy and Pretorius 2009), resulting in poor water quality in the Mpumalanga Province (Ramontja et al. 2011).

According to the United States Bureau of Land Management (2013), abandoned mines can produce highly acidic, water-rich metals for more than 100 years after closure, thereby posing a significant threat to human health. The WWF (2011) also maintains that the high-risk period for the contamination of water, resulting from coal mining, occurs during the post-mining phase, when water pumping and treatment ceases and the abandoned mines are left to flood and decant. The major threat is that the groundwater that flows through abandoned mines is often tainted with depressed pH levels and elevated hydrogen sulphide, iron, aluminium, and nitrates levels, and such water is typically high in copper, zinc, mercury, and lead, with levels exceeding the recommended water quality guidelines (Biagioni 2003).

A practical example of this is seen in the Olifants River Catchment area and the Witwatersrand, where high levels of water contamination have occurred as a result of abandoned and unused mining sites. According to a CSIR report on AMD in South Africa (CSIR

2009), post-closure decanting of AMD in the Witwatersrand has posed a great threat to the water ecosystem, while in the Highveld coalfields of Mpumalanga, the intensity has been more visible as a consequence of the high pollution levels in the Loskop Dam and the Olifants River Catchment. A study conducted by WWF (2011) argues that the contaminated state of the Olifants River Catchment is likely to worsen as the list of surrounding abandoned mines and rehabilitation backlogs remains, and this problem will only be remediated when the affected rivers are adequately rehabilitated.

Communities located near mining fields suffer the externalities of mining through the altered natural environment, which, in turn, impacts negatively on their health and well-being. Many of these communities are poor, voiceless, and powerless to influence decisions affecting them. Measures that are implemented to get them to participate on such important matters often fail to increase the voices of such communities. This study focuses on the perceptions of the community of Carolina, in the Mpumalanga coalfields, on the health risks associated with mining externalities, with specific reference to AMD. An overview of coal mining in the Mpumalanga coalfields and the challenges related to AMD in Mpumalanga will be presented in this paper. Furthermore, the paper will draw from the case study of the Witwatersrand gold fields of South Africa. The legislative framework of mining is evaluated on its strengths and weaknesses in relation to interested and affected mining communities. Lastly, the study reports on the findings of the Carolina case study and deploys environmental justice in the interpretation of the findings.

2 Background of the study area

Carolina is a small mining and farming town, located in the Chief Albert Luthuli Local Municipality (CALLM), under the Gert Sibande District Municipality, in Mpumalanga, South Africa. The town is located in the northern-eastern tip of the Ermelo coalfields, which falls within the Mpumalanga coalfields (Fig. 1). The reason for the construction

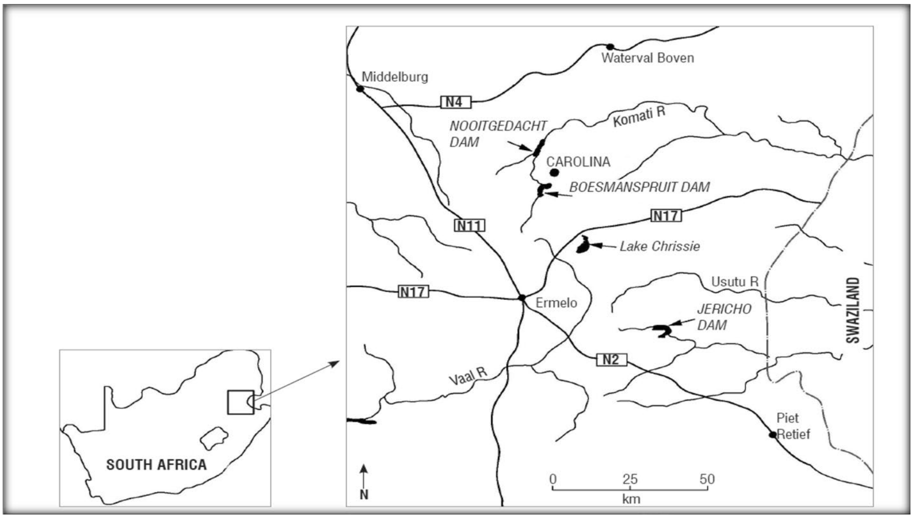

Fig. 1 Study area locality map. *Source*: Reproduced with permission from Hallowes and Munnik (2016)

of the town of Carolina was the need for a stopover point between Middleburg, Ermelo, Swaziland, and Mozambique (Hallowes and Munnik 2016). Active mines, abandoned mines, and railway sidings are among the coal mining activities around the town.

The community is distributed in three sections: Carolina central/Padkamp (which constitutes the middle class), Caro Park (the upper working and business class), and Silobela (the lower economic class in Carolina). According to CALLM Integrated Development Plan 2011–2016, the town constitutes only 10% of the municipality's total population, which amounts to approximately 19,400 community members, with less than 4600 households (Chief Albert Luthuli Local Municipality (CALLM) 2012a).

Carolina's water supply comes from the Nooitgedacht Dam, one of the most significant dams in the province, as it also supplies water to ESKOM—the country's biggest electricity supplier—and to the Boesmanspruit Dam, which is the immediate source of Carolina's raw water. The Nooitgedacht Dam and the Boesmanspruit Dam are both located in the upper Komati River catchment, which crosses into Swaziland and Mozambique (Inkomati Catchment Management Area (ICMA) 2010) (Fig. 2).

Mining, farming, and forestry are among the main activities from which the community generates income, with coal mining remaining the largest sector in the economy of Carolina. Over the years, some of the coal mines located around the town of Carolina have been closed, and some abandoned, resulting in the contamination of the

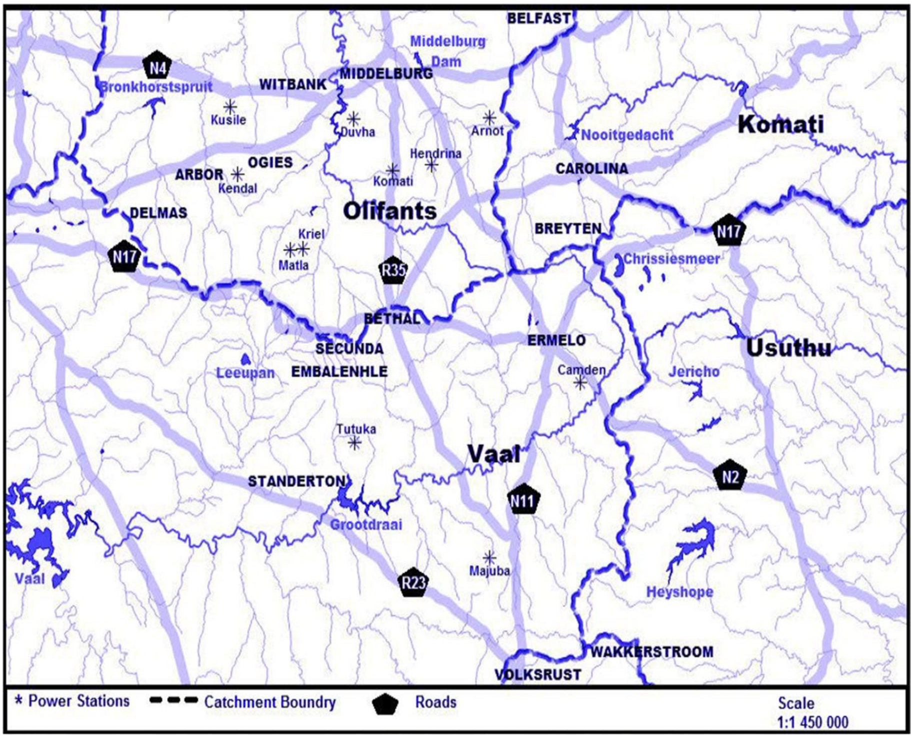

Fig. 2 Catchment area (Highveld catchment). *Source*: Reproduced with permission from Hallowes and Munnik (2016)

Boesmanspruit Dam with acid mine drainage, which then resulted in a dramatic change in the supply of potable water (CALLM).

3 Acid mine drainage in the Mpumalanga coalfields

Coal mining in Mpumalanga started in 1899, with at least four operational collieries in the Middelburg and Witbank coalfields (Banks et al. 2011), which were established to provide energy to the growing gold mining industry (Munnik et al. 2010). Mpumalanga coal mining is largely focused in the Highveld, Ermelo, and Witbank, which, together, contribute significantly towards the country's total power generation capacity (Hobbs, cited in Banks et al. 2011). Currently, about 60% of the surface area in Mpumalanga is being mined or subject to prospecting and mining rights applications (Centre for Environmental Rights et al. 2016).

Coal mining in Mpumalanga is replete with adverse effects on the natural environment and local communities. The Olifants River, where the upper catchment area is densely populated with coal mines and industries that have existed for over 120 years, is severely polluted, while the Komati River catchment also suffers the effects of acid mine drainage from coal mining (Hallowes and Munnik 2016). In addition to the run-offs and spills from the mining activities, which contaminate the water resources, the adverse effects of mining also include air pollution from coal-fired power plants (Centre for Environmental Rights et al. 2016).

Carolina is among the towns that suffer the effects of coal mining. Over the years, the rapid growth in coal mining activities in the town of Carolina has resulted in the expansion and diversification of economic activities, although coal mining remains the largest sector in the economy of Carolina (McCarthy and Humphries 2013).

Abandoned and active mines, located near the Boesmanspruit wetlands and the railway sidings—where coal is heaped, stored, and loaded into trains—are the main sources of AMD in Carolina (Hallowes and Munnik 2016). Acid mine drainage in the Carolina area had been seeping into the Boesmanspruit catchment for some time, without it being realised (Tempelhoff et al. 2012). These authors argue that the accumulation of AMD started in the wetlands, located in the upper sub-catchment, and was later accelerated by the absence of water transfers from a local dam, known as the Jericho Dam, to the Nooitgedacht Dam in 2011 (Fig. 1). The water transfers that normally occur between the two dams play an important role in diluting AMD seepage, and the absence of these transfers worsened the presence of undiluted AMD seepage. This situation was furthermore worsened by a thunderstorm in January 2012, which released the AMD seepage that had accumulated in the wetlands into the Boesmanspruit Dam (CALLM 2012b).

The community of Carolina was then exposed to the crisis of AMD-polluted water. The grievances regarding the state of the water were reflected in the spread of water-related service delivery protests, which drew media attention during 2012. Remedial interventions were then put in place to address the water contamination problem, but the effects of the contaminated water on the health of the community remain insufficiently explored. Thus, this paper seeks to explore the perceptions of local communities concerning the health risks associated with acid mine drainage.

4 Environmental legislation relating to mining: the South African context

Over the years, South Africa has seen changes and improvements in mining legislation and mining technologies, as well as an improvement in public awareness about mining, which have led to some of the environmental hazards posed by mining being remediated (Ochieng et al. 2010). According to the "Coal and Water Futures in South Africa" report (WWF 2011), mines were inadequately regulated during the period between 1903 and 1990. Up until 1990, processes relating to mine closures and the environmental and social responsiveness of mining houses were not sufficiently regulated and enforced (WWF 2011). The environmental mining problems experienced currently are related to abandoned, defunct, and unrehabilitated mine sites, rather than active mines.

The transition of the mining legislative framework from the Mines and Works Act, 27 of 1956, to the Mineral and Petroleum Resources Development Act, 28 of 2002 (hereinafter referred to as "MPRDA") brought about significant improvements in mining processes. This is seen through the integration of environmental management principles into mining (section 38, MPRDA); rehabilitation of the environment to its natural state, post-mining activities (section 38 (1) (d), MPRDA); and the management or remediation of negative environmental impacts (section 41, MPRDA) (South Africa 2002). On the other hand, the Constitution of South Africa (South Africa 1996) and National Environmental Management Act, 107 of 1998 (South Africa 1998) (hereinafter referred to as "NEMA"), expand on the principle of environmental rights for communities.

Section 2 of NEMA provides detailed environmental management principles towards attaining environmental justice, community empowerment, and participation regarding matters affecting their environment (South Africa 1998). Legislatively, an environmental impact assessment should be conducted prior to a mining permit application being approved, according to the requirements of the Act (NEMA) (South Africa 1998). The decisions relating to the approval of such an application are greatly influenced by the measures that should be implemented in the mitigation of the environmental impacts and the long-term effects of the mining on the environment (Gauteng Department of Agriculture, Environment and Conservation 2008). These same legislative provisions facilitate the enforcement of rehabilitation post-mining activities, prior to a mine closure licence being issued. Other relevant items of legislation include the Mineral and Petroleum Resources Development Regulations GN R 527 (GG 26275 of 23 April 2004); the NEMA Environmental Impact Assessment (EIA) Regulations GN R385 (GG 28758 of 21 April 2006); the National Water Act, 36 of 1998; and the Minerals Act, 50 of 1991.

Although environmental management principles have been integrated into mineral development legislation, a major challenge lies in the implementation and enforcement of such legislation. According to the Bench Marks Foundation's Policy Gap 9 Report on South African coal mining (2014), challenges relating to mine abandonment, without proper closure and rehabilitation, still remain. These authors argue that, over and above the 6000 abandoned mines in South Africa, certain coal mine majors have developed a tendency of selling off mines that are approaching the end of life to juniors, in order to avoid dealing with the mine closure requirements (Bench Mark Foundation 2014). Liefferink (2017) also argues that challenges exist with regard to implementation and enforcement. This author maintains that some of the applicable measures, like the "polluter pays principle" and the apportionment of liability for legacy mines, which include the abandoned and unused mines, remain a challenge (Liefferink 2017). Further challenges arise in situations where such legacy mines are responsible for the acidic water crisis that the country is currently faced with. The question of who should be liable for such a crisis remains debatable. Acid mine drainage, which has had a severe socio-economic impact on, and is an expensive financial burden for, the South African government and society, is just another example of the weaknesses in enforcement of legislation and the apportionment of liability.

Another challenge that has recently received attention among mining-affected communities and civil societies relates to the inadequate participation of affected populations in matters relating to their local environments. Section 10 of MPRDA makes provision for the participation by and consultation with interested and affected parties (South Africa 2002). According to this section, interested and affected parties may be called upon to submit their comments regarding an application for prospecting rights, mining rights, or a mining permit (South Africa 2002). Any objections to such an application must be referred to the regional manager, who will then forward them to the relevant committee for consideration and advice (South Africa 2002).

The amendment Bill to this same legislation (Mineral and Petroleum Resources Development Bill 2013) expands on this section, as it makes further provision for the possibility of the applicant consulting with the person(s) objecting to the application (South Africa 2013). However, it does not give details relating to the consultation and post-consultation process, especially in cases where the applicant and interested and affected parties fail to reach an amicable solution. Effectively, it remains unclear as to what extent the objection to an application by interested and affected parties may influence the outcome of the application. The Bench Marks Foundation (2014) argues that the weaknesses of MPRDA and the amendment Bill can be attributed to the fact that this legislation does not specifically require the consent of the affected community for proceeding with mining activities. This, therefore, contributes to the inadequacy in dealing with the rights of communities affected by mining externalities and to the failure to place sufficient responsibility on mining companies that benefit more from the mining activities than the communities do. Another weakness can be argued to exist in relation to the procedures governing the consultation of interested and affected parties by the state in the case of new mining right or permit applications, which will be explored in Sect. 8.2.

5 Management of acid mine drainage in South Africa

The management of acid mine drainage in South Africa ranges from short-term measures to long-term projects that aim at finding a more permanent solution. The short-term interventions to deal with AMD are aimed at maintaining environmental critical levels, thereby reducing environmental risks, such as the contamination of groundwater, the flooding of underground infrastructure, increased seismic activity, and the ecological impact on major rivers (Solomons 2016). A popular current treatment for AMD is by means of making an upward adjustment of the pH levels—the water is made more alkaline (Federation of a Sustainable Environment 2017). The challenge with this treatment is that different metals precipitate at different pH values, so the metals in the water do not disappear, but merely change to a different oxidation state; in other words, from a soluble form to a solid form and, should the water become acidic, this process could be reversed and contaminants would be mobilised (Federation of a Sustainable Environment 2017).

Another form of AMD treatment technology currently being implemented in the Witwatersrand, as a short-term intervention, is the high-density sludge (HDS) process for neutralisation and metal removal (Federation of a Sustainable Environment 2017). The long-term solution entails turning the AMD problem into a long-term sustainable solution by producing fully treated water. The treatment option includes reverse osmosis for desalinating the water and ion exchange (IX) for uranium removal (Creamer 2016; Department of Water and Sanitation 2017).

Efforts to manage the problem of AMD in water resources will cost around R12 billion for implementation by 2020, with the public being responsible for 33% of the cost of implementing AMD solutions and the rest being recovered through an environmental levy from current mining companies (Liefferink 2016). In addition to communities suffering the effects of AMD through contaminated water, such communities will continue to suffer through increased water tariffs aimed at raising the funds needed for a long-term AMD solution. Accordingly, Krause and Snyman (2014) argue that the immense environmental and financial costs of past failures have been borne by the government and the whole of society, in particular affected communities, who continue to live with the direct and indirect harmful effects to their health and well-being.

6 Methods

This study adopted an exploratory case study research design to explore the perceptions of the Carolina community regarding the health risks of AMD. Qualitative methods were used during data collection and analysis. In order to enhance the validity and credibility of the data collected during field visits, a process of triangulation was employed. This was achieved through the use of various qualitative methods for data collection. The primary data, which were based on the perceptions of the community regarding the health risks of AMD, were collected through personal visits to the sampled households, interviews, and the administering of semi-structured questionnaires. The secondary data on reported environmental diseases that could be associated with heavy-metal-contaminated water in Carolina were collected through interviews with personnel from the Silobela Clinic and Carolina Hospital. Data on water quality assessment results were accessed through the Technical Services Department of the Chief Albert Luthuli Municipality.

A total of 56 households, 28 from Carolina central and 28 from the Silobela Township, were sampled to participate in the study. Probability sampling was applied to select the sample households that formed part of the data collection. A stratified sampling technique was employed because of the heterogeneity of the households with regard to their socio-economic conditions within their geographical location. Homogeneous subsets were derived from the population on the basis of their locations and similar socio-economic conditions.

The first stratum comprised households sampled from the Silobela community. The largest proportion of the population of Carolina is found in Silobela, where challenges relating to unemployment and illiteracy were more dominant than in other parts of Carolina. This community depends entirely on the communal water tanks and taps provided by the municipality. The second stratum covered households in the Carolina central community. This community constitutes the middle working class, with better socio-economic conditions than the Silobela community. This community also depends on municipal water; however, some households use boreholes and others purified retailed drinking water.

The perceptions of the community regarding the health risks of AMD were considered together with the information provided by the hospital and municipality. This enabled the researcher to identify emerging themes and similarities between the perceptions of the community and the data from the hospital and municipality. However, it is worth noting that the different sets of data were not used to determine any cause–effect relationship between AMD and the identified and reported health cases, but solely for the purpose of triangulation.

For households, the researcher personally visited and administered the semi-structured questionnaires to sampled households in Carolina central and Silobela Township. For each household, one questionnaire was administered. Upon receiving the questionnaire, members of the household would go through the questions together and one adult member of the household would complete the questionnaire. In other cases, the adult member of the household, who was available at the time of the visit, would complete the questionnaire on behalf of the household. In cases where the respondents had difficulties in reading and understanding the questions, the researcher read out the questions, explained the questions, and allowed the respondents to either complete the questionnaire or be assisted, in case they were unable to complete the questionnaire due to an inability to write. Additional information that the participants volunteered, regarding their situation(s), was captured as additional field notes.

As regards the data on reported environmental diseases that could be associated with heavy-metal-contaminated water in Carolina, nurses from the Silobela Clinic and a senior nurse in the Diseases Control Department of the Carolina Hospital were interviewed. Archived data, regarding the reported cases that could be associated with the presence of heavy metals in water or acid-mine-contaminated water, were provided to supplement the data collected during the interview.

Data on water quality in Carolina were collected through an interview conducted with an official in the Technical Services Department of the Chief Albert Luthuli Municipality. The interview covered the AMD water crisis that occurred in 2012 and the nature of the contaminants found in the water during that period. In addition to the interview, reports that summarised the results on the water quality assessments and the incident reports compiled by the municipality to describe the nature of the crisis relating to the water in Carolina were also provided by the Technical Services Department.

The primary data were then analysed, using thematic analysis. Emerging themes from the collected data were coded and grouped accordingly. The emerging themes from the collected data pointed to the subject of environmental justice. The naming and definition of themes was largely data driven; however, the interpretation was largely influenced by the subject of environmental justice. The quantitative data, which consisted of reported health cases, were analysed using Microsoft Excel.

7 Results

An understanding of the perceptions of communities located near mining fields regarding their local environment plays a significant role in assessing the knowledge possessed by such communities as regards the water contamination from local mining activities and the potential health risks associated with the consumption of such water. Presented here are the key findings of the study, which will cover the perceptions of the Carolina community about the quality of water in their area, the health risks associated with the water, the diseases inventory obtained from Carolina Hospital, and the water quality data of the Boesmanspruit Dam, acquired from the municipality.

7.1 Demographic profile of the respondents

Female participants dominated the study, constituting 68% of total respondents, owing to their availability and willingness to participate. Of these, 53% were from Silobela and 47% from Carolina central. Of the males, the majority were from Carolina central. A little over three quarters of the total respondents, 79%, were youth and young adults, aged between 20 and 40 years. The demographic profile of respondents can greatly affect the perceptions of individuals and is an important factor in perception studies. As a result, pertinent demographic variables were assessed, such as age, gender, education, household composition, and employment status of the household member participating in the study. This revealed that the employment statuses in the two sampled sections are different, with only 29% of the participants from Silobela being formally employed, while 96% of the participants from Padkamp/Carolina central were formally employed. The educational levels of the participants were also unevenly distributed, with the highest qualification obtained by the majority of respondents from Silobela being matric, while the majority of the participants from Carolina central possessed a post-matric formal qualification (Table 1).

7.2 The community's perceptions of the overall water quality in Carolina

Three questions were posed through a semi-structured questionnaire to elicit responses on the issues on the water quality. The first question was based on the participants' perceptions

Table 1 Demographic profile of the respondents

Gender of active respondent, per household	18 males (8 from Silobela and 10 from Carolina central)
	38 females (20 from Silobela and 18 from Carolina central)
Age of active respondent, per household	18–29 (21 respondents)
	30–40 (23 respondents)
	41–50 (4 respondents)
	51–60 (4 respondents)
	61 + (4 respondents)
Educational status of active respondent, per household	**Silobela**
	20 respondents with no matric
	8 respondents with matric + formal education
	Carolina
	8 respondents with matric
	20 respondents matric + formal post-matric qualification
Employment status of active respondent, per household	**Silobela**
	8 respondents formally employed
	16 respondents unemployed
	4 pensioners
	Carolina
	1 respondent unemployed
	27 respondents formally employed

of the quality of the water in the area. The question, "*What is your view over the quality of water in your area?*", was used for this purpose; the second and third questions related specific time frames to the quality of the water. The questions read: "*How was the quality of water in your area before 2010*?" and "*How was the quality of water between 2011 and 2013?*" These questions were intentionally posed with reference to time frames so as to evaluate whether the perceptions were based on the severe water crisis that occurred in 2012, or whether the community had concerns over their water even before 2012.

All the participants agreed that the state of the water was bad and that this problem had worsened in 2012. In comparison with the previous years, 80% of the participants felt that the water was rather good before 2011, while 20% felt that the water was just satisfactory before 2011. The community explained that after 2011, the water became toxic and was even declared undrinkable during the year 2012.

In describing the state of the water, the community referred to colour, taste, odour, chemical concentration, and the effects it had on their skin. The community maintained that (i) the water looked rusty, brownish, and often greenish and changed the colour of clothing when used for laundry; (ii) the water tasted strange and almost bitter on certain days and, when used for cooking, the meals would taste very strange; (iii) some community members also maintained that the water was unfit for consumption and looked different from normal water, and would result in various ill-health effects after use or ingestion; (iv) the community members, who used the water for bathing, explained that the water was very harsh on their skin and would cause dryness when used for bathing; and, lastly, (v) the community complained about the odour of the water, which would worsen if the water was stored for more than 2 days.

7.3 The perceptions of the community on the probable water contaminants in Carolina

The question, "*In your opinion, what is the source(s) of water contamination in your area*?", was posed to assess the perceptions of the community regarding the probable water contaminants in their area. The majority of the respondents perceived mining to be the main water contaminant in their area, while a smaller percentage associated the contamination of their water with old and corroded water infrastructure. A few respondents indicated having a lack of knowledge on the probable water contaminants in their area. The responses were summarised under these categories:

7.3.1 The mining sector as the source of water contamination

Over 70% of the respondents identified mining as the source of water contamination in their area. These respondents argued that the high concentration of mines in their area, some of which were abandoned and without having proper closure and no form of rehabilitation, facilitates the storing of acidic water in the sink holes of these mines, which then leaks into the local water bodies. These were their exact words:

> The chemicals used in the mining sector leaked into the local water bodies, resulting into water contamination and the chemicals found in the water are similar to those found in the mining industry.
>
> The mine waste contaminated the local water bodies through decanting pipe system.

> There is high concentration of mines in the area, some of which have been abandoned with no form of rehabilitation. As a result, the sink holes are storing acidic water which then leaks into the local water bodies.

7.3.2 Water infrastructure as the underlying cause for the state of the water

The second largest source of water contamination identified by the community was the old water infrastructure. Those who identified water infrastructure as being the problem behind their contaminated water argued that the water treatment plant was built years ago and had managed to cater for the needs of the society over past years. However, over the years, the population has increased considerably and the water distribution system has become dilapidated. Below are the responses of the participants:

> The pipe system is old and not well maintained while the effectiveness of the purification system is challenged by the high demand for water.

> The local mines have been in existence since the 1960s and we never experienced any water related problems until now. We therefore feel the water management authority is not managing the water well, therefore resulting in deteriorated quality.

7.3.3 Unknown source of water contamination

About 4% of the respondents did not really know or understand the contamination processes and explained that they had no idea what could be linked to the contamination of their water. Their response in this regard was:

> The municipality informed us that the mines located around Carolina were responsible for the contamination of our water; however, we lack knowledge of the processes involved. We rather believe that the chemicals used to neutralise the water are often over-used, especially by some of the incompetent employees in the water treatment plant.

7.4 The community's understanding of AMD and the associated health risks

The community, the majority of whom were from Silobela, indicated a limited knowledge of acid mine drainage, while a few made it clear that they knew nothing about acid mine drainage or the processes it entails. The following questions were asked in order to assess the knowledge of the participants regarding coal mining externalities and AMD: (i) *What do you consider the costs and benefits associated with coal mining in your area?* (ii) *What do you know about acid mine drainage?* (iii) *Do you think the quality of water in your area could be linked to acid mine drainage?* (iv) *Why do you think there is/there is no linkage between AMD and the quality of water in your area?*

In responding to the question of mining costs and benefits, the majority of the respondents identified the contamination of water as being the main cost of having mines in the area. In addition, they pointed out the bad condition of the road infrastructure, which they associate with usage by large mine trucks, the cracks in walls of their houses from blasting, and the dust released during the mining operations.

Regarding the question relating to their knowledge of AMD, only a few respondents from Carolina central possessed some knowledge of acid mine drainage and were able to link it to the contaminated state of the water in their area. Nevertheless, many of the respondents, who indicated having a lack of knowledge regarding acid mine drainage, were also able to associate the water contamination in their area with local mining activities. However, the only simple explanation the latter could give was that the mine wastewater decants into the local streams through unmanaged corridors and then contaminates the water.

As regards the effects of heavy-metal-contaminated water on their health, all the respondents appeared to possess some knowledge of the effects of the consumption of contaminated water on their health. Although many could not clearly explain the relationship between contaminated water and adverse health risks, they could still relate some of the diseases they had experienced during and after the abrupt water crisis that occurred in 2012 to the state of the water at the time.

The respondents identified gastrointestinal problems, such as diarrhoea, abdominal pains, and vomiting, as the immediate health effects, which could be associated with the consumption of such contaminated water (Fig. 3). They further identified skin rashes, which could be the result of irritations to the skin caused by the chemicals in the water, and, lastly, kidney problems/failure as a long-term effect, which could be a result from the consumption of acid-mine-contaminated water.

Some of the respondents confirmed that their perceptions about the identified health risks were backed up by their experiences, as they maintained that most of the identified illnesses were experienced severely for the first time in 2012, during the period when the local water had high concentrations of chemicals. In addition, some of the community members further explained that they would experience some of the identified illnesses a few minutes or hours after consuming the municipal water, while some illnesses would occur after repeated use of the water. The sudden outbreak of the same health effects in households consuming the same water served as confirmation to the community that the health effects were associated with the water.

The respondents further maintained that the gastrointestinal problems were reduced as more of the community members changed their water source from the communal municipal standpipes to the water collected from the Muslim community's boreholes and to bottled water purchased from local retailers. However, the skin rashes remained an issue, as these communities continued using the municipal water for bathing and other domestic chores. A reduction in the skin rashes was realised after intense water purification attempts by the local water authorities.

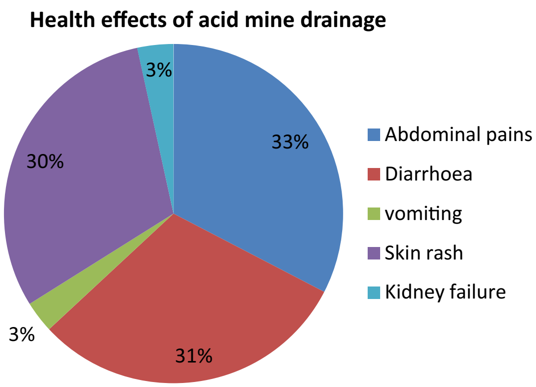

Fig. 3 Health effects associated with acid-mine-contaminated water—community's perceptions

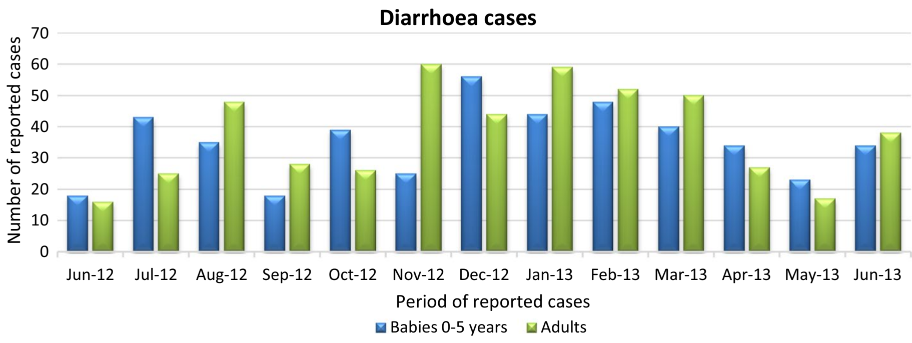

Fig. 4 Diarrhoea cases recorded in 2012 and 2013. *Source*: Reproduced with permission from Carolina Hospital (2013)

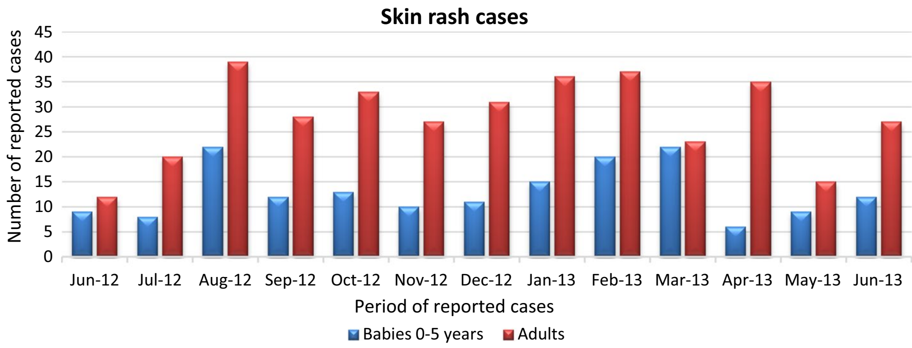

Fig. 5 Skin rashes reported during 2012 and 2013. *Source*: Reproduced with permission from Carolina Hospital (2013)

7.5 The Carolina diseases inventory and water quality results

In addition to the perceptions of the community regarding the health risks of AMD, interviews conducted with the nursing personnel at the Silobela Clinic and a senior nurse in the Diseases Control Department of the Carolina Hospital confirmed reported cases of diarrhoea, skin rashes, and abdominal pains. Supplementary data to the interviews were provided on the reported cases of diarrhoea and skin rashes during the period between June 2012 and June 2013 (Figs. 4, 5). Data prior to this period were not provided by the hospital. The limitation of the presented data is the absence of data from January 2012 to May 2012, which could have supplemented the presentation of a clear picture of the incidents of diarrhoea and skin rashes for the entire 2012 year. However, the reported data still provide an indication of cases reported during the period when the water was perceived as having poor quality. Another limitation of these data is that they only represent the cases that were reported at the local public hospital, and do not cover cases treated through private medical facilities. Furthermore, these data omit other gastrointestinal infections, such as the abdominal cramps and vomiting as identified by the community.

These data reveal reported cases of diarrhoea which affected adults and children aged between 0 and 5 years. Based on the presented data, incidents of diarrhoea were different across the months under review. Skin rashes are the second highest on the list of health effects identified by the community as being possibly associated with the contaminated water. According to the hospital records shown in Fig. 5, the reported cases of skin rashes were much higher in numbers than the reported cases of diarrhoea were, with adults being affected more than children were. The presented data on the reported cases of diarrhoea and skin rashes are used in the study for the purpose of supplementing the primary data on the perceptions of the community regarding the health risks of metal-contaminated water and to confirm reported cases of the health risks identified by the community.

7.6 Water quality results from the Chief Albert Luthuli Municipality

According to the Incident Report compiled by the Technical Services Department of the Chief Albert Luthuli Local Municipality, on 11 January 2012, after a heavy storm, the municipality learned of the deterioration in the quality of water processed at the Carolina Water Treatment Works. Water quality tests to assess the nature and extent of the problem, which were commissioned by the Technical Services Department, revealed low pH levels and a high concentration of heavy metals in the water. Further investigations revealed that fish in the local river and Boesmanspruit Dam were dying and generating bad odours and that the water had a dark green colour. The findings of the water quality assessment indicated a high concentration of pollutants such as sulphate, aluminium, iron, manganese, and cadmium.

8 Discussion

8.1 Community perceptions: the quality of the water

According to Doragu et al. (2009), socio-demographic factors, such as age, education, and political ideologies, have a significant influence on the perceptions, views, awareness, attitudes, and concerns about certain environmental issues and risks. The difference in the responses of the participants in the study suggested the influence of socio-demographic factors operating on perceptions and knowledge. Although the respondents showed a unified response as to the general quality of the water in their area, individual knowledge, views, and experience of poor-quality water could have influenced the responses of the participants. This is evident in how the same respondents, who all agreed about the state of the water, did not seem to agree about the time frame relating to the state of the water.

It is noteworthy that the issue of water quality is subjective, and this is influenced by formal knowledge of what constitutes good-quality water, by having access to water and by other socio-economic issues. Members of one community, with the same quality of water, seldom have the same responses about the quality of the water in their area. In cases where there would be a general consensus that the water is bad, the water would have changed from its natural form to having developed a strange colour or odour. In the case of Carolina, the majority of the respondents judged the quality of their water based on colour and odour, which then alerted them to the condition of their water. Pre-2011, before the abrupt AMD water crisis, many could not identify the water as poor quality, while some maintained that even then, they preferred sources of water other than the municipal water. According to the groundWork's report, "The Destruction of the Highveld—Digging Coal" (Hallowes and Munnik 2016), when the AMD crisis erupted in 2012, the water system in

Carolina was already weak, with a Department of Water Affairs Blue Drop (drinking water quality certification) score of 17.5% in 2010; 9.8% in 2011; and 18.4% in 2012, compared with the required score of 90%—notwithstanding a cholera crisis that had been experienced in Carolina during 2007.

The question of knowledge and awareness, as partly influenced by socio-demographics and the socio-political environment, comes into play in this regard. Furthermore, these same factors could have contributed to the uninformed decisions and actions regarding the use of the water, regardless of its state or condition. Such an example is presented in an online publication, "Tunatazama—a Network of Southern African Communities Living near Mines", which reports on how community members of an informal settlement in eMalahleni, Mpumalanga, let their livestock drink acidic water and their children swim in acidic water (Moraba 2015). A similar example is seen in the Tudor Shaft informal settlement, in the Witwatersrand gold mining area, where about 1800 people live in shacks built on radioactive and toxic soil, with children swimming in the radioactive dams and other religious activities, like baptisms, taking place in the radioactive dams (Olalde 2015).

8.2 Knowledge of AMD by the community

The concept of acid mine drainage has gained momentum over the past few years, and several attempts have been made to remediate its effects on the environment. Despite the several attempts made to remediate the associated effects, the reality is that mining remains an important contributor to the economy of South Africa and more mining permits are being issued for mining sites near communities. Therefore, communities located near these mines are on the receiving end, as their daily lives are adversely affected by acid mine drainage and other mining externalities. It is, therefore, important for these communities to understand the issues surrounding acid mine drainage and how their everyday lives are affected by this. Accordingly, this study has revealed that the majority of the participants were not fully informed about acid mine drainage.

The lack of knowledge by community members in this regard might suggest issues of lack of empowerment and participation in matters affecting their well-being, which could, in turn, represent their voicelessness, powerlessness, and vulnerability, or their being caught up in the "deprivation trap", as coined by Robert Chambers in his book, "Rural development: putting the last first" (Chambers 1983). Swanepoel and De Beer (2011) further clarify this, explaining that the poor have limited access to information and limited ability to influence issues and policies that affect them. Doragu et al. (2009) support the importance of local communities possessing knowledge about their environment and issues affecting their well-being. These authors argue that perception studies applied to the affected people can be used not only to evaluate the risk of that population, but also to contribute to public participation action, to increase awareness among the local people, and to facilitate an understanding of the views and values of the affected communities.

Planning and decisions relating to mining activities often exclude local communities from fully participating and influencing all decisions that will affect their well-being. In terms of Regulation 3 of the MPRDA Regulations GNR527, interested and affected persons should be consulted during the mining permit application process (South Africa 2004). A notice should be published through an applicable provincial gazette, magistrate's court, and a local or national newspaper (South Africa 2004). The methods used to inform affected parties of the mining permit application might effectively exclude communities that are uneducated and not well informed, but who are nevertheless directly affected by the approval of such application. The voiceless, vulnerable, and powerless communities, as referred to in Chamber's (1983) deprivation trap, have limited knowledge of and access to such important information. As a result, even if such information is made available to the public, the same information might not necessarily reach the most affected populations. Krause and Snyman (2014) maintain that creative ways of bringing community voices and interests to the fore of decision-making must be applied, because communities affected by mining largely comprise vulnerable and less-resourced segments of the population, who, as consequence, experience obstacles in accessing justice and realising their socio-economic rights.

An example is seen in an article titled, "Residents left in dark over acid mine drainage treatment", dated 11 February 2017 (Bega 2017). According to the article, the Department of Water and Sanitation had been accused of excluding locals from the official launch of the Eastern Basin's AMD plant, which had earlier been subjected to petitions and concerns over fears of water contamination and blasting (Bega 2017). Another example is seen in Kendal, near Ogies (which is part of the Mpumalanga coalfields), where farmers demanded that the cumulative impact of mines in their area be clarified, especially in as far as water quality was concerned, as this impacted on their farming activities and planning (Bench Marks Foundation 2014).

The exclusion of affected communities from accessing such important information, the unawareness of which might later expose the same community to adverse environmental effects, indirectly perpetuates the poverty situation of these communities. In their paper, "The cost of gold: environmental, health and human rights consequences of gold mining in South Africa's West and Central Rand", the Harvard School of International Human Rights Clinic (2016) argue that communities near mining fields or abandoned mine sites are particularly impoverished and frequently constitute black residents. The same authors advocate for the inclusion and engagement of such communities in mining issues that might affect them, as well as in decision-making and information dissemination in order to ameliorate the associated risks on these communities.

Sumi and Thomsen (2001) have argued that, in order to respond effectively to mineral development, local communities need to know the context and information necessary to understand and weigh the issues which they will be confronted with. Accordingly, this highlights the importance of communities—located near mining fields—being able to understand the current and future impacts that mining activities may have and will have on their well-being. In the case of Carolina, it is therefore important for the community to gain a good understanding of the nature of the externalities associated with the active and abandoned mines in their area. Consequently, the cumulative impacts of coal mining on their water and environment should be communicated to the community to enable them to make informed decisions about their well-being and livelihoods.

8.3 Perceptions of the community regarding the effects of AMD and water-related diseases

Although the community members possessed a limited knowledge of acid mine drainage, they were still able to link the prevalent environmental diseases to the contaminated water in their area. However, the community could only identify the short-term health effects—abdominal pains, diarrhoea, vomiting, and skin rashes—which occurred and worsened when the water became very toxic and undrinkable. In identifying these health effects, the majority of the respondents based their responses on previous experiences, as some possessed minimal or no formal education and knowledge regarding water contamination and the associated health threats. Moreover, many of the respondents maintained that the identified ill-health effects would lessen in severity, as more community members changed their water sources. The identified diseases were then checked against the contaminated-water-related diseases inventory from the local hospital, namely Carolina Hospital, which confirmed the reported cases of diarrhoea and skin rashes in Carolina during 2012 and 2013.

Some of the respondents maintained that they suffered from other illnesses, which they might not have linked to the water they were consuming as a possible cause. According to Hendrick (2016), many communities are unaware of the symptoms associated with the consumption of contaminated water and, as a result, many other health-related problems go unnoticed, even though they could have long-term health implications. The lack of official statistics on certain health issues renders the problem invisible (Martinez-Alier et al. 2014), and, as a result, little is done to respond to the problem, while the effects could be deleterious for affected populations.

The Federation for a Sustainable Environment (2017) maintains that long-term exposure to AMD-polluted drinking water may lead to increased rates of cancer, decreased cognitive function, and the appearance of skin lesions. However, documented and statistical information on the health cases associated with AMD is not accessible, consequently making the health risks of AMD less amenable to consider in significant research and policy arenas. Consequently, this re-emphasises the importance of educating these communities about their environment, how the natural state is altered through mining processes, and how the associated effects can be managed to reduce effects on their health and well-being. Facilitating access to educational services for communities close to mines could significantly improve the health and well-being of these communities (International Institute for Environment and Development 2002).

8.4 Empowerment and participation of mining-affected communities: an environmental justice approach

The concept of environmental justice has a strong history, which traces back to the 1980s. Environmental justice, which was formally known as environmental racism, emerged in the USA as an activism response to struggles against pollution which affected people of colour and low-income populations (Martinez-Alier et al. 2014). The reference to environmental racism was associated with the bad treatment and the suffering which people of colour and low-income populations had endured as a result of pollution and other social and environmental costs associated with resource extraction (Martinez-Alier et al. 2014).

Environmental injustice is manifested through three mechanisms—exclusion from decision-making, enclosure of resources, and the imposition of externalities (Munnik 2012). This author unpacks the three mechanisms as he argues that interested and affected parties often lack access to information pertaining to their environment and well-being. Decisions that could potentially impact negatively on these communities are made in their absence, and important information is either withheld or made available in manner that makes it impossible for these very communities to access it and use it effectively. The enclosure of resources is applicable in cases where communities are refused access to, or are dispossessed of, resources that they could derive benefits/livelihoods from, in order to benefit only the minority. South African mining is another typical example of enclosed resources because of its strong linkage to the historical, forceful removals of black people from their lands. In other cases, common resources like water streams are enclosed for the benefit of the minority. The last mechanism talks to the imposition of externalities, whereby local communities bear the negative costs of resources extraction, production, or manufacturing activities.

Schlosberg (2007), in his book entitled "Defining environmental justice", argues that contemporary theories of justice go beyond distributive justice, to a standpoint that includes theories about participation, recognition, and the way people function. Conde and Billon (2017) maintain that participation, as informed by an environmental justice paradigm, is linked to recognition and, like distributive justice, the lack of which could potentially impede justice. Hallowes and Munnik (2016) support this paradigm of environmental justice, citing the reality of environmental injustice in the Mpumalanga coalfields, demonstrated in the degradation of the environment, which people depend on; the dispossession and privatisation of common or public goods; and the exclusion of local communities from political and economic decisions over matters affecting them.

The mechanism presented above attempts to paint a picture of the realities of communities near mining fields. The complex nature of the challenges confronting these communities calls for a holistic approach to be taken towards addressing the underlying socio-political foundations of a system that works injustice. The empowerment of communities affected by mining, through inclusion, participation, and environmental education, may not be the sole answer to the question of environmental justice. However, this empowerment has a great potential to facilitate responses/action to some of the challenges that these communities face with regard to mining and their local environment. This supports the argument presented in Sect. 8.2 that the lack of awareness and knowledge might comprise a contributing factor in some of the uninformed decisions and actions pertaining to communities and their local environment.

Communities aspire to determining their own development path and having their voices heard, and to be able to influence decisions affecting their lives and have their rights recognised (Conde and Billon 2017). Leonard (2017) maintains that there is a dearth of literature that has explored the effectiveness of the inclusion of local communities and their participation in mining development and the extent to which they have influenced the approval or rejection of mining development. The paucity in the literature in this regard does not imply that mining-affected communities are completely disempowered and do not have an interest in participating in matters affecting their well-being.

Over the past few years, we have seen an increase in social movements for environmental justice, also known as environmental justice organisation/activism, the focuses of which range from grassroots issues to eminent socio-political issues. It is through these organisations that interested and affected parties became vocal about their concerns over the approval of mining applications in environmentally sensitive areas, the impact of mining on local communities, and the exclusion of local communities from decisions pertaining to their environment. This, therefore, shows that communities are not able to influence matters and decisions relating to the environment, because they are not empowered by government and mining houses to do so. These communities just need to be empowered and not be excluded from matters pertaining to their own environment and, consequently, their well-being. Hedin and Ranangen (2017) argue that the sustainability of a mining company is dependent on how well the local community is valued and prioritised.

9 Conclusion

The limited knowledge possessed by the community regarding acid mine drainage did not completely hinder the community from relating the prevalent environmental diseases in their area to the condition of the water. The community was able to identify gastrointestinal problems, such as diarrhoea, abdominal pains, and vomiting, as well as skin rashes, and then relate these health effects to the quality of the water provided to households by the municipality. The identified gastrointestinal problems and skin rashes corresponded with the reported cases of diarrhoea and skin rashes noted in the inventory from the Carolina Hospital. Moreover, the water quality report from the municipality confirmed a high concentration of pollutants, such as sulphate, aluminium, iron, manganese, and cadmium, found during 2012.

Consequently, this study has identified the struggles and injustices that communities near mining fields face as a result of the social and environmental costs of mining. Some of the struggles include the imposition of externalities, which in the case of Carolina, are seen in the poor water quality which is the result of acid mine drainage; the poor knowledge among the community of their local environment; and their exclusion from participation in planning and decision-making.

Thus, this study suggests that the establishment and enhancement of environmental health education programmes for communities located near mining fields should be prioritised so as to keep these communities informed about what is happening in their environment. Furthermore, the inclusion of mining-affected communities in planning and decision-making processes should be promoted and encouraged. This, therefore, implies the redefinition and transformation of current strategies being followed by the government and mining houses to promote and encourage the participation of communities in matters and decisions affecting their well-being. Relevant legislation should provide clearly detailed processes relating to affected communities' participation and consultation in mineral resources development. Challenges relating to the enforcement of legislation should also be addressed in order to bring about environmental justice in mining communities.

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