Double burden of mine water resources and the prospect of corporate sustainability as adaptation strategy: perspectives from Ghana, West Africa

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Abstract

Understanding the hydrologic dynamics is primary for any meaningful water management strategy but such information is hardly available within mine-take watersheds since they are poorly gauged and are scarcely studied. The case of West Africa is alarming due to intensifying hydroclimatic hazards, which will double burden the surrounding socioecological systems and affects operational performances. This study explores the dual effects of mine water and associated hydro-sociological systems, considering operational activities and changing climatic conditions. Drawing on empirical perspectives from operational sites in Ghana, and West Africa, the study establishes a link between mining and local hydroclimatology. This insight underscores the significance of extending corporate interest beyond operational sites, emphasizing the importance of watershed assessment as an initial step in adapting to the local effects of climate change and coexisting with fringing communities, especially in vulnerable regions like rural West Africa.

Keywords: Climate variability, mining sustainability, mine water, social licence, watershed hydrology

Introduction

Poor management due to failing mine water models and other site-specific factors lead to increased exposure of operations and their surrounding communities to the risks associated with the variability in local climatic conditions. Literature is explicit on the effects of changing climate on sustainable mining (Gonzalez et al. 2019; Hodgkinson et al. 2014; Mavrommatis & Damigos 2020; Odell et al. 2018; Tannor et al. 2023). In particular, mine water systems risk double exposure of both climate change and poor site management practices, though hardly considered in literature from a holistic perspective.

Studies focusing on mining and basin drainage-hydrogeochemistry interactions have advanced across several mine-take watersheds of the global north compared to the global south. A cursory search via Web of Science delimited to "mining and hydrology" between the years 2000 and 2023, yielded at least hundred articles across the Americas, Europe, Australia and Asia whereas Africa recorded the least. In particular, studies focusing on the influence of mining on local watershed dynamics abound whereas, the influence of local watershed dynamics on mining performances and their surrounding communities have not received adequate attention irrespective of the global significance of the industry. For instance, studies focusing on hydrologic regime and environmental quality (Kovács et al. 2006), storm water and diversion channels (Flatley & Markham 2021; Rybnikova et al. 2023) or water abstraction (Coldewey & Wesche 2017) in mine-take watersheds are critical not only to ensure sustainable mining but the resilience of surrounding resource systems. Such information would be unparalleled for mine-take watersheds across West Africa where operations have close relationship with the surrounding communities.

The Ghanaian perspective is skewed toward water quality and mining interactions. In fact, a recent review on hydrological studies in Ghana affirms the knowledge gap in key areas such as rainfall-river flow processes and their controls (Ampadu 2021). Most of the river basins are poorly gauged and sparsely furnished with meteorological stations thus making hydrological studies a challenge. Few studies have been conducted within major mine-take river basins such as the Black Volta (Logah et al. 2021; Shaibu et al. 2012), Pra (Awotwi et al. 2021), Ankobra (Aduah et al. 2017) and Tano (Larbi et al. 2022). The unavailability of adequate hydroclimatic data have often resulted in poorly designed and malfunctioning site water balance models and as well as stormwater systems. The situation will escalate with time due to increasing climatic variability across the West African region. The region has been identified as a hotspot to climate vulnerability (Nkrumah et al. 2014; Sylla et al. 2016).

Given that increasing climatic variability affects water resource systems of both operations and their surrounding communities, corporate interest in collaborative research by watershed approach would be key to address the local effects of changing climate within the entire mine-take watershed. The International Council for Mining (ICMM) attest to the need for mines to look beyond traditional operations-based water management toward the dynamic interactions within the wider basin which include holistic understanding of the hydrology and landuse as well as the socio-political institutions (ICMM 2017). Their position buttresses the attitudinal and behavioural influences of local stakeholders such as the public as identified in previous studies (Wolkersdorfer et al. 2022) as well as employees toward sustainable mine water management.

The aim of the study is therefore to establish a case for corporate interest in watershed assessment extending beyond operational sites, by examining the vulnerability of mine water systems to operational practices and local effects of changing climate using the adapt to coexist framework.

Methods

1. Conceptual framework

The Adapt to coexist framework (Fig. 1) is an interdisciplinary assessment tool previously developed by the author to examine the local effects of climate change on the resilience of mining operations within rural landscapes (Tannor, 2024). The framework consists of three main components namely the (i) Interactive mining eco-sociotechnical system (A, B and C), (ii) Exposed subsystems (D and E) and (iii) Intervention unit (F). In this study, the framework is used as an analytical guide to categorize the complex interactions of mine water and surrounding socio-hydrological systems and to propose actions to address the outcomes.

i. Interactive mining eco-sociotechnical system and GEC (A, B and C)

The author argues from industrial ecology that an industry is embedded within the natural system (Chertow & Portlock 2002; Ehrenfeld 2007). Thus, the West African mine operate as an eco-sociotechnical system in which the components (natural, social and technical) interact dynamically to generate outputs (mineral resources) outcomes (environmental aspects). The natural component (A) include the biotic and abiotic factors including the edaphic and climatic factors, mineral resources as well as the surrounding human communities and their ecosystem and services. The social components (B) include the socio-political institutions such as the diverse actors stakeholders governing the industry at local, national and global levels. These include the mining organization, the employees and their attitudes and behaviours. Similarly, the technical component (C) includes the mining best practices, the mine infrastructure as well as the technologies employed in operations.

ii. The exposed subsystems

The exposure component consists of the features of operational performances (D) and the surrounding resources (E) such as the socio-hydrological system (SHS) whose sustainability are influenced by the feedback from the dynamic interactions. A distinct usefulness of this framework is the provision to examine the indirect outcomes emerging from the exposed subsystems, which can influence the overall performance of the mine. The exposed subsystem informs the unit of analysis and determines the scope of any study.

iii. The Intervention Unit (F)

This is the pragmatic component of the framework engendering collaborative approaches including corporate sustainability management to address direct and emergent outcomes. Thus, this section typifies the fact that the economic performance of an operation is insufficient to determine the sustainability of a mine as traditionally perceived. Rather, operations performances depend on the capacity of the mine to manage the outcomes emerging from the dynamic interactions.

1.2 Empirical research setting

Fig. 1 shows drainage basins of Ghana, highlighting the major mine-take river basins within the country and the study area. Generally, the surface water and drainage of Ghana are categorized into three systems, namely the Volta, Southwestern and Coastal systems. The Southwestern system (SWB) consists of the Pra, Ankobra, Tano and Bia basins, occupying 22%. The Tano and Bia rivers are transboundary, originating from Ghana and joining the Gulf of Guinea in Ivory Coast via the Aby lagoon. The SWB is the most humid part of the country hosting the Tropical Guinea forest, with mean annual rainfall between 1500 mm and 2000 mm. Based on the mineralogical geology of the country, the mining basin can be categorized into northwestern and southwestern Domains (Masurel et al. 2021). The southwestern falls within SWB, thus major mining operations in Ghana are located within the Tano, Ankobra and Pra River basins including the study area. Three mine operations across the SWB namely Pra, Ankobra and Tano river basins accepted to participate in the study as shown in Fig. 1. Two of the operations are surface mining whilst one operates both surface and underground mining.

Based on secondary data, the Adapt to coexist framework was used characterize the systemic nature of mine water and surrounding socio-hydrological system as well as the vulnerability of this coupled system to local effects of changing climate. Guided by the framework, mixed method approach was employed to design the field research activities. As an initial step, key actors of mine water system were identified. These included the community affairs officers, environmental engineers, mine planners, production engineers, maintenance engineers, metallurgical engineers and project engineers working within the three selected operational mines as well as officials from the Ankobra Basin Secretariat. These served as key informant interviewees in September 2018 to examine mine water management and increasing extreme climates across southern Ghana. The outcome of the interviews was used to develop a survey instrument, which was conducted within the operations. Owing to the Covid-19 burden at the time of the field research (April–October 2020) the criteria for participation was based on the availability of the mineworkers on site.

2. Mine water system in Ghanaian mine-take watersheds are double burdened

Guided by the Adapt to coexist framework, the interactions of mine water and local climatic variability as a complex system within mine-take watersheds were characterized to understand the simultaneous exposure of mine water systems to operational management outcomes and local hydroclimatic conditions. These include the outcome and outputs of the interactive mine water sociotechnical system as well as the influence of the operational outcomes and direct local climate extremes on the exposed subsystems. In addition, a debate is initiated on the interventions to address the double exposures.

2.1 Key characteristics of the mine water sociotechnical system

The main components of the mine water socio-technical system and their interaction with changing climatic conditions were examined. Generally, mine concessional lands can be characterized as intact and disturbed forestlands protecting headwaters, hence making water management an issue to sustainable mining. Others can be categorized as agricultural lands usually interspersed with rural human settlements. Natural resources in Ghana including minerals and water belong to the people of Ghana but held in trust by the President according to the 1992 Constitution. Readers are kindly referred to Tannor et al. (2023: p. 6) for detailed profile of mining across southwestern Ghana including the local regulatory and climatic regimes. Empirically, operational workers and their surrounding households have confirmed the changes in local climatic conditions across southwestern Ghana (Tannor et al. 2022; Tannor et al. 2023).

2.2 Exposed subsystems

The unit of analysis in the study is the mine water system performances including the dewatering infrastructure, mine water balance model, AMD and environmental quality management. The dewatering infrastructure controls mining planning production activities whereas most mine water balances focused on raw water demand-supply dynamics relevant for metallurgical activities. Stormwater and stormwater and diversion structures are dependent on project phase and pioneer mine operational developments just as acid mine drainage (AMD) and environmental monitoring management protocols. Management practices of mine water systems combine with local hydroclimatic changes, to generate direct operational and emergent outcomes (Fig. 2). This dynamic relationship between mine water and the surrounding systems thus affirm the insufficiencies in traditional site-specific water management practices.

2.3 Interventions

Given that, emerging outcomes of surrounding socio-hydrological system that have been exposed to hydroclimatic hazards will influence the overall performance of the mine, corporate participation in hydroclimatic assessment and adaptation strategies within mine-take watershed is imperative. Three key areas identified to empower operations to move from traditional onsite based water resources assessment toward watershed level assessment as similarly recommended by the ICMM are summarized below:

- Watershed approach to mine water assessment and management in place of site-specific approaches including inter-mines collaborations.
- Operations-academic collaboration to address real time hydroclimatic and related mine water problems.
- Capacity building of surrounding communities on climate change awareness and behavioural changes towards rapid land use change within mine-take watersheds.

3. Mineworkers perspectives on mine water systems and extreme climate events

Sixty mineworkers participated in the survey to underscore the vulnerability of mine water systems to changing hydroclimatic conditions within southwestern Ghana. Respondents generally associated high extent of vulnerability of Pit dewatering and site drainage management (92%), Site water balance (83%) as well as Mine planning and production scheduling (65%) to extreme rainfall variability across southern Ghana.

Conclusions

The study conceptualized the double burden of mine water and their surrounding hydro-sociological systems to the effects of operational activities and changing climatic conditions. Empirical perspectives from operational sites across Ghana, West Africa affirmed the strong association between mining and local hydroclimatology. Hence, corporate interest in watershed assessment beyond the operational site can be a start-up strategy towards adapting to the local effect of changing climate particularly within vulnerability hotspots such as rural West Africa. Operational workers' perspectives stress the vulnerability of key mining activities to prolonged rainfall and persistent dry conditions in southwestern Ghana, underlining the need for a collaborative industry-wide approach to hydrological studies within mine-take watersheds.

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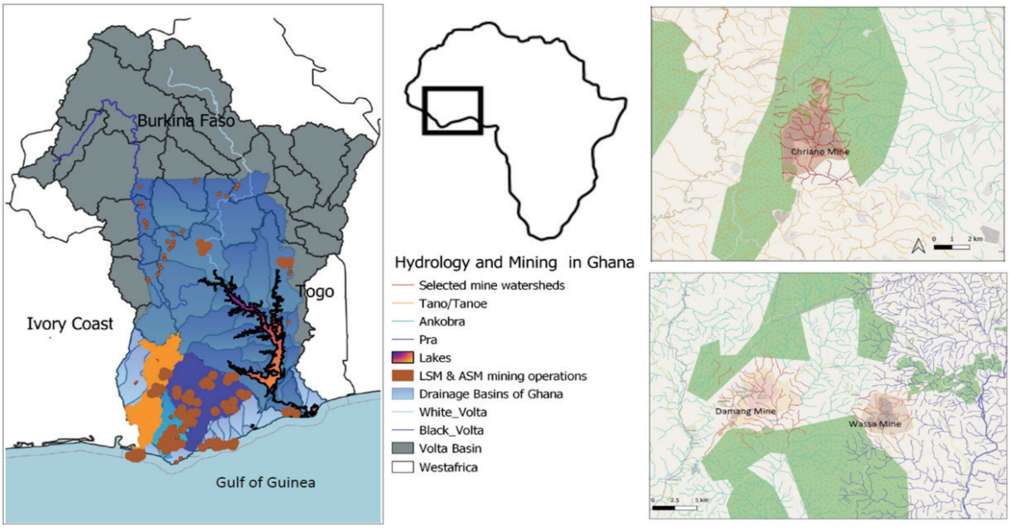

Figure 1 Major mine-take river basins in southwestern Ghana (Map: developed by Author)

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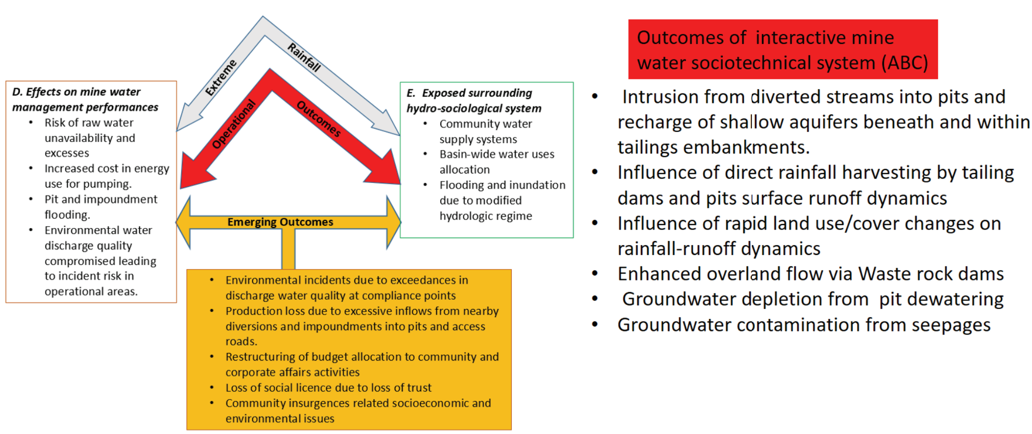

Figure 2 Double burden of mine water and surrounding socio-hydrological systems

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