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Impacts of Coal Mining on Deka River Water Quality and Livelihoods of the Surrounding Community

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Abstract: Coal mining is one of the major contributors to Zimbabwe's Gross Domestic Product. However, it presents numerous adverse challenges on the environment, local ecosystems and livelihoods. This study sought to assess the impacts of coal mining on the quality of the water in Deka River and livelihoods of the nearby community in Hwange district. Data was solicited using two methods; water sampling and analysis; and focus group discussions (FGDs). Water samples were collected on three sampling sites/sections (upstream, middle and downstream) of Deka River for three consecutive years from 2019 to 2021, in a 2 x 3 factorial experimental design. Concentration levels of eight physico-chemical parameters (pH, DO, TDS, EC, Mn, Fe, turbidity and sulphates) were assessed. Conversely, 40 respondents were selected using stratified random sampling technique to participate in two FGDs to gather their perceptions on how their livelihoods were impacted by coal mining pollution. The study found the middle section, to be the most polluted as pH, TDS, EC, Mn, Fe, turbidity and sulphates levels were significantly higher than the maximum allowable WHO standards. Statistically, there was a significant interaction effect at $p<0.001$ between Sampling site and Year (time) on the levels of seven water parameters in Deka River. All respondents highlighted that they were negatively impacted by coal mine pollution of Deka River, which they were using for drinking purposes and for their livelihoods. They complained of high incidences of a plethora of diseases among themselves and their livestock as well as death of fish, livestock and people.

Keywords: Acid mine drainage; Effluent; Environment; Health; Heavy metal; Pollution

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INTRODUCTION

Mining can be defined as the extraction of materials from the earth, typically from an ore body, lode, vein, seam, reef, or placer deposit. Such materials include coal, gold, and diamond among others. Mining is extremely important to many economies across the world and most importantly in the developing countries (Badamasi et al., 2023), as it generates revenue and contributes significantly to the Gross Domestic Product (GDP). In Zimbabwe, one such important mineral is coal. It is most commonly mined in Hwange district.

Coal is treasured for its energy content and has already been used in electricity generation since 1880 (Olson and Lenzmann, 2016). Coal has a plethora of uses including as a fuel in the steel and cement industries to extract iron from iron ore and to manufacture cement and in the smelting and alloy production industry. World over, coal mining provides income and employment to tens of millions of people while also providing economic benefits to millions of people who are not directly involved (Paltasingh and Satapathy, 2021). The rapid growth of coal mining in Zimbabwe is a consequence of the government's 12-billion-dollar mining roadmap, which anticipates coal mining industry to contribute about USD 1 billion (Ncube-Phiri et al., 2015). However, on the flipside of all the aforementioned positive benefits of coal mining are several adverse impacts on the environment (including greenhouse gas emissions, deforestation and climate), local ecosystems, as well as the health of local communities and workers (Badamasi et al., 2023; ELAW, 2010).

The receiving waters of coal mining effluents are heavily impacted. Deka River is a perfect example of this coal mining effluent pollution. Water is universally recognized as an economic and social good that is finite, non-substitutable, and essential to all forms of life (Hülsmann et al., 2019; Lin et al., 2022; Sur et al., 2022). It is worth noting that all living things rely on water for survival, and thus, water should be available in the best possible condition in terms of quantity and quality, hence the need to conserve it. Water pollution, on the other hand, has caused water bodies to deteriorate (Lin

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et al., 2022; Xu et al., 2022). Water pollution is defined as changes in the condition of water caused by the introduction of substances in relative quantities that render it unsuitable or harmful for its intended purposes (Brirhet and Benaabidate, 2016; El Sayed et al., 2020).

Water pollution degrades the quality of water and harms public health, as well as affecting ecosystems and imposing costs on the economy and the cost of water treatment (Chitata et al., 2022; Lin et al., 2022; Masere et al., 2012). This is visible in the dramatic transformation in the once clear Deka River water in Hwange, which has turned green with an unpleasant odour and gradually becoming a safety hazard for aquatic life (Prosser et al., 2011). Mining operations often results in massive land clearing and deforestation (Nyahwai et al., 2022), leading to significantly large deposits of eroded soil particles and sediments into rivers thereby lowering the quality of the water and reducing the river's maximum capacity (Ekwule et al., 2019). Similarly, abandoned mines and mine tailings have a long-term impact on water resources due to acid mine drainage (AMD), which is caused by the accelerated weathering and oxidation of sulphide-rich ore deposits and mine water, resulting in acidic effluent with high metal concentrations (Matveeva et al., 2022).

It is critical to note that AMD is still a major source of water pollution in the mining sector around the world (Apua, 2020; Montes-Atenas, 2022). Deka River is constantly polluted by AMD and heavy metals leading other challenges like threats to public health of communities relying on the river for their livelihoods. Thus this study is critical in assessing the impacts of coal mining on the quality of water in Deka River over a time period. Specifically, the study sought to determine the influence of coal mining effluent on the physico-chemical parameters of water in Deka River and subsequently the nearby community. In order to address these objectives, this research was conducted along Deka River in Hwange District, Zimbabwe from 2019 to 2021.

MATERIALS AND METHODS

Study Area

Deka River originates about 80 kilometres southwest of Hwange, the commercial centre of Hwange District. Hwange is a mining town located North West of Zimbabwe close to the border with Zambia and Botswana (as shown in Figure 1). The river passes through Hwange town and many rural communities as it runs northeast-ward into Zambezi River. Hwange district falls in agro-ecological regions IV and V, which are characterized by semi-arid to arid conditions where annual rainfall ranges from 450-650mm and less than 450mm respectively (Moyo et al., 2012). The soils are mostly Kalahari sands. Park vegetation is typical of dystrophic savannas, with mostly bushland interspersed with patches of woodlands and grasslands, which are especially common near waterholes.

The economic activities revolve around mining and wildlife enterprises. Due to a lack of functioning drinking water boreholes, community members from nearby villages use the river water for domestic purposes, feeding/watering their livestock and for catching fish for relish (Ruppen et al., 2022). Hwange's farming system is semi-extensive multiple cropping systems that includes small stock and cattle production as well as the cultivation of grain crops such as maize, groundnuts, sorghum, cowpeas, and pearl millet (Ncube-Phiri et al., 2015). The coal mining industry continues to be the most important economic factor in the area.

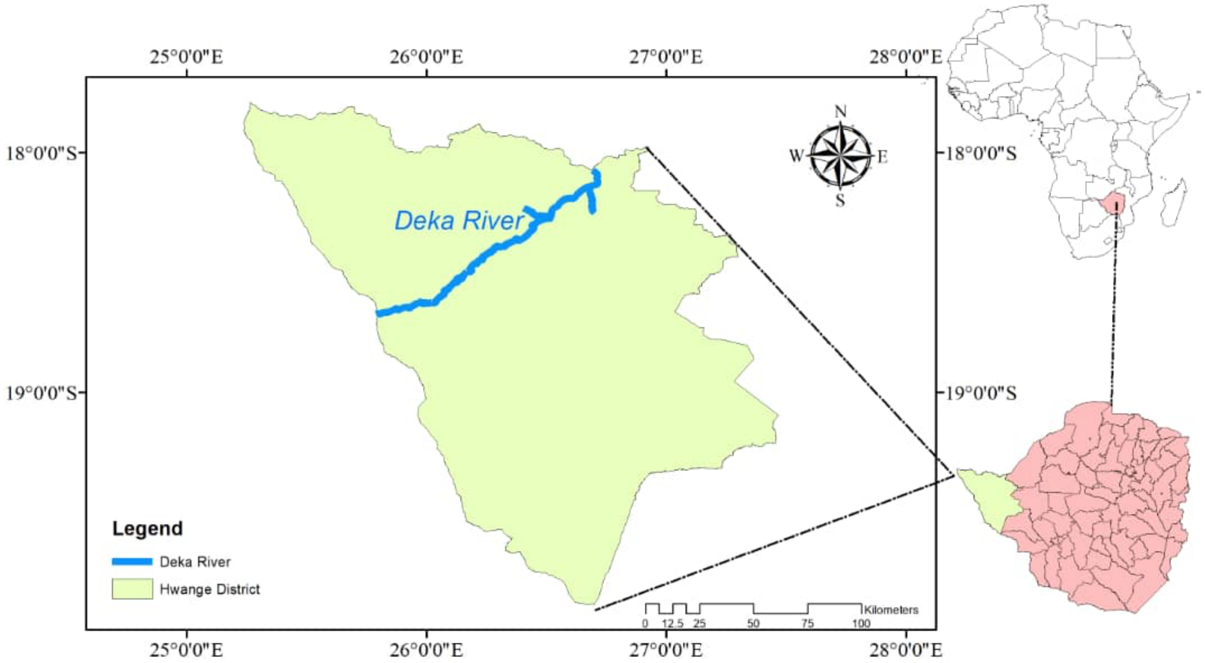

Figure 1. Geographic location of the study area; (a) Hwange District (b) Zimbabwe (c) Africa

Data Collection

Data was solicited using two main methods namely: river water sampling and analysis; and focus group discussions (FGDs). Purposive sampling was used to collect water samples along Deka River. Water quality kits were provided by the Environmental Management Agency Laboratory (EMAL) which performed the water quality analyses. The water quality kits included containers for all sample parameters to be analyzed and the preservatives required. Samples were collected into 2-litre clean plastic containers. Each sample was labelled with its specific reference tag. A waterproof marker was used to label all samples. The following information was captured on each sample: Reference number, Source of sample, Date and time of sampling, Location, Name, and address of the sampler, Reason for analysis, and the Name of province. The samples were then tightly sealed and securely placed into a cooler box and were delivered to the laboratory within 24 hours.

The study utilized a factorial experimental design with two factors (sampling site/section and year), both of which had three levels conducted in a completely randomized design. Three sampling sites/section (Sample Site A, Sample Site B and Sample Site C) were established along Deka River, as shown and described in Table 1, from which composite samples were collected monthly for three years (Year 1, Year 2 and Year 3). Each composite sample was made up of three representative subsamples. Descriptions of each of the sampling sites/section are shown in Table 1.

Table 1. Sampling site location and description

Sampling Site	Position along the River	Description/Notes
A	Upstream, before Runduwe Tributary joins Deka River	It was located above the mining area. Used as a control
B	Middle section of Deka River, at the confluence with Runduwe Tributary.	At this point, the samples were taken to note the impact of mining on the river water quality
C	Downstream	This site was chosen to assess the river water quality downstream of the mining site and to compare it with other sites

All the water samples were analysed at the EMAL for the selected eight physico-chemical water quality parameters namely; pH, iron (Fe), manganese (Mn), turbidity, sulphates, dissolved oxygen (DO), total dissolved solids (TDS) and electrical conductivity (EC). As shown in Table 2, the laboratory analyses were performed using the standard operating procedures for chemistry methods at the EMAL. These methods include the Atomic Adsorption Spectrophotometer (AAS), titrimetric and the gravimetric analyses among others (Table 2).

Table 2. Experimental parameters and laboratory methods were used

Parameter	**Method**	**Units**
pH	Electrode	
Fe	AAS Flame	mg/litre
Turbidity	Turbidimeter	NTU
Sulphates	Titirmetric	mg/litre
Mn	AAS Flame	mg/litre
EC	Conductivity meter	uS/cm
TDS	Gravimetric	mg/litre
DO	Electrode	Saturation %

Statistical water quality data analysis was done using the R-Software to determine the impact of coal mining on the quality of water in Deka River. Analysis of variance (ANOVA) was conducted to isolate the sources of variation in the concentrations/levels of the selected eight water quality parameters. Further, the interaction effect between factors (sampling point and year) was investigated.

In order to understand the impacts of coal mining on the livelihoods of the community around Deka River, two FGDs were conducted. A total of 40 respondents were selected using stratified random sampling technique, to participate in the two FGDs where their perceptions were gathered. Location of respondents' homesteads in relation to the water sampling sites was used as the strata. Thus, 20 respondents were randomly selected from those residing close to sampling site B (which is the confluence of Runduwe tributary and Deka River), with the remaining 20 respondents being randomly selected from those residing in the vicinity of sampling site C (which is located downstream Deka River) (Table 1).

The main questions in the FGD guide included: What are your sources of livelihoods? Given this area is dominated by coal mining, what do you perceive to be advantages and disadvantages of coal mining? What are your main sources of water for domestic, agricultural and/or any other purposes? Are you satisfied with the quality of water in Deka River? Have you been affected in any way after using Deka River water for domestic purposes? Explain the importance of Deka River to you? The qualitative data generated from perceptions of respondents on the impacts of coal-polluted Deka River on their livelihoods was analyzed through the emergent themes approach.

RESULTS AND DISCUSSION

The levels of pH ranged from 4 to 9 which are generally in line with the World Health Organisation (WHO) stipulated range of 6.5 to 8.5 for river water standards except for sampling site B, which was acidic. At the upstream of Deka River pH was generally alkaline throughout the three-year study period whereas at sampling site B, which is the confluence of Runduwe tributary and Deka River, pH was acidic (Figure 2). Sampling site C, which is downstream of Deka River, pH was generally neutral to slightly alkaline.

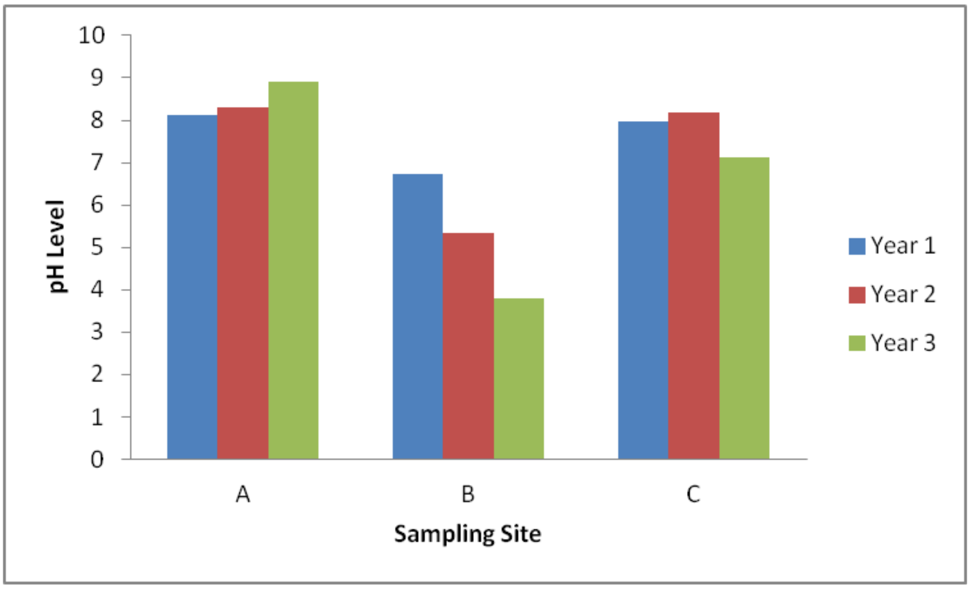

Figure 2. Average pH levels at different sampling sites along Deka River over three years

A possible reason the alkaline conditions upstream could be that there was no mine effluent contamination, unlike at sampling sites B and C. The lowest levels of pH were recorded at sampling site B due to contributions from Runduwe tributary which is contaminated with mine effluents. In similar studies (Gotore et al., 2022; Masere et al., 2012), it was noted that tributaries loaded with acidic wastes are capable of altering the pH level in the receiving waters. Statistically, both factors (Sampling site and Year) were significant at $p<0.001$ and there was a significant interaction effect between Sampling site and Year on the pH of water in Deka River (F = 718.3; d.f = (4, 18); $p<0.001$). The interaction plot between the two factors is shown below (Figure 3). The variations in pH levels over time and at different points may also be attributed to AMD, which is as a result of the reaction of pyrite, oxygen and water (Baxter, 2017).

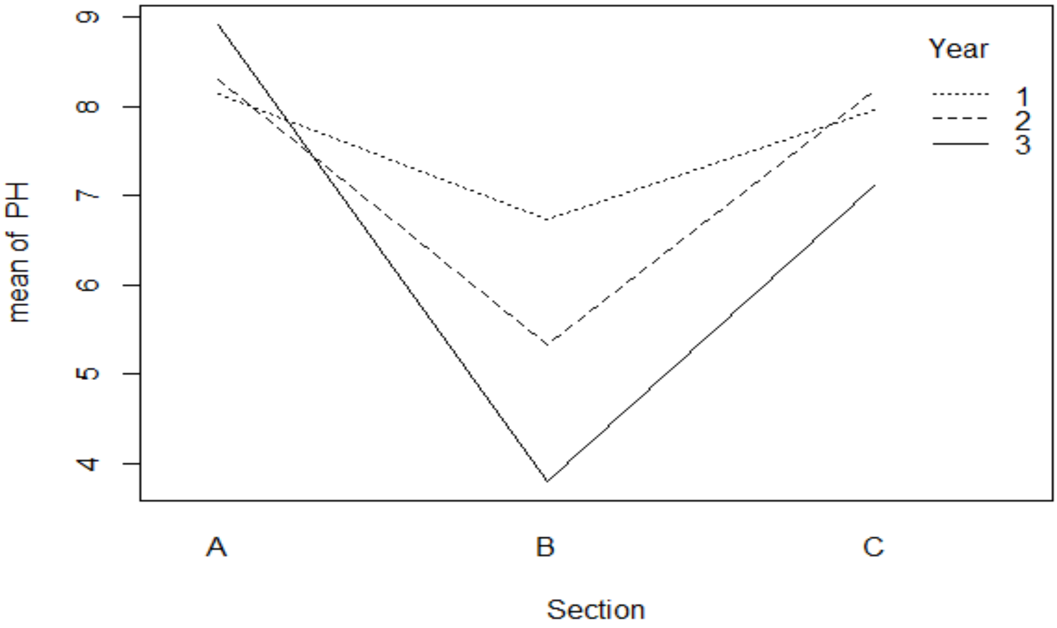

Figure 3. Interaction plot indicating the effect of both Sampling site and Year on pH levels

Manganese levels generally increased over time from Year 1 to Year 3 across all the three sampling sites. The levels of Mn at sampling sites B and C were significantly higher than the EMA standard of 0.1 mg/l for drinking water. Upstream (Sampling site A), there was minimal contamination whereas there was significant contamination at Sampling sites B and C. Manganese levels were highest at Sampling site B mainly because it is located at the confluence where Runduwe tributary, which is contaminated by coal mine effluent, meets with Deka River (Figure 4). This contaminated inflow from Runduwe tributary also affects the Mn concentration downstream (Sampling site C).

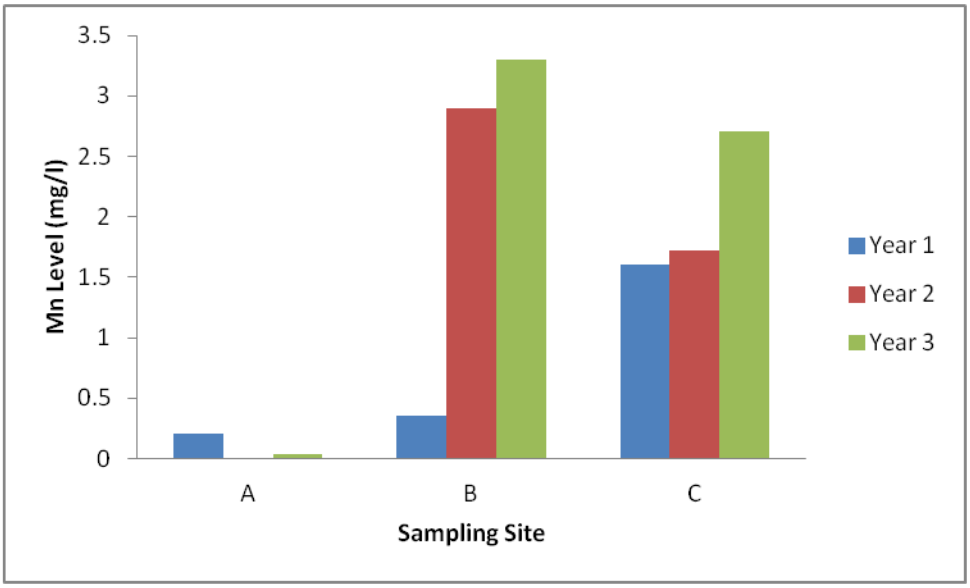

Figure 4. Average Mn levels at different sampling sites along Deka River over three years

Another possible reason for the increase in Mn level could also be linked to the acidic conditions (low pH levels) obtaining especially at sampling site B. Mn is dissolved in some rocks and soils. It is associated with high iron content and acid water. Similarly, Matveeva et al. (2022) and Ruppen et al. (2021) obtained results that showed that Mn levels were increasing downstream of a river near a coal mine. Statistically, both factors (Sampling site and Year) were significant at $p<0.001$ and there was a significant interaction effect between Sampling site and Year on the Mn of water in Deka River ($F = 480.8$; d.f = (4, 18); $p<0.001$). The interaction plot between the two factors is shown below (Figure 5).

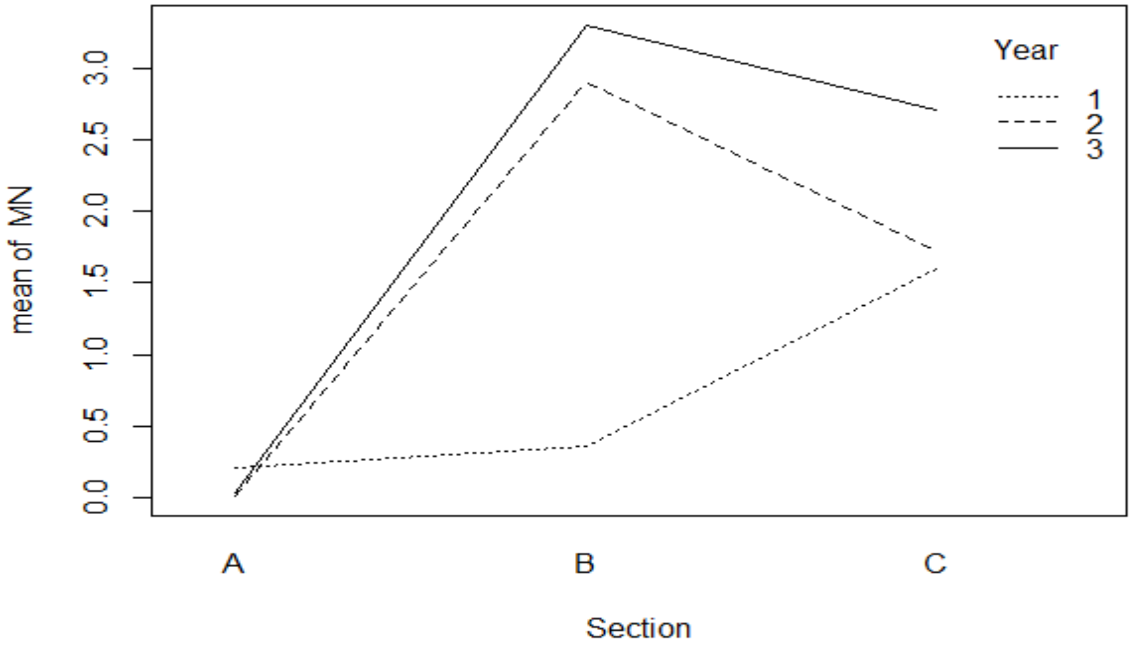

Figure 5. Interaction plot indicating the effect of both Sampling section and Year on Mn levels

Iron concentrations were generally higher at sampling site B than at sites A and C. Sampling site B also recorded increases in Fe concentration from Year 1 to Year 3 whereas similar Fe levels were observed across the three years at Sampling site A (Figure 6). The Fe concentrations at sampling site B for all the three years was above the WHO maximum allowable level of 0.1mg/l for river water. This shows the influence of how pronounced the effect of Runduwe tributary on Fe concentration in Deka River is.

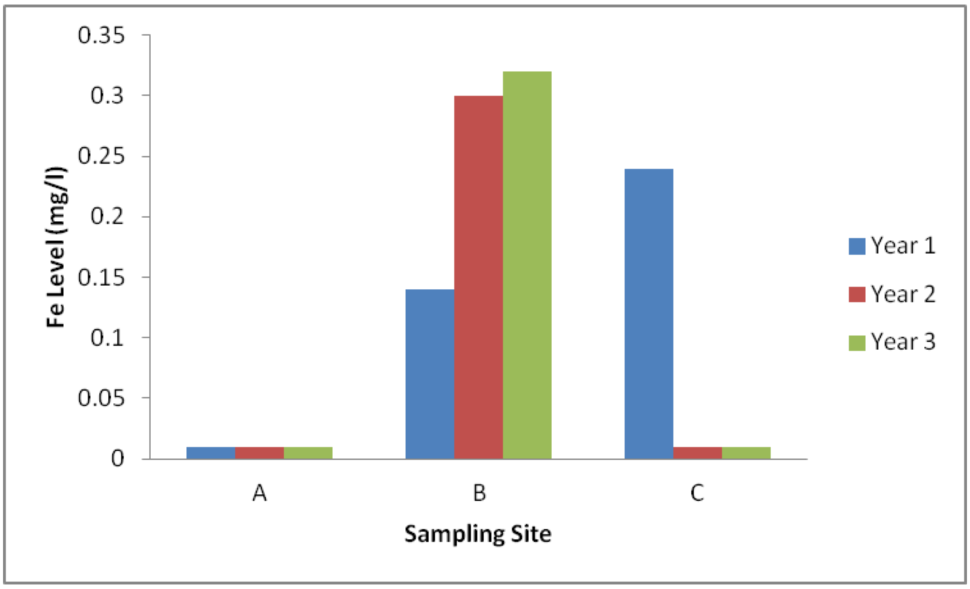

Figure 6. Average Fe levels at different sampling points along Deka River over three years

Fe (along with acidity and aluminum) is often the principal contaminant of concern present in AMD from coal mines. Fe is dissolved in rocks and can be dissolved by low pH water hence Fe concentration has a relationship with low pH (US EPA, 1994). Statistically, both factors (Sampling site and Year) were significant at $p<0.001$ and there was a significant interaction effect between Sampling site and Year on the Fe of water in Deka River ($F = 606.0$; d.f = (4, 18); $p<0.001$). The interaction plot between the two factors is shown below (Figure 7).

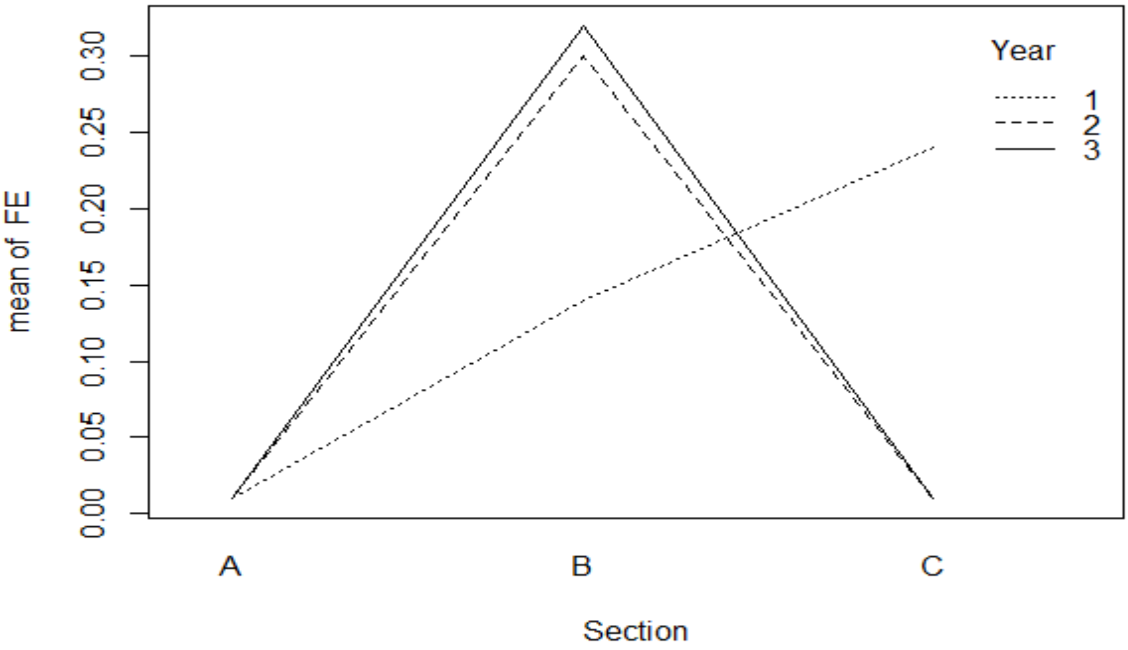

Figure 7. Interaction plot indicating the effect of both Sampling section and Year on Fe levels

The lowest turbidity levels were recorded upstream of Deka River (sampling site A) while sampling site B recorded the highest turbidity concentrations throughout the three-year period (Figure 8). This is because site A is upstream of the Deka River and was not affected by coal mining. Despite the relatively low levels of turbidity at sampling site A, all the sites recorded significantly higher turbidity levels that are above the WHO allowable limit for drinking water of 1 NTU.

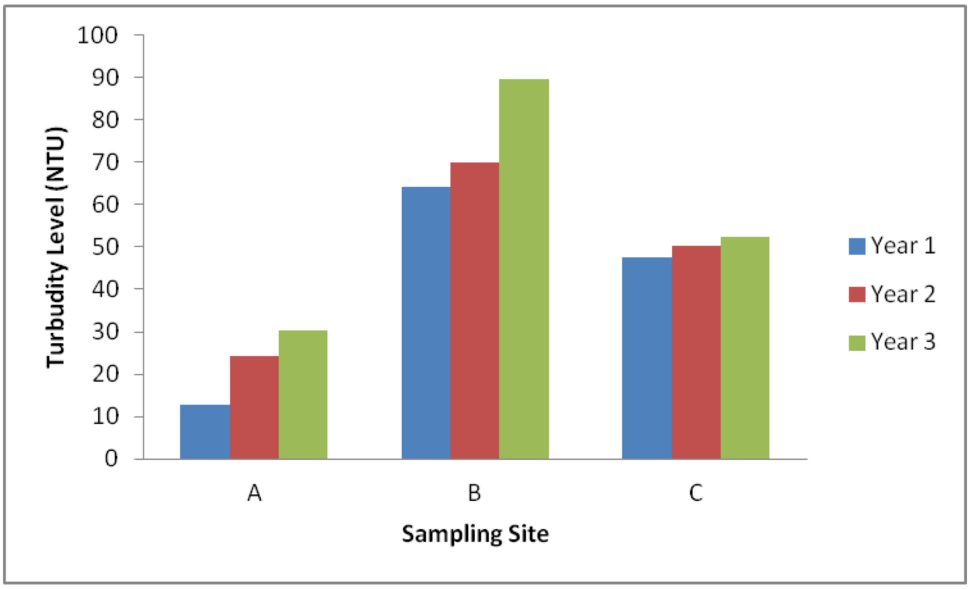

Figure 8. Average turbidity levels at different sampling sites along Deka River over three years

Clearly, pollution levels in Runduwe tributary is responsible for altering the turbidity levels in Deka River as highlighted by results obtained at Sampling sites B and C. Turbidity concentration at Sampling site C, while higher than at site A, is significant lower than sampling site B levels due to the dilution effect. Anthropogenic factors like mining activities contribute to elevated amounts of suspended matter which include clay, silt, and fine fragments of organic matter (Apua, 2020; Masere et al., 2012). Statistically, both factors (Sampling site and Year) were significant at p<0.001 and there was a significant interaction effect between Sampling site and Year on the turbidity levels of water in Deka River (F = 1199; d.f = (4, 18); p<0.001). The interaction plot between the two factors is shown below (Figure 9).

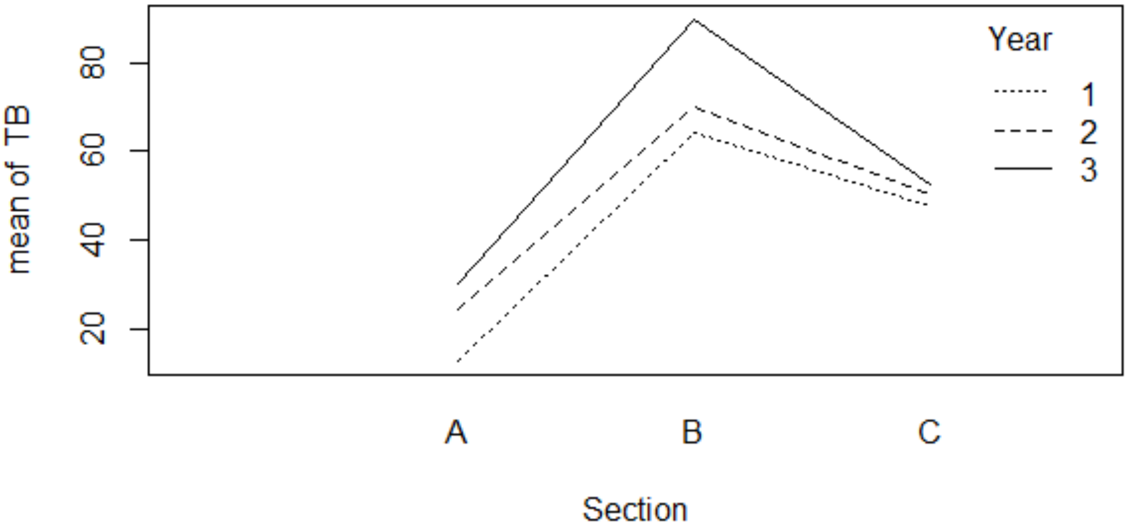

Figure 9. Interaction plot indicating the effect of both Sampling section and Year on turbidity levels

Figure 10 shows that sulphate concentration was increasing with time (from Year 1 to Year 3) in the Deka River. Sulphate levels were highest at sampling site 2 and lowest at site 1. As already discussed the upstream of Deka River (Sampling site 1) was not affected by mining activities and mine effluents. At sampling sites 2 and 3 sulphate levels were higher than the WHO maximum acceptable levels of 250mg/l for river water particularly for Years 2 and 3. Similar findings were obtained by Ruppen et al. (2021), who found sulphate levels in river water to be increased as a result of the influence of AMD.

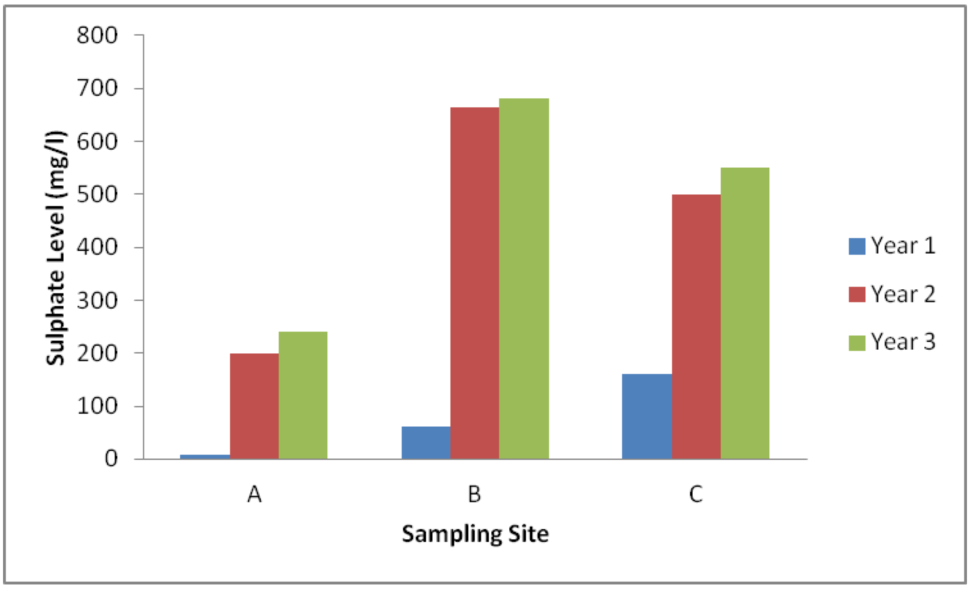

Figure 10. Average sulphate levels at different sampling sites along Deka River over three years

Statistically, both factors (Sampling point and Year) were significant at $p<0.001$ and there was a significant interaction effect between Sampling site and Year on the sulphate levels of water in Deka River (F = 45947; d.f = (4, 18); $p<0.001$). The interaction plot between the two factors is shown below (Figure 11).

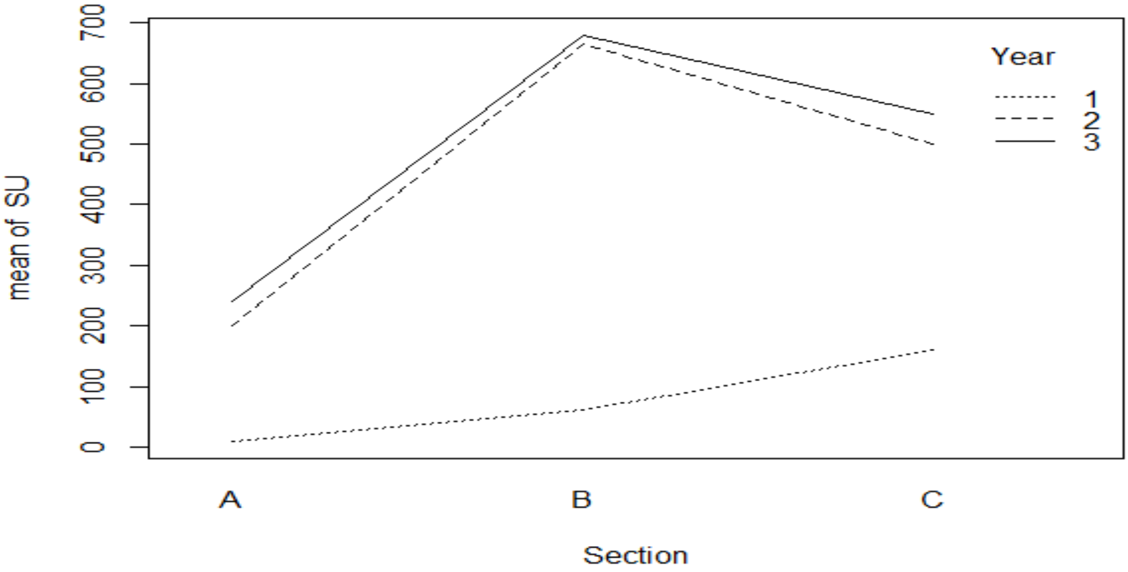

Figure 11. Interaction plot indicating the effect of both Sampling section and Year on sulphate levels

DO saturation percentage in Deka River generally decreased with time, particularly after Runduwe tributary joins the River (Sampling sites B and C) (Figure 12). DO saturation percent levels observed during Year 3 was significant lower that 75% recommended by EMA, at all the three sampling sites. DO levels closer to 100% saturation were observed upstream (Sampling site A).

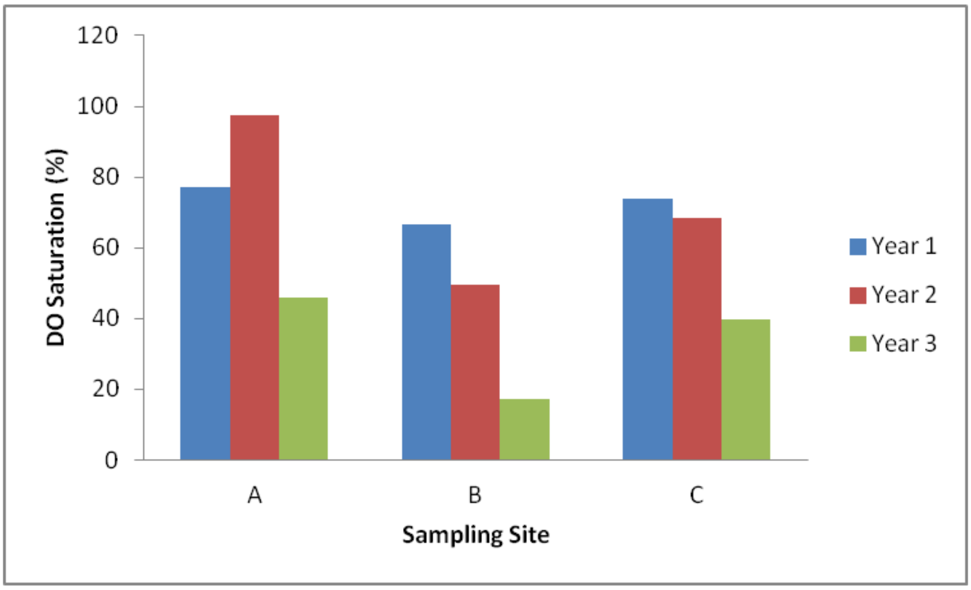

Figure 12. Average DO levels at different sampling sites along Deka River over three years

Statistically, both factors (Sampling site and Year) were significant at $p<0.001$. Sampling point ($F = 11.856$; d.f = (2, 22); $p = 0.000$); Year ($F = 26.666$; d.f = (2, 22); $p<0.001$). However there was no significant interaction effect between Sampling site and Year on the DO saturation levels of water in Deka River. Sufficient DO levels are essential for the growth and reproduction of aerobic aquatic life (Gotore et al., 2022). Low DO saturation percent is as a result of higher temperatures experienced near Deka River due to excessive cutting down of trees and vegetation clearings during mining operations. Further, the mining effluents deposited in Runduwe tributary and later-on in Deka River are responsible for reduced DO. Pollutants from human activities like mining (and AMD) and agriculture (phosphorus and nitrogen compounds) produce direct chemical demands on oxygen in rivers (Gotore et al., 2022; Masere et al., 2012).

Average concentrations of TDS increased year-on-year for sampling sites B and C while at the upstream (Sampling site A) the TDS concentration remained relatively the same from Year 1 up to Year 3. Site A was the only one among the three sites that had TDS levels below or equal to the WHO standard of 500 mg/l over the three-year study period. Again this speaks to the influence of mine effluents which are transported through Runduwe tributary (Figure 13). The main reason for the increased TDS is the blasting and subsequent removal of the overburden material, which covers the coal seam. The process allows exposure of these materials to physical and chemical weathering which can release soluble constituents into the surrounding water resources (Odenheimer et al., 2013; Wang et al., 2021).

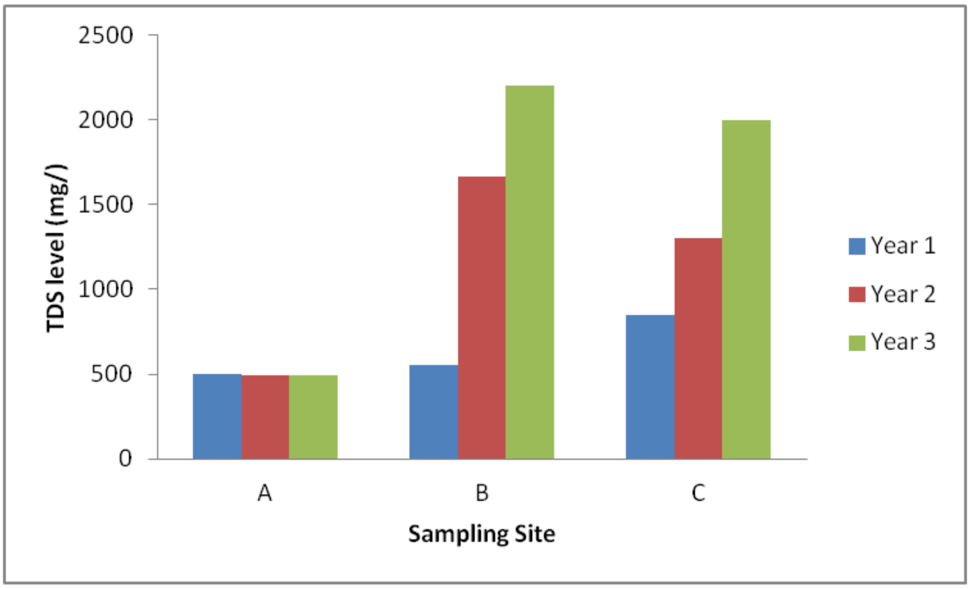

Figure 13. Average TDS levels at different sampling sites along Deka River over three years

Statistically, both factors (Sampling site and Year) were significant at $p<0.001$ and there was a significant interaction effect between Sampling site and Year on the TDS levels of water in Deka River (F = 581839; d.f = (4, 18); $p<0.001$). The interaction plot between the two factors is shown below (Figure 14).

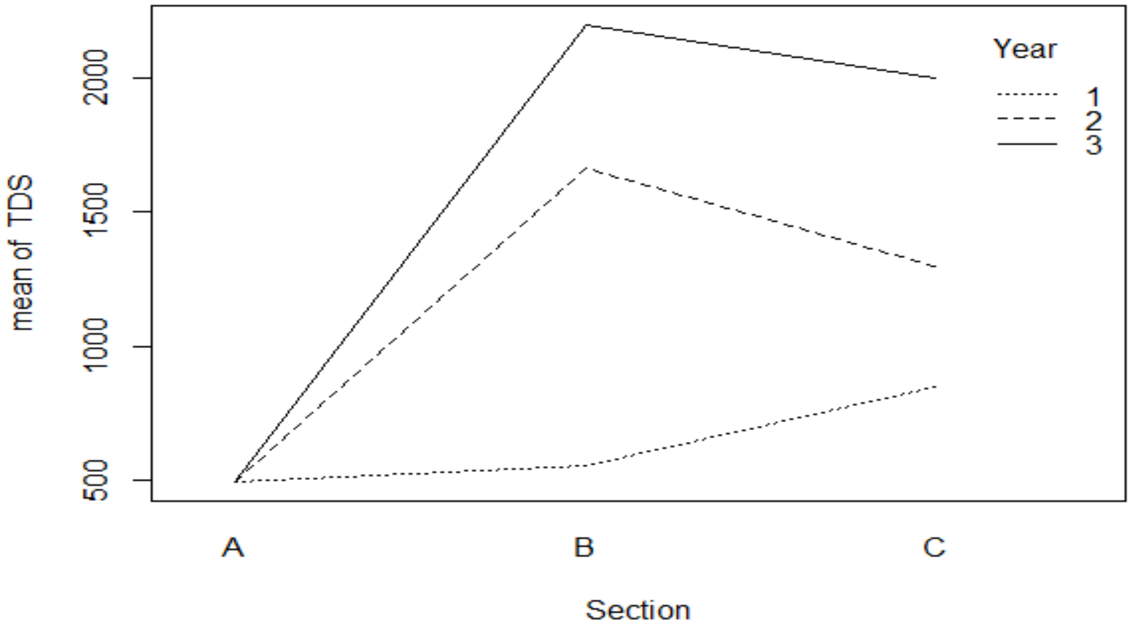

Figure 14. Interaction plot indicating the effect of both Sampling section and Year on TDS levels

Generally the mean EC levels ranged from a low of 176 uS/cm (Sampling site A) up to peak of 1428 uS/cm (Sampling site B) (Figure 15). EC levels were highest at sampling point B due to the contribution of Runduwe tributary (which carries coal mine effluent) into Deka River thus increasing the conductivity of the river. Site B consistently recorded TDS level greater than the WHO standard of 1000 uS/cm while the downstream site recorded levels greater than the WHO threshold in Year 3. There are several factors that potentially contribute to high EC levels. According to International

Mining (2010), just about any activity disturbing the earth surface and increasing TDS can lead to high EC levels. Mining operations often result in removal of layers of rocks to uncover coal seams. Consequently, these mine-disturbed rocks are exposed to rainfall leading to leaching and entrainment of major ions from unwanted rock surfaces into headwater streams, thus causing increased conductance of receiving waters (Wang et al., 2021).

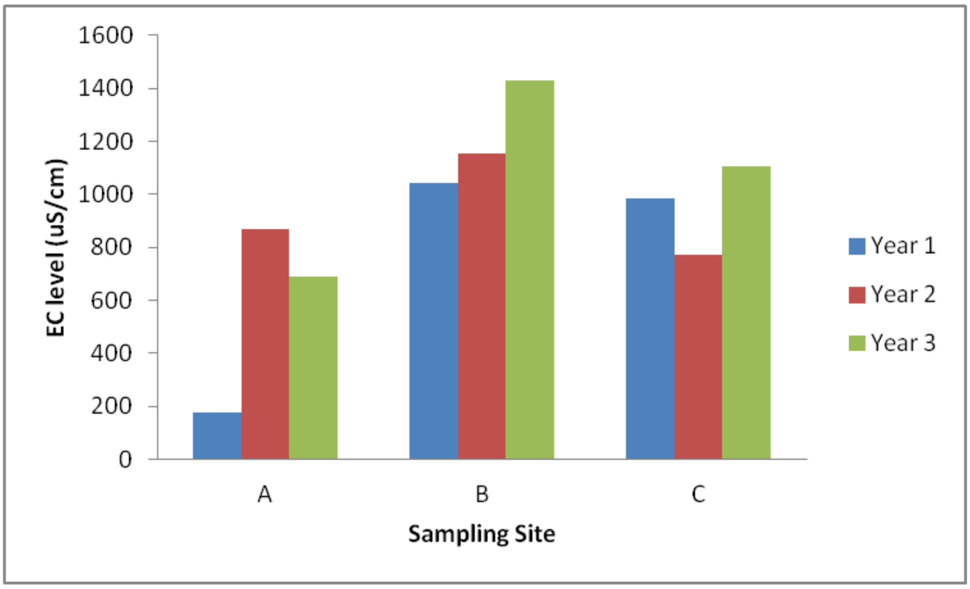

Figure 15. Average EC levels at different sampling sites along Deka River over three years

Statistically, both factors (Sampling site and Year) were significant at p<0.001 and there was a significant interaction effect between Sampling site and Year on the EC levels of water in Deka River (F = 72650; d.f = (4, 18); p<0.001). The interaction plot between the two factors is shown below (Figure 16).

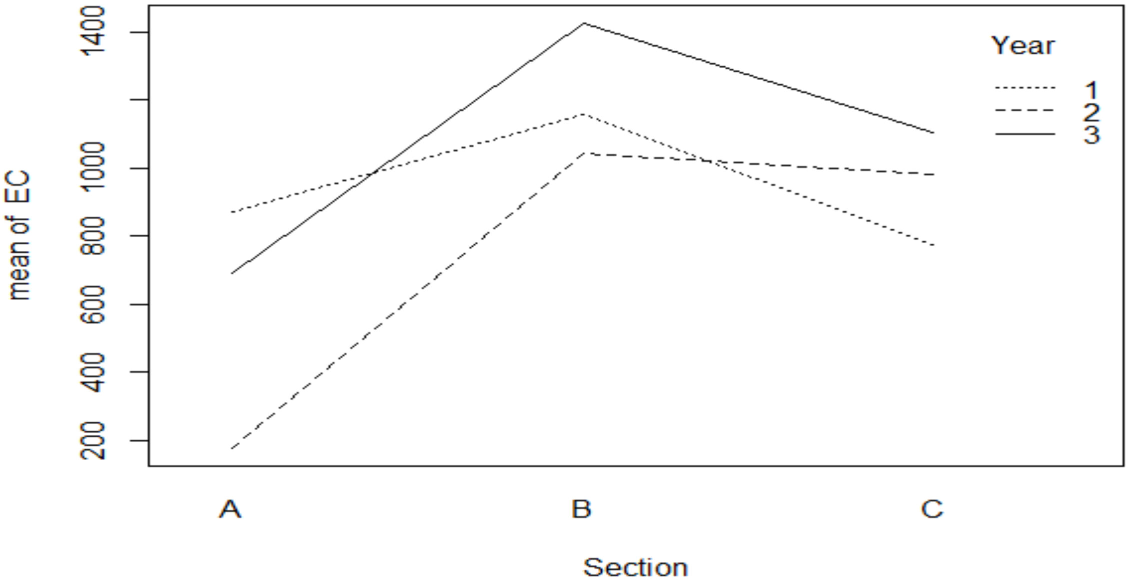

Figure 16. Interaction plot indicating the effect of both Sampling section and Year on EC levels

In both FGDs, it was clear that Deka River is very important to all the respondents for a plethora of reasons including as a source of drinking water and other household chores, as well as a source of livelihood. This finding concur with findings by Ruppen et al. (2022) that lack of functioning boreholes has restricted the villagers around Deka River to use the river as a source of drinking water. Respondents (100%) were unanimous in highlighting that Deka River water quality was declining leading to several challenges. Respondents highlighted like greenish colour of the Deka River to be indicative of coal mining effluent pollution. They also nominated the influx of several players (particularly the Chinese-owned) in the coal mining industry in Hwange since the turn of the millennium as the major cause of worsening Deka River pollution. Some respondents (37.5%) went further to suggest that it was the foreign-owned were notorious for discharging untreated coal mine effluents and other pollutants. However, this notion was dismissed by the Environmental Management Agency (EMA), which is mandated by law to monitor and protecting the environment. EMA officials highlighted that it was not easy to pinpoint which one of the companies are responsible for polluting Deka River. All the respondents (100%) also indicated their unhappiness with the authorities, including EMA, whom they say have not been able to do anything to arrest the coal mining pollution or to enforce compliance of its own laws and statutes on offending companies, despite registering their concerns about the deteriorating situation of Deka River countless times, beginning many years ago. Most respondents (72.5%) suggested that EMA is either poorly resourced or incapacitated to do proper profiling and conduct compliance inspections on all the major players in the coal mining industry. Other respondents (12.5%) went as far as indicating that corruption was at play and was the major reason why officials are turning a blind eye on the situation. Ncube-Phiri et al. (2015) warned against the continuation of such a situation unabated often leads to untold costly ecological disasters including loss of biodiversity and destruction of ecosystems and livelihoods.

Two broad themes emerged from respondents' perceptions of how coal mining pollution in Deka River is impacting them. These are: public health challenges and threatened livelihoods. Both of these challenges speaks to how the coal mining companies are infringing onto human rights of the communities to health and clean water (SDG 6). With regards to public health challenges, respondents listed a plethora of diseases they have suffered from due to drinking and utilizing Deka River water including stomach pains, diarrhoea, skin diseases and kidney diseases. This finding is consistent with findings by Munyai et al. (2021) and Rambabu et al. (2020). Chowdhury et al. (2016) and Hu et al. (2019) attributed the human health challenges to heavy metal exposure, with severity of illness dependent on time period of exposure. Similarly, Zaveri et al. (2020) found that children who consume or are exposed to polluted water may have height loss challenges in adulthood. As a result of the mentioned health challenges, respondents highlighted that they are incurring unnecessary medical bills, yet most of them are not formally employed. The respondents reported that the mining companies are preferred to bus people from outside of Hwange district to work on the mines as opposed to employing locals. The respondents often resort to selling off some of their livestock (mostly goats) to buy medication.

The coal mine effluent-polluted Deka River has also threatened the livelihood of most of the respondents (70%) and their families. The affected respondents indicated that fishing, basket making from reeds and animal husbandry that used to be their main livelihood sources were being significantly affected by pollution. Fish and goats were dying while cattle were suffering stillbirths and deformities after drinking from the polluted Deka River. Similarly Munyai et al. (2021) found that AMD threat to ecological systems and human health is due to its low pH and non-biodegradable heavy metal contamination in living organisms and food chains. One FGD respondent said she 34 goats within a short period of time (fortnight) after drinking from the polluted Deka River. Further, these animal health challenges require respondents to visit the veterinary services for check-ups and treatment. This increases costs of running their animal rearing enterprises.

The diseases suffered by both people and animals are consistent with the effects of consumption of water containing similar levels of physico-chemical parameters like TDS, pH and Mn observed in Deka River water, which is being used for drinking. While this study did not directly investigate the number of human fatalities as a result of consumption of the polluted Deka River water, it is not far-fetched to apportion a significant number or percentage of deaths occurring around the area to consumption of polluted water or fish. Thus, the situation currently obtaining in Hwange, particularly around Deka River, is dire and corrective action must be taken to address pollution of Deka River by coal mining effluents.

CONCLUSION

This study investigated the impacts of coal mining on the water quality (physico-chemical parameters) along Deka River. The empirical results indicated there is a significant influence of coal mining effluent on the physico-chemical parameters of the water quality in Deka River. There was an interaction effect between time period (Year) and Sampling site/section on the concentration of seven of the eight physico-chemical parameters tested. The study showed that, with each passing year, pollution levels are increasing in Deka River. Among the eight physico-chemical water quality parameters studied, only DO concentration did not involve time period (Year) and Sampling point working together. Despite this, both the year and sampling point affected DO saturation in Deka River separately.

At the upstream section of Deka River there was very little or no pollution. Conversely, higher concentrations of pollutants were observed after the joining in of Runduwe tributary on Deka River (Sampling site/section B). At sampling sites B (middle section of the river) and C (downstream section of the river) the levels of all the eight tested physico-chemical parameters (pH, EC, Fe, Mn, TDS, DO, sulphates and turbidity) exceeded the local EMA and WHO maximum acceptable standards for both river and drinking water. The foregoing points to Runduwe tributary as the direct receiving waters of coal mining effluents and how it is acting as a conduit for introducing pollutants and contaminants in Deka River. In this way, the tributary can be viewed as point source pollution. As with all point source pollution, remedial action should be employed on Runduwe tributary to reduce the concentrations of pollutants that find their way into Deka River.

Beyond this, the coal mining companies should be encouraged to find efficient ways of treating their effluent before discharging them into the environment or directly into Runduwe tributary. The heavy metal and AMD pollution in Deka River has severely impacted the surrounding communities through infringing on their human rights to health and clean water. Through consumption of polluted Deka River water diseases like stomach pains, diarrhoea, and skin itchiness have been are noted within the communities.

Livelihoods have not been spared either as fish and goats are dying and cattle are suffering stillbirths due to the pollution of Deka River. The obtaining situation has continued unabated for some time now despite cries and calls for action by the surrounding communities to the authorities to avoid health catastrophes, potential human fatalities and destruction of biodiversity and livelihoods. Therefore, future studies should take into consideration appropriate ways of finding a lasting solution to this coal mine effluent and AMD pollution saga so as to prevent destruction of biodiversity and loss of human lives and their livelihoods.

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