MNK Publication

International Journal of Latest Research in Science and Technology **ISSN (Online):2278-5299**
Volume 5,Issue 6: Page No.60-65, November-December 2016
https://www.mnkpublication.com/journal/ijlrst/index.php

ASSESSING THE EFFECT OF INTEGRATED WATER RESOURCES MANAGEMENT ON WATER QUALITY IN GHANA

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Abstract- This study assesses water quality in the Pra Basin after the implementation of Integrated Water Resources Management (IWRM) using the water quality index (WQI). The study reports on changes in WQI before and after the first cycle of the implementation of IWRM. The Wilcoxon signed-rank test was used to statistically establish the significance of any difference during the implementation of IWRM. Eight (8) water sampling points from upstream to the downstream of the Basin were selected for sampling. Eight (8) physico–chemical and microbial parameters were used for the water quality measurement .Dunkwa-On-Offin (D F) recorded the lowest WQI whilst Adiambra (A M) recorded the highest WQI. The deterioration in D F has to do with the numerous and advance system of illegal mining occurring in D F and the tributaries which feeds it. The study revealed that water quality has deteriorated as a result of the high levels of suspended solids in the rivers. For WQI, the deterioration was significantly high during the IWRM implementation (Mdn = 40.25) than before the implementation (Mdn= 72.19) T = 0.00, p = 0.012, r = 0.66.The presented results, create doubt about the practicality of the action plan and the compliance of the basin officers to the action plan.

Keywords – Integrated water resources management, water quality , Impact, Implementation, Pra Basin

I. INTRODUCTION

A flow of water of good quality in an environment, does not only sustain the environment, but it also ensures human development, economic growth and good health. Protecting, securing, maintaining and sustaining the quality of safe water in an environment is a very challenging task(Falkenmark and Rockström, 2004). Globally an accepted principle proposed to achieve safe and sustainable water in an environment is an integrated water resources management (IWRM) system.It has however been claimed that IWRM is not effective (Biswas, 2008a).That notwithstanding, the IWRM concept has gained broad adoption by many countries due to the over-popularization by the initiators (Merrey, 2008) and also its simplicity (Biswas, 2008a). According to Biswas (2008), IWRM is an old concept which failed in the past due to implementation difficulties. He explains that there are varying ideas when it comes to IWRM in operational terms even among the promoters of the principle. The challenge of the IWRM implementation is not due to the vagueness of the concept, but rather the inability of technocrats to bridge the gap between theory and practice(Rahaman, 2005). Rahaman does not see any vagueness in the IWRM concept;however, he sees the inability of technocrats to translate policy on paper onto the field as the main challenge. According to van der Zaak (2005), the challenge to IWRM implementation is the absence of the institutional capacity to bring about the integration. van der Zaak admits there are issues with IWRM concept in the area of institutional capacity but also disagree with those who claim the concept is not practical. He see's having the right institutional capacity in place as an important step in making IWRM practical to be able to integrate all water and its related sectors and relevant stakeholders such as the water supply companies(WSC's) , environmental protection agency(EPA), irrigation authority(IA), industry, community based organization (CBO's) etc.

The IWRM concept is gradually losing credibility in some continents (like Asia)because of lack of reliable data to even prove that it is working (Asian Development Bank., 2007: cited in (Biswas, 2008b). Nevertheless,African countries like Burkina Faso, Nigeria, South Africa and Ghana started implementing the IWRM concept.It is therefore important to know the extent to which IWRM is working. In summery, there are IWRM implementation challenges, one of which is the evaluation of the expected outcomes. However, when ever or where ever IWRM is implemented, it is expected to solve an existing, emerging or anticipated problem.This study will look at how IWRM has contributed to pollution reduction in the Pra basin by measuring the difference in water quality before and after the implementation process.

The Pra Basin is located between latitude 5^0 N and 7^0 30'W and longitude 2^0 30' W in south central Ghana West Africa (figure 1). The total basin area is approximately 23,200km^2 and extends through three of the ten regions of the country. The southern part is relatively flat with the northern sections and fringes of the eastern parts showing elevations of up to 800 meters above sea level. The basin population is approximately 4.2 million with a population growth rate of 3.1%, according to the 2010 population and housing census. The basin is known for its numerous mining activities, both legal and illegal.

In Ghana and specifically the Pra basin, one of the reasons for the implementation of the IWRM were to solve the problem of water pollution. In the sections that follow, we will go through the IWRM and its implementation framework in the Pra basin. The next section will assess the impact of IWRM implementation on the quality of water in the basin by

Publication History

Manuscript Received	:	*14 December 2016*
Manuscript Accepted	:	*19 December 2016*
Revision Received	:	*25 December 2016*
Manuscript Published	:	*31 December 2016*

measuring the change in quality of water before and after the implementation using water quality index (WQI).

IWRM Implementation Framework

According to Kennedy (2009), there is a continuous four step loop which is critical in an IWRM implementation. The steps are 1) recognition and identification, 2) conceptualization, 3) coordination and planning, and 4) implementation, monitoring and evaluation. So much work has been done on these four steps in both developed and developing countries. Nonetheless, little attention has been paid to the monitoring and evaluation part of the loop. A situation which is very common in developing countries like Ghana where IWRM has been implemented (Merrey, 2008).

A thorough study of the surface water resource in Ghana reveals that the water bodies are seriously polluted due to discharge of untreated wastewater from industry, uncontrolled small scale mining activities and bad farming practices (Nasirudeen, 2014). IWRM was considered appropriate for putting this situation under control. As a result, a water resources commission (WRC) was established by an act of parliament to take up the responsibility of coordinating all the water related activities in Ghana. Setting up of the WRC before the implementation of the IWRM concept was very prudent as it eats away a lot of time if it is setup just when implementation is to take place.The WRC, in taking a step in the implementation process, started exploring and identifying the problems and the challenges pertaining to Ghana's water environment and based on the peculiar nature of the problems identified, divided the entire surface water in Ghana into six (6) basins namely, the Volta,Ankobra, Densu, Bia, Tano and Pra. The present study, focuses on the Pra basin. Rapid socio-economic changes have impacted negatively on the water resource in the Pra basin. Data collected in the basin identified problems in the following areas:1) water resource availability;2) water quality and;3) environmental and ecosystem sustainability(WRC, 2012).The collected data were harmonized with those of the sector which were not directly in water through workshops and round table discussions. The following plans :1) the creation of awareness and the sensitization of stakeholders about the negative impacts of land degradation; 2) the provision of incentives to change behavior and providing alternatives to lost livelihoods, and an implementation of a buffer zone policy; 3) strengthening the institutional capacity to enforce compliance to regulations ; 4) support the metropolitan, municipal and district assemblies (MMDAs) to enact By laws for enforcement of environmental laws; 5) support the MMDAs to rehabilitate, expand and build new waste treatment facilities to meet the increasing demand; 6) enforce regulations on waste management and pollution control of surface and groundwater resources ;7) strengthen the institutional capacity at all levels for waste management; 8) implement the Polluter Pays Principle and recover costs(WRC, 2012) were outline for action in solving the identified problems. Available data reveals that,much has been done in problem recognition and identification ,and conceptualization and planning(WRC, 2012). However little attention is paid to monitoring and evaluation.

This study is to evaluate and document the water quality changes of the various baseline sampling sites within the basin after the implementation of IWRM and classify them using the National Sanitation Foundation (NSF) water quality index (WQI). In order to statistically confirm the significance of the impacts, the Wilcoxon signed-rank test will be employed.The results from this study will provide an idea of how IWRM has performed so far in an area of remediating polluted water resources in the Pra basin and thereby offer a platform for practical evaluation of the plan of action,for possible adjustment and improvement.The classification after the implementation of IWRM would help to locate the highly polluted areas ('hot spots'), so that special monitoring package could be mounted for further evaluation and improvement.

II. MATERIALS AND METHODOLOGY

The current study involved sampling and analyzing eight (8) sites to measure changes in the surface water quality (table 3a and 3b). The eight (8) sites were chosen because they had been used in 2010 to establish the water quality of the basin (baseline) before the implementation of IWRM. Sampling was done from April to August in 2016.Samples were collected just beneath water surface in quiescent areas with the container facing the direction of the current flow to prevent collecting larger debris at the water surface. The accuracy of the sampling process was checked using equipment blank and field blank.All sampling containers except that for the microbial analysis were pre-treated with dilute hydrochloric acid, and rinsed with double distilled water before air drying them. For the microbial analysis, sample containers were pre-treated with 70% ethanol and allowed to air dry in a dust free area.In all, a total of 40 samples were collected for the analysis. All sample containers were filled to the neck during sampling to allow aeration and mixing before sealing tightly. Parameters such as pH, temperature, total dissolved solids, conductivity, dissolve oxygen, and salinity were measured on site using a standard water machine. The other parameters such as nitrates, total phosphates, biological oxygen demand (BOD), total suspended solids were measured as per the American Public Health Association (APHA) procedures.

In this study the National Sanitation Foundation (NSF) water quality indexes method was employed. In the NSF method, graphs or charts are used to convert field data into quality value (**Qn**) and then multiplied by their corresponding developed weighting factor (**Wn**) or unit.

Water Quality Index (WQI) is calculated as:

$$WQI = \frac{\Sigma \text{ Qn Wn}}{\Sigma \text{ Wn}}$$

Table 1 is a presentation of the drinking water standards of the parameters used in the analysis with their corresponding weighted factor whereas table 2 shows the classification status and grading use in classifying water bodies.

Table 1: The standard values and weighting factors (Wn) of selected parameters

Sr. No.	Parameters	Standards	Unit Weight (Wn)
1	pH	6.5-8.5	0.11
2	Dissolved Oxygen (mg/l)	5.00	0.17
3	Total Suspended Solids(mg/l)	500	0.07
4	F. Coliform (count/100ml)	0	0.16
5	Temperature ^{0}C	15	0.10
6	BOD_5 (mg/l)	5	0.11
7	Nitrates (mg/l)	45	0.10
8	Phosphates (mg/l)	0.3	0.10
			$\sum Wn = 0.92$

Table 2 :Water Quality Index Status and Grading

Water Quality Index	Water Quality Status	Grading
0-25	Very bad	A
26-50	Bad	B
51-75	Medium	C
76-100	Good	D
Above 100	Excellent	E

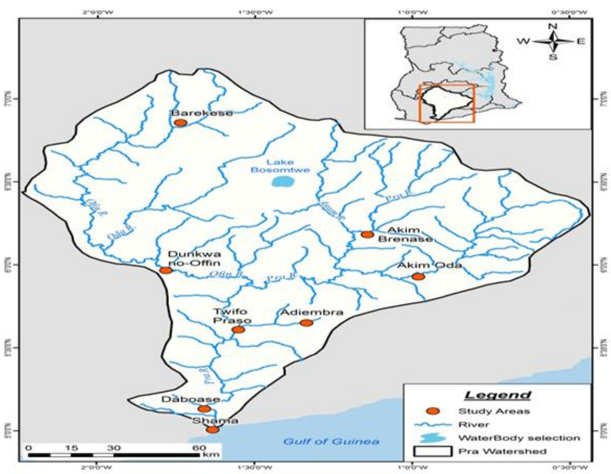

Figure 1: Map of Pra Basin

III. RESULTS AND DISCUSSION

The results of the various water quality parameters are shown in table 3a and 3b. The results are for the mean current situation as well as the baseline.

Table 3a: Water Quality Values for Current and Baseline Assessment

Sites	Temperature ^{0}C		PO_4^{3-} (mg/l)		NO_3^- (mg/l)		F. coliform count/100ml	
	Current	Baseline	Current	Baseline	Current	Baseline	Current	Baseline
D F	30.2	24.3	1.19	0.255	3.05	0.434	$13x10^2$	16
P S	29.64	26.6	2.01	0.234	2.45	0.476	10	9
A O	28.2	29.3	0.87	0.15	1.29	0.441	$4x10^2$	14
B T	33.05	26.2	0.99	0.097	0.41	0.080	$5x10^2$	30
D B	28.20	30.6	1.54	0.206	2.84	0.484	10	40
A B	29.63	29.3	0.47	0.118	1.905	0.299	$13x10^2$	80
B K	33.70	33.70	0.69	0.049	0.495	0.251	200	0
AM	29.1	29	1.54	0.094	0.47	0.245	10	2

D F:Dunkwaw offin, P S:Praso, A O: Akim Odaa, B T:Bosomtwe , D B:Deboase, AM:Adiembra, A B:Akim Breniase, B K:Barekese

Table 3b: Water Quality Values for Current and Baseline Assessment

Sites	Total Suspended Solids (mg/l)		Dissolved Oxygen (mg/l)		pH		Biological oxygen Demand (mg/l)	
	Current	Baseline	Current	Baseline	Current	Baseline	Current	Baseline
D F	2371.50	116	29.87	84	8.87	7.96	27	3.74
P S	525	224	24.52	93	7.80	7.72	17	3.10
A O	564.5	115	34.02	93	7.44	7.66	10	3.8
B T	2.5	6	34.58	101	9.11	9.09	18	4.80
D B	88	225	17.27	103	7.39	8.10	22	3.40
A B	307.50	24	35.52	92	7.37	7.62	23.5	4
B K	9.5	5	45.14	48	7.11	7.35	24	3.50
AM	394.5	17	29.50	69	8.29	7.78	20	3.10

D F:Dunkwaw offin, P S:Twifo Praso, A O: Akim Odaa, B T:Bosomtwe , D B:Deboase, AM:Adiembra, A B:Akim Breniase, B K: Barekese

Water Quality Parameters

Prior studies have created uncertainties about the practicality of IWRM in achieving it purpose or targets.In 2005 van der Zaak, presented IWRM as a necessary principle for all to adopt without any doubt. A study by Akpabio (2008) indicated that IWRM has failed to make a full transition from theory to practice. Despite all the uncertainties associated with IWRM, many countries especially those from developing countries are still implementing the concept. The present study, focused on assessing the impact of IWRM on the quality of water in the Pra basin. The results gathered show a decline in the quality of water in almost all study sites.

The dissolved oxygen(DO) in water is a water quality parameter which is used to assess biological changes in water as aerobic or anaerobic(Gangwar *et al.*, 2012). DO is the main driving force for metabolic activities of aerobic organisms in water.It's level in water is therefore an important parameter to determine the safety of aerobic aquatic species. A DO saturation higher than 110 or below 90 is lethal to fishes in water(Kizha *et al.*).The measured dissolved oxygen in the basin is not only outside the percentage saturated range of 110 – 90, but it also widely deviated from the baseline measurement (table 3b). The current DO level poses a threat to the aquatic life(Kizha *et al.*)in the basin. The level of DO in water was influenced by factors such as the temperature, the level of organic matter, and the wind blowing on the water surface or the flow of the river (Davis, 1975) . Temperature influences the speed of reaction in aquatic environments. For example temperature can slow down or increase the rate at which algae and aquatic plants photosynthesize(Carr and Neary, 2008). Aquatic organisms have narrow tolerance for temperature(Carr and Neary, 2008). This means, a sharp variation in temperature over a short period as well as gradual variation over a long period are all significant to aquatic life and can result in the death of aquatic species.A temperature range between 28 – 30^{0}C is good for aquatic life as it enhances photosynthesis at the surface of rivers to generate more oxygen(Mortimer, 1956.) As can be seen in table 3a, measured temperatures for both the baseline and current values are within the range to facilitate the process of oxygen generation in the basin. However, this is not so, the observed DO saturation level in the basin currently was very low which indicated large contribution from either one or both of the remaining factors. The flow rate of a river is affected or influenced by the suspended particles it carries.

Suspended solids (SS) are the mass or concentration in mgl^{-1} of organic and inorganic matter,which are held in a water column of a stream, river , lake or reservoir (Bilotta and Brazier, 2008). These particles mostly come from anthropogenic activities such as soil and bank erosion, mining and farming. The SS when present in water can affect it physically, chemically and biologically(Bilotta and Brazier, 2008).Physically, it can reduce the volume or depth of the river through siltation, reduce the penetration of light , influence temperature changes and make the water aesthetically unattractive for recreational and drinking purposes(Lloyd *et al.*, 1987; Bilotta and Brazier, 2008). Chemically,suspended solids can carry along pesticides, heavy metals and nutrients such as phosphates into a water body (Dawson and Macklin, 1998; Haygarth *et al*., 2006).Biologically, suspended solids which contain organic matter compete with aquatic species for available oxygen.The color of the rivers as illustrated photographically in figure 2 is an indication of high levels of suspended solids in the basin.

It can be observed(table 3b) that apart from Bosomtwe(B T) and Barekese (B K) which saw a reduction in the level of the suspended solids, five of the remaining six sites saw between 100 - 200% increase in levels of the suspended solids.Site B T and B K unlike the other sites are located upstream the basin where there are no mining activities.In addition to the rise in suspended solids in the five sites, a difference of more than 1000% was observed in Dunkwa-On-Offin(D F).This striking difference might have been caused by the numerous and uncontrolled illegal mining activities occurring in that part of the basin and the close upstream tributaries.In addition, the advanced technology in mining in site D F employs the use of sophisticated equipment. As a result,the rivers are dredged and the soil is left at the banks of the rivers without caring about its future consequences.Currently the route of the river in site D F has been diverted for illegal mining activities.

Suspended solids may contain high levels of organic matter (OM) depending on their sources. Most often suspended organic matter get into rivers or streams through run-offs from upstream forest,farm lands and wastewater from anthropogenic activities.OM, when in water compete with living species for available oxygen which limit the level of oxygen in the water.OM, like any other suspended solid does affect the water physically, chemically and biologically (Lloyd, 1987).The physical effect has been well explained in paragraph 3 of this discussion. Chemically the OM carries along nutrients in the form of phosphates and nitrates into the water bodies(Smith, 2003).In the right concentration, phosphates are useful because they catalyze the growth of aquatic plants which serve as a source of food for fish (Smaya, 2008). However, an excess of phosphate and nitrate will cause algae, and aquatic plants to grow wildly, choke up the waterway and use up large amounts of the oxygen(Brian Oram, 2014) creating eutrophic conditions.Under a eutrophic condition, the living organisms compete for the available oxygen for survival and this creates high biological oxygen demand (BOD) levels in the rivers.Studies have shown that once eutrophication occurs in a river, it would take about 1000 years for the water to be restored under the best circumstances(Carpenter and Lathrop, 2008) , a condition the basin officers must try and avoid considering the high accumulation of the nutrients in the basin currently. Although the temperatures were favorable, the effect from the suspended particles completely nullifies that of the temperature, hence the observed DO values.

The BOD is the mass of the oxygen required by bacteria in decomposing an organic matter under aerobic conditions. Low BOD in a water body is an indication of the good quality of the water because it implies less decomposable organic matter in the water and less oxygen needed to break it down. The current results not only show excess of the permissible limit but also a sharp rise of about 3 to 5 times the baseline values confirming the influence of the high levels of the suspended solids in the basin rivers. Apart from the miners mining directly in the rivers, large volumes of soils dredged from the river beds are left at the bank of the river: these soils get washed by run offs from heavy downpours into the streams and rivers carrying along nutrients and other contaminants (Bilotta, 2008). Usually the less dense organic fraction of the soil is removed during run off and this adds up to the organic fraction of the suspended solids to make it rich (Debyle 1976).When BOD increases and nothing is done to restore the oxygen levels , many aerobic aquatic species are lost through death as anaerobic conditions set in.

In a water environment, water molecules dissociate and establish equilibrium with its H^+ and OH^- ions ($H_2O \leftrightarrow H^+ + OH^-$). Anytime H^+concentration exceeds that of OH^- , the water is said to be acidic and when the opposite occurs the water is said to be basic. The negative logarithm of the dissociated H^+ions from a water molecule is known as the pH.The pH is an important indicator of the solubility and the biological availability of chemical constituents such as heavy metals and nutrients such as phosphates and nitrates in water(Robertson-Bryan, 2004).It also has a link with the biological productivity in water. Though there are fluctuations in all the sites for the pH,that ofthe site B T should be of much concern because it is gradually increasing to 10 which could be very dangerous for the aquatic life. According to Alabaster (1980), pH values between 9 and 10 can result in the partial mortality of certain fish; as such there is the need to safeguard the pH from getting to that point to reverse complaints of the low fish harvest in the lake. The generally found pH range of 7 – 9 in the basin is in the range which is known to reduce the solubility of heavy metals in water and make it less toxic whilst ensuring smooth exchange of the gases between the aquatic species with the water(Alabaster, 1980).

Birim River **Pra River** **Offin River**

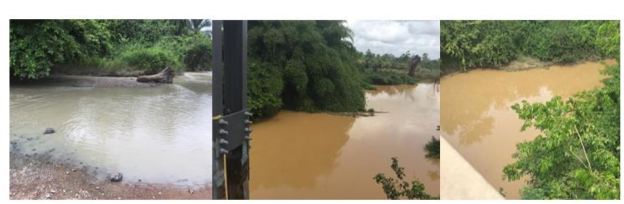

Figure 2: Colored Basin Rivers

Water Quality Classification

In the classification of the basin water quality, the water quality parameters were converted into quality values (Qn) and then multiplied by their corresponding developed weighting factor (Wn) as shown in the case for site D F in table 3c.

Table 3c: NSF Water Quality index for Dunkwa-on- Offin Site (D F)

Parameter	Sample site D F Baseline			Sample site D F Current		
	Wn	Qn	WnQn	Wn	Qn	WnQn
Temperature	0.10	14	1.4	0.10	10	1.35
PO_4^{3-} (mg/l)	0.10	91.87	9.187	0.10	35	3.5
NO_3^--N(mg/l)	0.10	94.5	9.45	0.10	84	8.4
F.C.(C/100ml)	0.16	66	10.56	0.16	21.5	3.44
T.S.S (mg/l)	0.07	81	5.67	0.07	20	1.4
DO % salt	0.17	90	15.30	0.17	20	3.4
pH	0.11	80	8.8	0.11	55	6.05
BOD_5 (mg/l)	0.11	59.33	6.53	0.11	4.5	0.5
			$\sum WnQn = 57.38$			$\sum WnQn = 28.04$

$$\sum \frac{WnQn}{Wn} = 57.38 / 0.92 = 62.36 \quad \sum \frac{WnQn}{Wn} = 28.04 / 0.92 = 30.47$$

The above procedure is used to calculate for WQI for the remaining seven sites.The WQI values of the sites are classified using the water quality status (table 2). The results are also compared to the baseline results to establish the level of impact (table 3d).

Table 3d: Water Quality Index and Classification

Sampling site	Summary of water quality index classification					
	Current WQI	Classification	Baseline WQI	Classification	Difference	Difference %
D F	30.47	Bad	62.36	Medium	-31.89	51.13
P S	43.23	Bad	78.38	Good	-35.15	44.84
A O	43.39	Bad	75.78	Good	-32.39	42.74
B S	43.46	Bad	72.54	Medium	-29.08	40.09
B T	38.75	Bad	69.20	Medium	-30.45	44
D B	45.47	Bad	71.84	Medium	-26.37	36.70
A M	54.61	Medium	72.69	Medium	-18.08	24.87
B K	51.02	Medium	71.13	Medium	-20.11	28.27

The calculated water quality index for the baseline and current values are summarized in table 3d. There is a large decrease of WQI values from the baseline to the current. The decrease is the sign of an increasing pollution load which is caused by the high level of suspended particles released into the water bodies through mostly illegal mining. The intensity of an illegal mining activity and the proximity of sampling sites to such areas is a major contributing factor to the variation in the measured suspended solids. The lowest water quality index was found in Dunkwa – On – Offin (D F) whilst Adiembra (A M) had the highest. The deterioration difference in WQI between these two sites can be linked to three reasons: 1) the number of mining sites, 2) the level or scale and the intensity of mining, 3) the nature of soil and its iron content. In classifying the eight (8) sampling sites , as many as 50% of the sites moved from medium to bad, 25% moved from good to bad, and only 25% maintained their medium state. Even the 25% which maintained their classification status show a decline in WQI. Wilcoxon signed-rank test shows that there is a significant change in the deterioration of the water quality in the basin. For WQI, the deterioration is significantly high after IWRM implementation (Mdn. = 40.25) than before implementation (Mdn. = 72.19) T= 0, p = 0.012, r = 0.66.

CONCLUSION

The suspended solid is a major problem for the Pra basin, Ghana. In this study, the suspended solids were far higher than the permissible levels which indicated that the Pra basin is polluted by suspended solids which pose a serious threat to the health of the river. The overall water quality index shows a deterioration in the quality of water in the basin which has been statistically proven to be significant. The presented results create doubt about the practicality of the action plan and the compliance of the basin officers to the action plan .The study therefore proposes that illegal mining activities which contributes heavily to the suspended solids should be monitored and regulated, especially in site D F and its surrounding areas. The existing environmental laws should be enforced to reduce the activities of illegal miners. An educational model on IWRM should be developed for all schools from the primary to the secondary level to widen the awareness and sensitization creation. Considering the pH range of 7-9 in the basin, there is the need for heavy metal analysis to be conducted on the river and its soil sediment from upstream to downstream. Interventions should be mapped to create jobs for the youth to keep them away from illegal mining.

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