Assessment of Water Quality Conditions of Abandoned Mine Paddock for Conversion into a Fish Pond

Apori Ntiforo, J.A. Ampofo and Frank K. Nyame

Department of Applied Physics, Faculty of Applied Sciences, University for Development Studies, P. O. Box 24, Navrongo, Upper East Region, Ghana

Water Research Institute, C.S.I.R, Accra

Department of Earth Science, Faculty of Science, University of Ghana, Legon-Accra

Abstract: This study explores the possibility of converting an abandoned dredged mine paddock into a fish pond. The aim of the current study is the assessment of the water quality conditions of nine surface water sampling points including paddocks/impoundments created by the operations of defunct dredged gold mine operations more than a decade for conversion into a fish pond. The concentrations of twenty water quality parameters (major ions, physicochemical and trace metals) were determined and compared with threshold values for protection of aquatic life to evaluate the suitability of the paddocks for development into a fish pond. The prevailing legal framework concerning water resources management in Ghana as well as the geophysical conditions of the studied sites was favorable for the development of the abandoned dredged gold mine paddocks into a fish pond. But the elevated levels of the analyzed concentration of copper, lead and cadmium ranging from 0.006 to 0.213 ppm, 0.002 to 0.047 ppm and 0.002 to 0.007 ppm, above recommended upper permissible limits of 0.00038, 0.0036 and 0.00054 ppm respectively for the protection of aquatic life may be a constraint because of the toxicological effect on humans when fishes from the facility are ingested. The nutrient loading and the major ion concentration of the studied sites were moderate; the waters were therefore slightly eutrophic. These conditions will enhance the productivity of the riverine ecosystem. The conversion of the abandoned paddock must be preceded with the acquisition of an appropriate entrepreneurial skills and comparative toxicological studies of the fishery products from the paddocks, other impoundments as well as the products from the entire Awusu drainage basin to ascertain their suitability for human consumption.

Keywords: Abandoned, defunct, dredge, paddock, riverine-ecosystem and eutrophic.

INTRODUCTION

This study examines the geophysical as well as water quality conditions of an abandoned dredged mine resources with the aim of crafting solutions for possible conversion into a fish pond. Land and soil use, mineral exploitation and water resources management, according to Okigbo (1999), are global challenges that impinge on human survival, development and welfare, peace and security which are related to the provisions of the charter of the United Nations. The operations and subsequent closure of the dredge mine undertaken by the defunct Goldenrae Mining Company over the Awusu basin led to the diversion of Abudusu, Obire-ne-Obeng, and Awusu watercourses upstream as well as the excavation of mining paddocks and conversion of Anikawkaw Swamp (All these constituting the Awusu meshwork) into a Slime Retention Area for the purpose of mining Fig. 1.

The disturbed meshwork is underlain by Birimian formations which are covered by forest oxisols (Griffis et al., 2002). The resources which are obtained from the study area depending on the mineralisation of the underlying geology include alluvial gold as well as diamond embedded in the underlying rocks along the watercourses (Kibi Goldfields, 2001) which may be exploited through dredging by mining firms. These alluvial gold deposits were mined through dredging. This may cause the mobilisation of heavy metals into water bodies in the study area with attendant toxicological effects in some segments of the ecosystem (Armad and Carboo, 1997; Blay Jr and Adu-Anning, 1997; Sarkodie et al., 1997; Carboo and Sarfo-Armah, 1997).

The abandoned dredged mine operations generated bodies of large stagnant water in the area. According to Wipenny (1997), human behaviour can modify the physical environment thereby making useful water scarcer. Notwithstanding the perceived negative impacts, such abandoned schemes have the potential benefits, especially the paddocks, for use in surface
Lack of access to water is expected to be one of the key constraints to achieving food security in the coming decades (UN, 2002). It is important to note that around one-fifth of the total value of fish production comes from freshwater aquaculture and 30 to 40% of the world’s food also comes from the irrigated 17% of the total cultivable land (Winpenny, 1997). According to a study conducted by Satyadeep et al. (2008), Ghana was able to supply 511,836 tonnes of her total fish demand of 913,992 tonnes in 2007 from marine and freshwater resources creating a shortfall of 402,156 tonnes. FAO (2001) as cited by the authors also indicated that fish accounts for 82% of dietary protein.
of Ghanaians. Hence water development for fish production thus constitutes an important element to the stability of food supplies in the next century.

The conversion of an abandoned dredged paddock into a fish pond for sustenance of the livelihoods of the vulnerable in a mining community after mine closure is a welcome development provided the regulatory framework concerning the decommissioning of abandoned mined lands as stipulated by the constitution is not flouted. This development should be in consonance with the legal instruments governing the abstraction and use of water for socio-economic development as encouraged in the Act 522 that sets up the Water Resources Commission. The conversion of abandoned mined resources into alternative beneficial uses ensures that such resources continue to provide life sustaining goods and services thereby reducing the perceived undue depreciation of the value of these assets which were hitherto considered as environmental liabilities.

The abandoned dredged mined paddock is at the bottom of a gentle slope from the Atewa range, with the Awusu, Obire-Obeng and Abudusu upstream draining into it. It is about 120 m wide by 60m long having an average depth of about 2-3 m. This will help keep the water levels high, as well as naturally be able to neutralize the waste products from fish populations if the paddock is converted to a fish pond (Reconnaissance survey 2005). The water is retained, not drained easily which is suggestive that the underlying rock or the linings of the paddock may be composed of fine clay that is impervious.

Large fishery facilities are normally developed from impoundments such as the Volta Lake created by the construction of the Akosombo hydro-electric dam (Gordon and Amatekpor, 1999), Irrigation facilities: Bontanga and Tono dams, depressions and possibly abandoned excavations such as the one being considered. The utilization of this abandoned dredge paddock with the aforementioned geophysical characteristics will reduce or eliminate the need/ cost of excavation and haulage of spoil that are to be associated with the development.

This development apparently contradictory to Act 522 of 1996 that established the Water Resources Commission and section 17(2) of the water use regulation of the legal instrument 1692 (LI 1692) of 2001, which mandates the permit holder to return the water to the same body of water from which the water was originally diverted or abstracted. The conversion of the paddock to a fish pond will be in line with water use regulations that fulfil the goals of national socio-economic development as well as the principles underlying integrated water resources management in the grant of water use permits to applicants. But these issues:

- The point of return of water
- The water quality conditions and quantity of water returned
- The impact of such interference on water resource utilization on the maintenance of ecological functions of the environmental media, socio-economic development, agriculture as well as the gender implications which have a consequence on the livelihoods of the vulnerable in the society arising out of the requirements under the law will be fulfilled to a greater extent due to the geophysical characteristics of the abandoned paddock

The grant of water use permits by the Water Resources Commission will therefore not be a hindrance to the development.

Fish grown in this environment is likely to have a continuous supply of ‘clean water’ at moderate temperature and dissolved oxygen content that is optimum for growth. The study assesses water quality conditions such as the hydrochemistry and physico-chemical quality of nine surface water sampling points within the Awusu-Abudusu meshwork (including the abandoned dredged paddock) affected by the operations of the defunct Goldenrae Mining Company a decade after mine closure, in order to craft solutions for the possible conversion of the paddock and impoundments into a fish pond.

**MATERIALS AND METHODS**

**Sampling points:** Nine surface water sampling points were selected, demarcated and their coordinates located using a Global Positioning System GARMING 45XLS. Six of the sampling points were located along the Awusu-Abusu-Anikawkaw meshwork impacted by the mine operations, and then three on the Kutuani stream (not affected directly by the mine operations) as indicated on Fig. 1. These sampling points were quite representative for the purpose of the study.

**Field visits:** Water samples were collected for a period of six months spanning October 2005 to March 2006. The time at each site was taken. Photographs of any interesting human activity and abandoned structures at the mine site (study area) likely to impact on the possible conversion of the paddock into an aqua-culture facility were also captured.

**Manual sampling of water and preservation:** Pre sterilized one-litre polyethylene bottles were used in the
collection of water samples. For the collection of surface water from streams, the bottles were held near the base in the hand, plunged neck downward below the surface of water with the neck pointing slightly upward and mouth of bottle directed toward the current. Ample space (about 2.5 cm) was left in the bottles to facilitate mixing by shaking before examination. The collected water samples were placed in an ice chest containing ice to maintain the temperature at 4°C and transported to the laboratory for analysis. Within the period of sampling to analysis, the properties of water can be altered due to the chemical, physical, and biological reactions. Sample preservation was therefore necessary to inhibit the reactions in the samples until it was analyzed (Sliwka-Kaszynska et al., 2003).

Analysis of physico-chemical parameters: Some of the physicochemical parameters were measured on the field (site) using portable water kits. pH, temperature, electrical conductivity, salinity, and dissolved oxygen were measured using HORIBA U-10 Water Quality Checker. The instrument was calibrated on-site before measurements were taken.

Turbidity of the water samples was determined within twelve hours after sampling using the HACH 2100P turbid meter (APHA et al., 1995). The Apparent Colour was determined by visual comparison of the sample with specially and properly calibrated glass colour discs (0-30Hz and 30-70Hz) using the BDH Lovibond Nesslerizer MK 0.3 (APHA et al., 1995). For suspended solids, 500 mL of the samples were blended at high speed for two minutes. The concentrations of suspended solids were determined thereafter using the HACH DR/2000 Direct Reading Spectrophotometer. The depths of the streams at the sites were measured using a calibrated PVC pipe of about four-meter length. Appropriate reagents were added to the nutrient samples and their concentrations determined by spectrophotometric method using 6505 UV/Vis. Spectrophotometer. Other chemical parameters (such as the major cations and anions, hardness etc.) were determined through analytical chemistry using Standard Methods as specified by the American Public Health Authority (APHA et al., 1995).

With the exception of suspended solids and turbidity analysis carried out at the Laboratory of the Centre for African Wetlands at the University of Ghana-Legon, all other analysis were done at the laboratory of Water Research Institute of the Council for Scientific and Industrial Research (CSIR)-Accra.

TRACE METAL ANALYSIS

Water samples were collected into 80 mL polyethylene bottles that had been previously washed with acid (10% HNO₃), rinsed thoroughly with tap water and then with deionised water. The samples were acidified with conc. HNO₃ (pH <2) and kept in an ice chest maintained at a temperature of 4°C with ice cubes before transporting to the laboratory.

The sampled solutions were aspirated into a flame and atomized. The concentrations of the trace metals were determined at specified wavelengths by Atomic Absorption Spectrophotometer (AAS) using a calibrated Unicam 969 Atomic Absorption Spectrometer (APHA et al., 1995).

RESULTS AND DISCUSSION

Major ions and physicochemical parameters: Water quality guidelines provide safe water consistent with available resources in order to establish minimum treatment needs for various competing needs and beneficial uses (Ola, 2006). With the exception of three sampling sites (AW1, AW2 $ AB1-Table 1), the concentration of dissolved oxygen do not meet the minimum guideline interval of 4.0 to 6.0 ppm (Clark, 1992) for fish and wildlife propagation. The values of turbidity ranging from 3.33 to 53.73 NTU that is elevated above the recommended guideline value of 5NTU for domestic water consumption (Who, 2006) will affect photosynthetic activity of aquatic plants thereby reducing the dissolved oxygen content of the sampled media.

The values of temperature appear quite moderate but any sudden increase due to forcing environmental conditions will reduce dissolved oxygen which may then cause fish kills (Clark, 1992). Oxygen is required by aquatic organisms for respiration. The elevated levels of turbidity are associated with suspended matter, such as silt and microscopic algae that may be a source of food for juvenile fishes. This leads to colouration of water thereby affecting water clarity and light penetration needed for photosynthetic activity of aquatic plants. This can also lead to clogging of fish gills due to increased suspended matter (Clark, 1992). Land clearing, dredging during surface mine operations, erosion from devegetated lands and agricultural runoffs contribute immensely to sediment load of the studied sites. The resulting turbidity will shade out and reduce producer organisms thereby altering the food chain within the riverine ecosystem.

The analytical values obtained for pH for all the sampled media was within the guideline interval of 6.5 to 8.5; an indication of good quality physical characteristics of the water resource (WHO, 2006).The observed pH may be as a result of the buffering effect of the increased alkalinity due to water running off impervious surfaces, cleared lands, draining wetlands over the acidity by drainage of soils rich in reduced
The concentrations of major ions analysed in the samples in Table 1 are moderately lower even though there are no guideline for these ions for the protection of aquatic life; the intensity of eutrophication if moderate will not cause an appreciable change in the density of zooplankton nor cause algal blooms due to larger biomass of phytoplankton. The productivity of the impoundments including the abandoned paddock may be increased due to nutrient inputs (especially phosphates and nitrates) from agricultural drainage and storm water runoff from refuse dumps, remnants of animal feedlots, human excreta as well as overflowing septic tanks. Large nutrient inputs enhance increased productivity by photosynthetic phytoplankton. This accelerates oxygen depletion during warm conditions thereby leading to fish kills.

The presence of Bicarbonates ($\text{HCO}_3^{-}$) at relatively higher concentrations that contribute to the hardness of the water is due to dissolution from limestone and probably dolomite in the parent rock. This may likely be the case due to highly leached and acidic forest oxisols developed over pyritiferous phyllites in the parent Birimian formations underlying the study area that have poor retentive properties (Brian, 1962). The bicarbonates act as a buffer to the effects of acid mine drainage that is associated with the waste rocks left on the abandoned mined concession.

**Trace metals:** The concentrations of trace elements determined from the various sites in the study are presented in Table 2. Samples analysed from the sampling sites indicated that the concentration of dissolved iron was significantly higher than the other trace elements with cadmium recording the least values. The concentration of dissolved iron ranged from 0.096 to 4.979 ppm. There is no guideline value for dissolved iron with respect to the protection of aquatic life; it may not have any deleterious effect on aquatic life but such high elevated values may lead to colouration of the surface waters thereby reducing the aesthetic appeal of the fishery resources.

Based on the analytical results (Table 2), the concentrations of copper, lead and cadmium are elevated with respect to the upper permissible limits of 0.0036, 0.00054 and 0.000384 ppm, respectively (USA, 1997). The concentrations of copper, lead and cadmium ranged from 0.006 to 0.213 ppm, 0.002 to 0.047 ppm and 0.002 to 0.007 ppm, respectively. The values for zinc and arsenic are however lower in comparison with the permissible limits of 0.049 and 0.19 ppm as recommended by W.H.O (2006) for surface water intended for the protection of aquatic life.

With the exception of the sampling points; Awusu Upstream (AW1), Abudusu Upstream (AB1) and Abudusu Midstream (AB2:-putatively mine impacted area/abandoned paddock), all the other sampling sites may not be suitable for the protection of aquatic life or possible development into an aqua-culture facility due to the higher concentration of trace elements above guideline values. The concentration of trace elements around the mined out area (Abudusu Midstream-Excavated Paddock) was below that of the pristine upstream environment (AB1 and AW1). This suggests that the disturbance at the mined out area accelerated the leaching of these trace elements within the area.
etc), radioactive elements, acids and other toxic heavy metals (lead, mercury, cadmium, arsenic, zinc, etc), radioactive elements, acids and other toxic substances (Clark, 1992; Ukpebor and Unuibe, 2003; Ikhuoria and Uyamadu, 2000; Oyewo and Don-Pedro, 2003). The most important or significant source of heavy metals in freshwater ecosystems in Ghana have been attributed to mining and associated operations not excluding mineral processing (Carboo and Sarfo- Armah, 1997; Armad and Carboo, 1997; Blay Jr and Adu-Anning, 1997; Akabzaa, 2000). These heavy metals accumulate in fish tissues, foodstuffs and irrigated vegetables and are passed on to humans (Sarkodie et al., 1997). Also the drinking of water or ingestion of food including fish products contaminated with these trace elements at relatively low dosage in the parts per million concentrations (or at instances parts per billion) can lead to brain damage, birth defects, and infant mortality among others (Clark, 1992; Cunningham and Saigo, 1999; Baird, 1999). These toxic heavy metals (trace metals) may also be released from weathered rocks/natural soils, carried by storm water runoff into rivers or percolate into groundwater.

The occurrence of heavy metals in various aspects of the environment has also been attributed to the indiscriminate disposal or discharge of industry and mine waste or effluent (Ikhuoria and Uyamadu, 2000). These activities, according to Sarkodie et al. (1997) had neither been regularized nor monitored. The situation has led to serious impacts on both the terrestrial and aquatic environment due to the high toxicity and persistence of these metals (Don-Pedro et al., 2004).

Mine drainage and leaching of mining wastes are serious sources of metal pollution of water (Cunningham and Saigo, 1999). However, waste piles left from the operations of the defunct Goldenrae Mining Company, refuse dumps and abandoned washing plant after mine closure remain a visual blight on the landscape. They may contain some amounts of potentially toxic ions, such as lead, arsenic, copper, mercury, cadmium, zinc, dissolved iron and other trace metals, which have low solubility. In addition to experiencing the contamination due to these potentially toxic trace elements, the conversion of the natural riverine ecosystem by the activities of the defunct Goldenrae mining company will be affected by the introduction of alien species of aquatic plants and animals.

CONCLUSION

The operations of the defunct Goldenrae Mining Company led to the fragmentation of the Awusu-Abudusu meshwork into impoundments such as the Mining Padocks and the slime Retention Area in the study area. Land clearance, erosion from mined out lands, agriculture, forestry and community runoffs, domestic waste, human and animal excreta contributed to turbidity and nutrient loading of the freshwater ecosystem in the study area. Hence the freshwater ecosystem is moderately eutrophic and productive. The relatively low concentration of trace metals at the Abudusu Midstream (the mine impacted area where the mine paddock is) is an indication that acid mine drainage has reduced tremendously. It may also be attributed to the resilience, enhanced assimilation capacity as well as the restoration of the integrity of water resource by the freshwater ecosystem after a decade of mine closure. Notwithstanding these observations, good environmental management and interventions for mitigation during mine operations might have enhanced the restoration of the quality conditions of the freshwater resources within the Awusu-Abudusu meshwork.

Alternative approach to reclamtion of abandoned mine lands for the sustenance of livelihoods has become apparent due to emerging concepts that emphasize the need for the conversion of fragmented/disturbed water resources to beneficial uses. The risk of developing the abandoned paddock and other impoundments into a fish pond as food security measure will be a worthy cause. The most probable constraint is that, the concentrations of three trace metals analysed copper, lead and cadmium were below the detection limit of the equipment (Atomic Absorption Spectrophotometer) used for the laboratory analysis. This detection limits were above the recommended guideline values for the use of the abandoned paddock/impoundments as a resource for aquaculture development.

The development of the impoundment into an aquaculture facility or fish pond must be preceded by the transfer of appropriate technology, needed financial resources and cost-benefit analysis based on market survey. There must also be stream sediment survey and comparative toxicological studies of the fishery products from the paddocks, other impoundments as well as the products from the entire Awusu drainage basin to ascertain their suitability for human consumption before embarking on the venture.

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