The Abra River System Water Quality Monitoring[*]

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Abstract

Water samples taken from different sites along the length of the Abra River System were analyzed in terms of physico-chemical characteristics – i.e. temperature, pH, dissolved oxygen, total suspended solids, total dissolved solids, biochemical oxygen demand, and nitrates, lead, mercury, chromium and cyanide concentrations. It was found out that except for temperature, all parameter readings exceeded allowable limits or did not meet minimum required concentrations set forth in DAO 34 for the river to be classified as Class AA, Class A, or Class B. This means that the river is polluted and is no longer suited for domestic use. Due to the pollution, the river may no longer be able to fulfill its productive and life-sustaining functions, as the river's assimilation and self-purifying capacity is greatly impaired. The evidence gathered suggests that much of the pollution in the river originate from the corporate mining operations.

Keywords: *Abra River, water quality monitoring, water pollution, river profiling*

INTRODUCTION

The Abra River System is one of the longest rivers in Northern Luzon. From its headwaters at Mount Data (in Mountain Province), one of the taller mountains in the region, it flows across the provinces of Benguet, Ilocos Sur, and Abra. A biodiversified ecosystem, its water quality was once capable of supporting diverse aquatic species, which, in turn, served as life resources for communities along the river's route. The advent of the mining industry, however,

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together with population growth, urbanization, and technology advancement, has contributed to the pollution of the river – upsetting the ecological balance within the river system and its surroundings. Deforestation of the upland pine forests due to *kaingin* (a slash and burn cultivation system) and logging of timber for fuel, housing, furniture-making, and tunnel shoring in mining areas have caused soil erosion and river siltation. Chemical pesticides, herbicides, and fertilizers used by farmers nearby are other possible sources of river poisoning.

The array of human activities overloaded the amount of materials and changed the nature of contaminants entering into the river, thus impairing its natural mechanism for self-purification. The assimilating and sustaining capacity of the river today shows signs of stressful conditions. It is this growing environmental concern that led to the investigation of the condition of the Abra River System through water quality monitoring.

Water quality monitoring provides an objective source of information for the wise management of vital water resources (Inter-government Task Force on Monitoring Water Quality, 1995). By determining the increase in the concentration of a material above the natural level, water quality monitoring gives an idea on the extent of degradation as well as indicates how the contamination level can be controlled. It has been noted that water quality monitoring information is used to protect human health, preserve and restore healthy ecological conditions and to sustain viable economy (ibid.).

Through water quality monitoring, it is the objective of this study to assess the river's capacity to receive waste discharges and later recover from such disturbance; to classify the river according to guidelines set by the Department of Environment and Natural Resources Administrative Order (DAO) 34; and, to recommend allowable utilization of the river. It further aims to discuss the factors affecting the river's water quality and suggest strategies to avert further deterioration.

MATERIALS AND METHODS

The river water quality was assessed through river profiling, water sampling, and analyses of some important physical and chemical parameters. In river profiling, point and non-point sources of pollution were located to identify appropriate sampling stations. A sampling route was designed, taking into account sites where the greatest concentration of contaminants is expected to occur as these are transported downstream. For quality comparisons, a control sample was taken from the headwaters at Mount Data, Mountain Province. During sampling, water was taken from the main flow of the river and from underneath the river's surface. Where effluent discharge or the confluence of tributaries occurs, samples were taken far enough downstream where the water is well mixed. Sampling was performed on a quarterly basis: The first sampling was done in October 2004, and the second, in February 2005. River physical parameters such as depth, width, and velocity were also determined during sampling.

For the water quality assessment, parameters such as temperature, pH, dissolved oxygen, solids content (dissolved and suspended), biochemical oxygen demand (BOD), nitrates, cyanides, and heavy metals (mercury, lead, chromium) concentration were determined. Methods employed for the analysis of the physical and chemical characteristics of the river water were classical gravimetric and volumetric methods which varied from simple field testing to laboratory-based, multi-component instrumental analyses. Analytical procedures were derived from the Standard Methods for the Examination of Water and Wastewater (1995). A Troll 9000 water quality monitoring instrument was used for on-site analyses. Solids analysis was done using the gravimetric method. BOD was determined by applying the Azide Modification Method. For cyanide and chromium concentrations, a Hach DR 890 colorimeter was used. Lead and mercury analyses were done using a Shimadzu Atomic Absorption Spectrophotometer.

RESULTS AND DISCUSSION

The physical characteristics of the river during sampling activities are summarized in Table 1. The average depth and width of the river generally increased from the headwaters to the downstream areas as more tributaries merged with the main river flow. On the other hand, the average surface speed of the water declined as the slope catchment leveled off.

Table 1: Physical characteristics of the river at time of sampling (February, 2005)

Sampling Point	Average Depth (m)	Average Width (m)	Average Surface Velocity (m/s)
Guinaoang (control)	0.35	2.0	0.189
Mill outlet	0.15	1.0	not recorded
Tailings Dam spillway	0.61	1.0	not recorded
Lepanto Bridge	0.28	4	0.690
Kayan	0.36	11	0.326
Gitlangan	0.33	11	0.571
Bulaga	0.38	12	0.140
Patungkalew	0.91	29	0.540
Banoen	1.08	38.5	0.112
Manabo	1.52	130	0.203
Bucay	1.0	67	0.724
Bangued	0.8	76	0.668
Banaoang	1.0	90	almost stagnant
Caoayan	2.5	200	almost stagnant
Santa	2.7	400	almost stagnant

Figures 1 and 2 show the on-site temperature, dissolved oxygen (DO), and pH in the first and second samplings, respectively. As expected, the water temperature increased as the river flowed from the cool uplands to the warmer lowlands. The figures also show a general decrease in the river's dissolved oxygen content in the downstream section. Dissolved oxygen is an indicator of the river's capacity to sustain aquatic life and to oxidize organic matter. The higher its concentration in water, the greater is the river's capacity to support life and to recover from organic matter overloads. A minimum concentration of 5 mg/L is required in order for a river to maintain its ecological functions. When DO levels reach critically low concentrations, fish kills may occur. In some sampling points along the Abra River, the dissolved oxygen concentration was way below the minimum. Although dissolved oxygen concentration in river water is influenced by many factors (such as temperature, atmospheric pressure/altitude, water turbulence, the type and number of organisms, and the amount of organic and inorganic matter), the fact that below normal concentrations were recorded at the mill outlet and the tailings dam spillway (see Table 2) means that low dissolved oxygen levels in the river are caused largely by industrial activity.

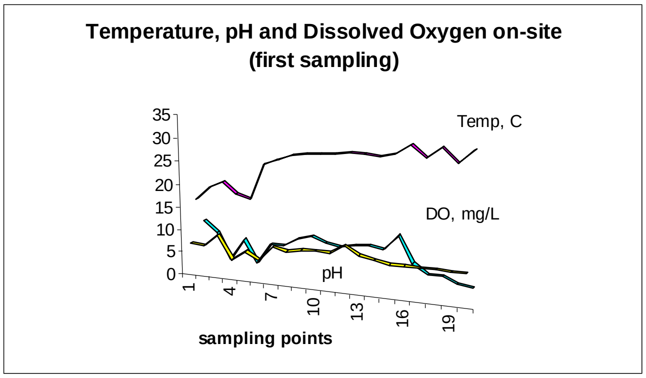

Figure 1

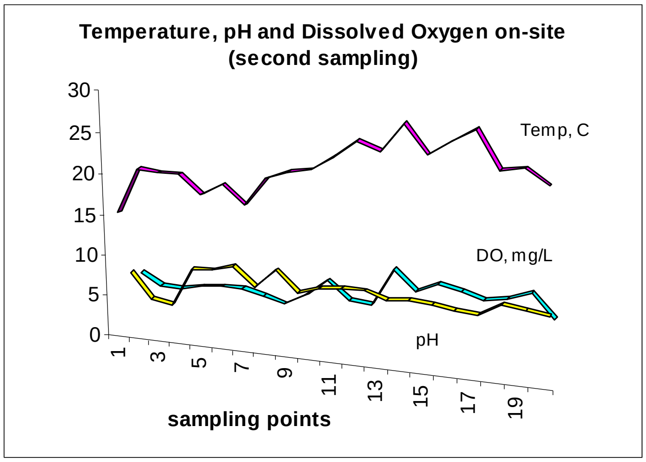

Figure 2

Table 2: Parameters at Critical Points Compared to Water Quality Criteria for Conventional and other Pollutants Contributing to Aesthetics and Oxygen Demand for Fresh Waters[1]

	Site	Sampling Concentration		Limits		
		First	Second	Class AA	Class A	Class B
Temp.		maximum rise in °C over ambient			3	3
pH	Mill Outlet 2	4.07	3.42	6.5-8.5	6.5-8.5	6.5-8.5
	Tailings Dam Spillway		9.23			
TSS	Mill Outlet 1	100K$^+$	225000$^+$	25	50	not more than 30% increase
TDS	Caoayan	9740	39000$^+$	500	1000	-
TS	Mill Outlet 1	102K$^+$	228000$^+$			
DO	Mill Outlet 1	1.98	4.73	5	5	5
	Caoayan	2.23				
	Tailings Dam Spillway		4.25			
BOD	Mill outlets 1 & 2	above 9	above 9	1	5	5
	Tailings Dam Spillway	3.798				
NO_3^-	Mill Outlets		exceeded limits	1 as N	10 as N	no recommen-dations made

(All units are expressed as mg/L except pH as units.)

The acidic/basic character or the pH profile along the river is likewise shown in Figures 1 and 2. In undisturbed or healthy surface waters, pH is expected to remain reasonably constant within the range of 6.5-8.5. The figures show, however, that in some sampling sites, the pH of Abra River deviated tremendously from the normal pH for surface waters. Samples taken at the mill outlet were of pH 4.07 and 3.42 in the first and second samplings, respectively. In contrast, the water sample at the tailings dam spillway suddenly turned basic, with a pH of 9.23 (see Figure 2 and Table 2). This change is a result of the direct liming treatment done by the company as a way of reducing the acidity of the water.[2]

The strength of the acidic or basic character of surface waters is an important water quality parameter because most life forms are sensitive to pH. A pH far from the acceptable range could kill off the active microbiological population responsible for decomposing organic and inorganic wastes in the water, thus weakening the river's capacity to self-purify. The biological effects of changes in pH can most easily be seen by the sensitivity of freshwater species to acid conditions. Population of salmon start to decrease below pH 6.5, perch below 6.0, and eels below pH 5.5; few species are able to survive below pH 5.0 (Reeve, 1994). In the case of Abra River, the *udang* (shrimp) and *igat* (eel) are reportedly becoming rare (STARM, 2003).

The weathering of minerals such as limestone or dolomite by water also becomes more rapid at low pH (Kiely, 1997), thus disrupting natural biogeochemical cycles and increasing the solids content of the water. Many metals such as iron and chromium also have an improved solubility in acidic water, making them more difficult to separate from the water.

The solids content (suspended and dissolved) profiles of the river are shown in Figures 3 and 4. Extremely high readings for both total suspended solids (TSS) and total dissolved solids (TDS) registered for water taken at the mill outlet and downstream, particularly Caoayan, exceeding acceptable concentrations by several thousands (see Table 2 for numerical values). Much of the suspended solids could have originated from soil erosion brought about by logging, mining, and construction activities but industrial effluents could also have contributed very significantly. The dissolved solids content, chiefly inorganic ions, could have come from chemicals used in farming and mining and the aggravated weathering of natural minerals due to abnormally acidic conditions. High solids content in water could pose a myriad of destructive effects to important biological functions as it affects dissolved oxygen levels in water. High solids content could effectively block sunlight and arrest the photosynthetic activity of aquatic plants and photosynthetic microorganisms which are an important source of dissolved oxygen in water. It could also serve to deplete dissolved oxygen as microbes and fungi consume oxygen to decompose suspended organic solids. High solids content have also been known to increase water temperature which lowers the solubility of oxygen in water. Aside from production inhibition and depletion effects to dissolved oxygen, suspended solids by themselves could stunt the ability of fish to see and catch prey, and damage fish and insect eggs as they form sediments on riverbeds.

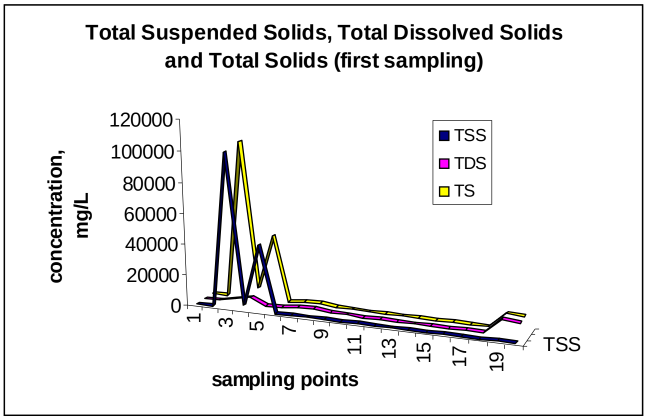

Figure 3

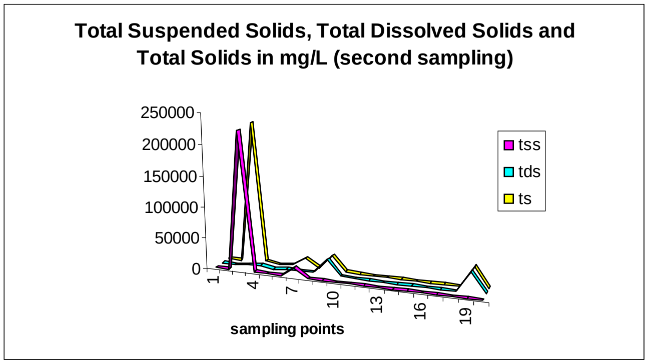

Figure 4

Figure 5 shows the biochemical oxygen demand (BOD) profile along the river for the first and second sampling activities. BOD refers to the amount of oxygen needed by microorganisms in the process of breaking down organic matter in water. A high BOD therefore indicates high amounts of organic pollutants. Pristine waters usually register a BOD of less than 1 mg/L while moderately polluted ones have 2 to 8 mg/L. As shown in the figure, most water samples had BOD levels higher than 2 mg/L. Samples at the mill outlets, in particular, even registered higher than 9 mg/L concentrations (see Table 2). Since oxygen to supply the BOD comes from dissolved oxygen (DO) in the water, the two parameters are intimately related. In places where BOD is high, DO is low, which means that there is less oxygen to go around for other aquatic species that need it to survive. As mentioned earlier, low DO levels could lead to fish kills. During samplings at the mill outlets and tailings dam spillway, no life forms in these parts of the river were observed.

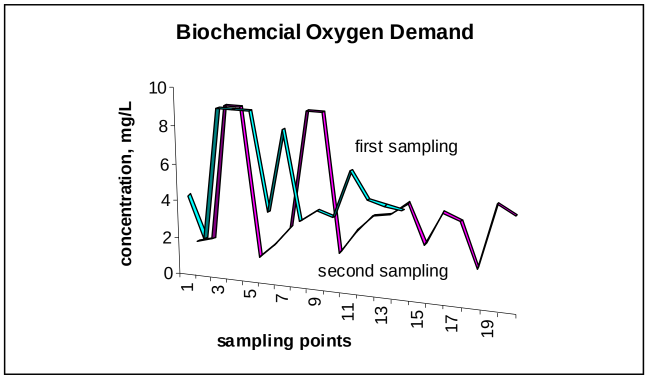

Figure 5

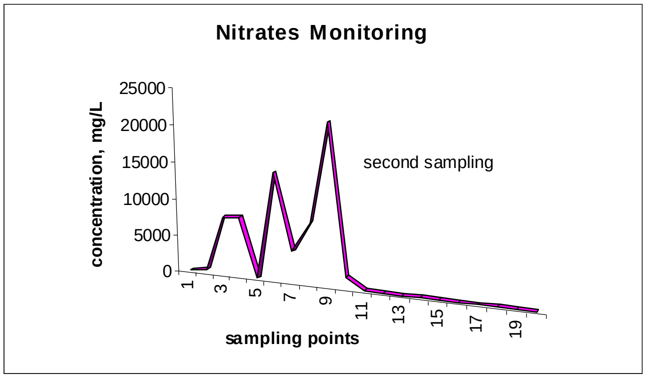

Figure 6

The Abra River also showed exceedingly high nitrate concentrations as shown in Table 2 and Figure 6. These nitrates could have come from fertilizer runoff, domestic and industrial effluents, and animal manure. Elevated nitrate concentrations can be dangerous to humans and aquatic life. When nitrate enters the body, it is easily converted to nitrite which reacts with hemoglobin and form methemoglobin. This renders the blood incapable of carrying oxygen and gives rise to a fatal infant disease called the blue-baby syndrome. In fish, a similar condition called the brown blood disease could occur. Aside from these direct impacts, nitrates are also a major food requirement of planktons, algae, and aquatic plants; thus if in excessive amounts, nitrates could trigger algal bloom and overproduction of aquatic plants (cf. Nazaroff and Alvarez-Cohen, 2001). When these die, their decomposition will consume much of the dissolved oxygen in the water, making the oxygen concentration drop to critically low levels. Figure 6 shows a high nitrate presence at the mill outlets and tailings dam spillway; there is a noted decrease in concentration going downstream, but still algal bloom existed.

The presence of toxic substances in water – in the forms of nitrates as discussed above, as well as heavy metals and cyanides – is a significant environmental concern. In water, metals may be in the form of ions, in inorganic molecular clusters known as metal complexes, or incorporated into organic molecules (Nazaroff and Alvarez-Cohen, 2001). Heavy metals may come from background geology, but if found in excessive amounts, they are most likely due to industrial discharges. In the case of the Abra River, this study found out that the heavy metals lead, mercury, and chromium are in concentrations much higher than the acceptable limits (Table 3). Figures 7, 8, and 9 show the concentration profiles of lead, mercury, and chromium, respectively, along the length of the river. In the case of mercury, Figure 8 reveals that the mining company may have recovered this metal at certain points, but the abrupt rise in sites downstream indicates the effect of accumulation over the years as well as of the small-scale mining (gold panning) at the outskirts of the mining company.

All these metals exhibit adverse effects to human health and the environment. These materials are hazardous because they do not naturally degrade and are toxic even in a relatively low concentration (Corbitt, 1999). Moreover, toxins that are rather dilute in the environment can reach dangerous levels inside cells and tissues through bioaccumulation. This refers to the uptake of chemicals by organisms from food items (benthos, fish prey, sediment ingestion, etc.) as well as via mass transport of dissolved chemicals through the gills and epithelium (Davies and Masten, 2004). As a result, biomagnification occurs in organisms, that is, the cumulative storing of a toxin or pollutant in organisms that are found in the food chain, where the organisms in higher trophic levels acquire progressively higher amounts of stored toxin as they ingest more prey (Tayo et al., 2004). Poisoning in humans due to these could result to physical deformities, weak immune systems, cancers, and mental illnesses.

Cyanide is another toxic material that was found to be in concentrations above acceptable limits, especially at the mill outlet and the mine tailings spillway as shown in Figure 10. Cyanide is the most common chemical used to extract gold from ore despite the fact that leaks or spills of this chemical are extremely toxic to fish, plant life, and human beings (STARM, 2003). Cyanide also forms complexes with metals, that is, it binds with metals and inhibits their capacity to precipitate and be separated from the water (Nazaroff and Alvarez-Cohen, 2001). Although cyanide can break down in the presence of sunlight and oxygen, the decomposition process is inhibited under cloudy or rainy conditions and by insufficient concentrations of dissolved oxygen as is the case in the sampling sites.

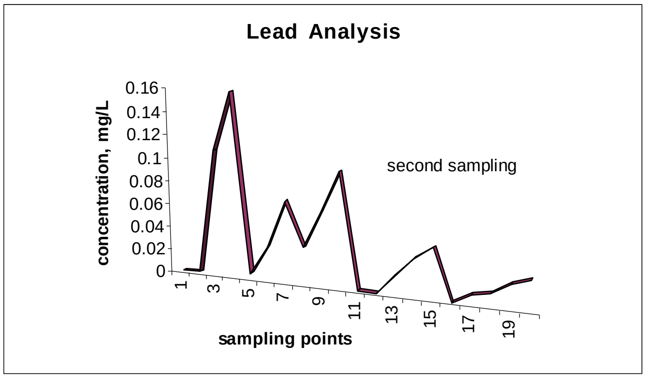

Figure 7

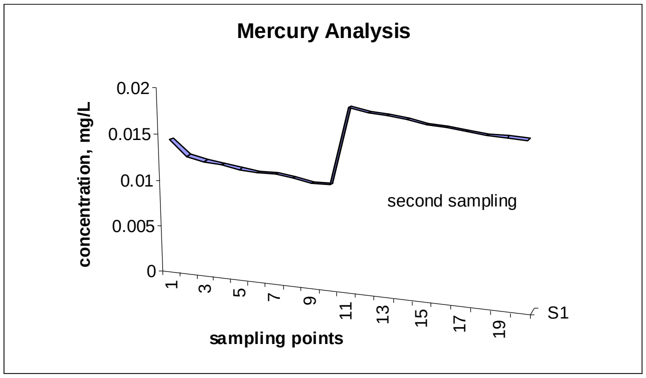

Figure 8

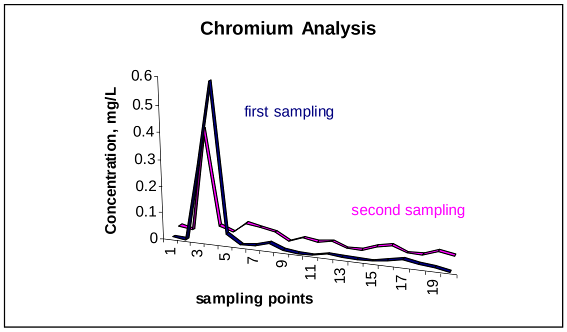

Figure 9

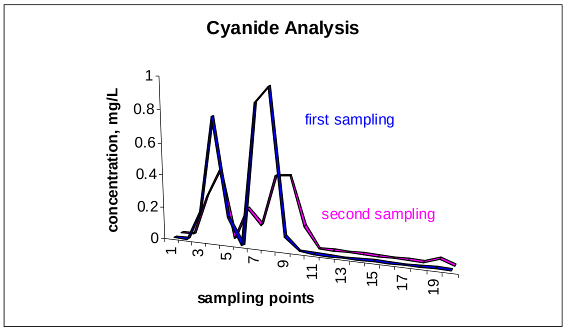

Figure 10

Table 3: Parameters at Critical Points Compared to Water Quality Criteria for Toxic and other Deleterious Substances for Fresh Waters (for the Protection of Public Health)

	Site	Sampling Concentration		Limits		
		First	Second	Class AA	Class A	Class B
CN	Mill Outlet 2	0.776	0.43	0.05	0.05	0.05
	Lepanto Bridge	0.98	0.436			
	Caoayan	0.095	0.032			
Cr	Mill Outlet 2	0.595	0.41	0.05	0.05	0.05
Pb	Mill Outlet 2		0.159	0.05	0.05	0.05
Hg	Gitlangan		0.019	0.002	0.002	0.002

(All units are expressed as mg/L.)

With the foregoing discussions on several parameters regarding Abra River's physico-chemical characteristics, an assessment of the river's status can now be made. The DENR sets classification criteria for fresh surface waters according to two types of possible disturbances: (1) conventional and other pollutants contributing to aesthetics and oxygen demand, and (2) toxic and other deleterious substances. These are embodied in DAO 34, and are listed in Tables 2 and 3 for comparison with parameters obtained at critical sampling points located in the upper Abra River. As can be seen in the tables, tolerable limits are exceeded and minimum required concentrations, where applicable, are not met. This means that the upper Abra River **cannot** be classified as Class AA (Public Water Supply Class I), Class A (Public Water Supply Class II), or Class B (Recreational Water Class I). Much the same conclusion can be made for the lower Abra River.

N.B.: *This current report covers the first phase of this study, which is part of a larger ongoing research spread out over the course of five years conducted by the Environmental Research Laboratory of the SLU College of Engineering and Architecture. Follow-up reports will be made on the results of subsequent assessments.*

CONCLUSIONS AND RECOMMENDATIONS

In the 1970s, the upper Abra River Sysem was classified as Class A and the lower section as Class B. Evidence obtained from chemical analyses of certain pollutants show that this classification can no longer be adopted based on DAO 34. It means that the river has deteriorated abruptly in the succeeding years due to the combined effect of many human-related activities. The study shows quite compellingly, however, that the mining industry is the major contributor to the river pollution.

As a result of the pollution, the river's capacity to assimilate wastes, self-purify, and support life is gravely weakened. This situation should be given urgent and appropriate attention, considering its adverse effects, as many of the populace living along the river directly use of the water for drinking and other domestic purposes.

The river has the capability to regenerate if proper management of waste disposal is met by the mining industry. A water quality monitoring system should likewise be instituted, with the objective of regularly measuring and controlling the discharge of pollutants. Other strategies could further be adopted, one of which is by dredging out the silted river – a method employed by Marcopper in Marinduque – in order to bring back the ecological system of the river beds. The destruction of cyanide molecules by oxidation can also be resorted to via the application of chlorine as oxidizing agent, or through electrolytic oxidation.

At the broader picture, the case of the Abra River pleads for radical changes in mining practices and stricter government implementation of environmental laws. That mining operations and environmental protection can go together is a highly realizable possibility. In particular, mining companies can utilize available technologies for the treatment of contaminated fresh surface waters; the efficient on-site reduction of metals; and, the control, storage, and beneficial utilization of mine tailings. It only needs financial resources and government pressure to implement these. In the long run, industries should foster sustainability consciousness in their business practices. A good business venture appreciates the need to operate in a framework that factors in in its overall expenses the cost of the negative impacts of its operation to the environment (Tayo et al., 2004).

ENDNOTES

[1] The water classifications in this table, as in Table 3, come from DAO 34 (DENR, 1990). Class AA means Public Water Supply Class I intended primarily for waters having watersheds which are uninhabited and otherwise protected and which require only approved disinfection in order to meet the National Standards for Drinking Water (NSDW) of the Philippines. Class A represents Public Water Supply Class II that requires complete treatment (coagulation, sedimentation, filtration and disinfection) in order to meet NSDW. Class B is Recreational Water Class I for primary contact recreation such as bathing swimming, skin diving, etc. (particularly those designated for tourism purposes).

[2] As regards this direct liming treatment done by the company, it is noted that there is no indication as to how regular treatment is applied on the impoundment so as to establish if the treatment is consistent or effective (STARM, 2003).

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