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Water quality assessment using macroinvertebrates along the mining area of Brgy

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ABSTRACT

In this research, water quality assessment in the Bigaan River, Brgy. Gango, Libona, Bukidnon was conducted to determine the impact of small scale mining on the aquatic ecosystem using macroinvertebrates as bioindicators. Analysis revealed that total suspended solid, total hardness and mercury content is higher in the downstream portion of the river. Species composition of macroinvertebrates differs between sites. Total abundance and species diversity is higher in the upstream portion of the river. The absence of pollution sensitive Ephemeroptera (Mayfly) and Tricoptera (Caddisfly) taxa in the downstream portion of the river indicates that the water quality is deteriorating. Although the level of mercury contamination in the downstream portion is low and within the standard limit, the outcome still indicates that long term exposure to mercury brought by small scale gold mining has detrimental effects on macroinvertebrate communities and on the quality and functionality of the river ecosystem.

1. Introduction

Small-scale gold mining (SGM) embroils the extraction of minerals, usually gold, using undeveloped techniques in small or medium sized operations. Commonly, it involves the use of considerable amount of mercury during mineral processing because it is inexpensive and simple to use (UNEP, 2008). Globally, SGM is responsible for approximately 37% of mercury emissions and is considered the largest source of water mercury pollution (UNEP, 2013a). Mining hotspots, which are identified sites of high metallic mercury concentration situated usually near flowing river, are the major source of mercury dispersion into aquatic ecosystems. Additionally, mercury-containing tailings are usually dumped in or beside bodies of water which results mercury contamination of soil, rivers, streams, ponds and lakes for a very long period of time (UNEP, 2008).

Mercury that contaminates into the bodies of water will be transformed by anaerobic microorganisms into its more toxic form, methylmercury. Methylmercury that formed is then absorbed by phytoplankton, ingested by zooplankton then by macroinvertebrates and eventually goes up into the food chain which becomes concentrated in fishes particularly in carnivorous species (WHO, 2007; UNEP, 2013b). Individuals exposed to mercury can develop changes in behavior, physiology, reproduction as well as acute effects which include morbidity and mortality. At the species level, changes in survivorship and population structure in addition to population declines or local extinction can be the endpoints of mercury exposure. Lastly, changes in the interaction among species and in the pattern of energy use and production are considered to be the ecological endpoints.

In water quality assessment, the used of biological indicators was adopted since most of the ecological and environmental bioindicators have strong association with some characteristics of their environment (McGeogh, 1998; Kitching et al., 2000; Davis et al., 2001) and thus more efficient in detecting long-term changes in water quality (Benetti et al., 2012). Among the communities that are considered bioindicators of water quality, the most frequently used are the benthic macroinvertebrates (Bonada et al., 2006).

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Macroinvertebrates are visible to unaided eyes, have sedentary and long life span and are significantly sensitive to organic pollution, thermal pollution, substrate alteration and toxic substances (Sharma et al., 2008). It has limited migration ability making them suitable for assessing the site specific impacts of certain environmental stressors. Furthermore, their assemblages are made up of species that constitute a broad range of trophic levels and pollution tolerances (Kripa et al., 2013). In this study, assessment in the upstream and downstream portion of Bigaan River was done using different physico-chemical parameters and macroinvertebrates' diversity and distribution to determine the impact of an active small-scale gold mining in Brgy. Gango, Libona, Bukidnon that uses mercury during gold extraction in the water quality of the river.

2. Methodology

2.1. Research settings

The study was conducted in the Bigaan River located at Barangay Gango, Libona, Bukidnon where an active small-scale gold mining exists. Brgy. Gango is bounded on the north by Misamis Oriental; on the south by Barangay Kinawe; on the east by Cugman River and on the western side by Bobonawan River. As shown in Fig. 1, the study area was divided into two sampling stations; the upstream (8° 24' 29.82" N and 124° 40' 29.40" E) and downstream (8° 23' 57.24" N and 124° 40' 39.12" E) portion of Bigaan River. The sampling station at the upstream portion of Bigaan River is situated prior to the area where small-scale gold mining activities exist.

2.2. Collection of data

Data were collected within the 100m transect line established in each of the sampling station: upstream and downstream portion of Bigaan River. Data for the physicochemical parameters including the width and depth of stream, type of substrate, water current, temperature and pH were taken in situ while total suspended solid (TSS), dissolved oxygen (DO), biological oxygen demand (BOD), total hardness and mercury content were determined through laboratory analysis. All of the parameters were taken once with three replicates. For the macroinvertebrates, opportunistic sampling was employed using grab method and dip net method. Collected samples from each sampling station were put in separate containers containing 70% ethanol and were brought to the laboratory for processing and identification using different photographic identification keys.

2.3. Analysis of data

Data obtained from the physico-chemical parameters in both sampling stations were compared to the standards set by DENR Administrative Order (DAO) 34 under class C standards. Diversity indices were calculated using the PAST software version 2.14 to determine and compare the species diversity of macroinvetebrates in the upstream and downstream portion of Bigaan River.

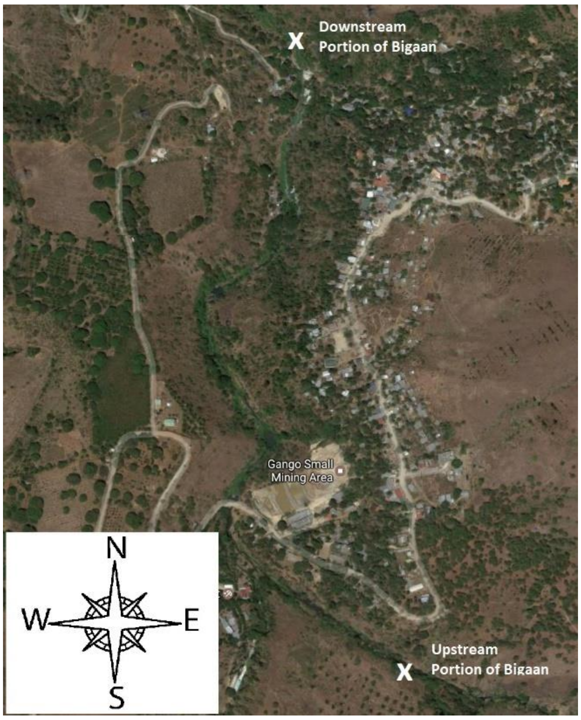

Fig. 1: Satellite view of the study area in Brgy. Gango, Libona, Bukidnon showing the two sampling stations in Bigaan River (courtesy of Google Earth)

3. Results and discussion

Analysis in the water samples revealed variations in the physicochemical aspects between the downstream and upstream portion of Bigaan River in Brgy. Gango, Libona, Bukidnon. Table 1 shows the result of the physicochemical analysis between the 2 sampling stations as well as the corresponding standards set by DAO-34 (Class C). The total hardness and total suspended solid (TSS) are notably higher in the downstream portion of Bigaan River as compared to the upstream portion and have even exceeded the standard limit set by DAO-34. The observed difference in the TTS between the sampling stations might be attributed to the existing land used in the downstream portion of the river particularly the mining activities that discharges soil particles from the underground tunnel during the excavation process. Conversely, the average water temperature and pH in the downstream portion is marginally lower than the upstream portion. As compared to the standard, the pH values in both sampling stations have exceeded the standard set by DAO-34. Furthermore, the temperature of the water can affect the amount of dissolved oxygen in it; as the water gets warmer, it cannot hold as much as dissolve oxygen as in colder water causing the level of dissolved oxygen to drop (Hickin, 1995).

Table 1: Physico-chemical parameters of the 2 sampling stations in Bigaan River, Brgy. Gango, Libona, Bukidnon

Physico-chemical Parameters	Downstream	Upstream	DAO-34 Standards
Width of the Stream	13.77 m	9.17 m	-
Depth of the Stream	0.37 m	0.39 m	-
Type of Substrate	Rocky-sandy	Rocky-sandy	-
Water Current	0.20 m/s	0.36 m/s	-
Total Hardness as CaCO3	201 mg/L	159 mg/L	-
Temperature	26.06 °C	26.60 °C	3°C rise
pH	8.71	8.74	6.5 - 8.5
Total Suspended Solid (TSS)	80 mg/L	<6 mg/L*	≤30 mg/L rise
Dissolved Oxygen (DO)	7.9 mg/L	7.0 mg/L	5.0 mg/L (min)
Biological Oxygen Demand (BOD)	<1 mg/L*	<1 mg/L*	7.0 mg/ L
Mercury Content	0.002 µg/ml	<0.001 µg/ml**	0.002 µg/mL

Legend: * - method detection limit; ** - reporting limit

Hence, the slight lower temperature in the downstream portion of the river might cause the dissolved oxygen in the water to be slightly higher as compared to the upstream portion. Lastly, the presence of mercury in the downstream portion can be attributed to the small scale mining activities occurring in the area which uses mercury for gold extraction. However, as compared to the standard set by DAO-34, the amount of mercury recorded in the downstream portion is still within the acceptable limit.

Collectively, as shown in Table 2, a total of 10 macroinvertebrates species that belongs to 8 different orders were collected in the 2 sampling stations of Bigaan River.

Table 2: Species composition and abundance of macroinvertebrates in the 2 sampling stations of Bigaan River, Brgy. Gango, Libona, Bukidnon

Order	Common Name	Down-stream	Up-stream	Total
Coleoptera	Water-penny beetle	3	19	22
	Whirligig beetle	0	6	6
Ephemeroptera	Mayfly nymph	0	141	141
Gnathobdellida	Leech	129	14	143
Hemiptera	Creeping water bug	2	0	2
	Water strider	25	232	257
Lepidoptera	Pyralid caterpillar	19	0	19
Lumbriculida	Aquatic worm	7	0	7
Mesogastropoda	Golden apple snail	5	34	39
Tricoptera	Caddisfly larvae	0	66	66
Total		190	512	702

The number of macroinvertebrates species found in the downstream and upstream portion of the Bigaan River is the same but the species composition varied. Creeping water bug, pyralid caterpillar and aquatic worm were found only in the downstream portion while whirligig beetle, mayfly nymph and caddisfly larvae were found only in the upstream portion. In terms of the macroinvertebrates' abundance, the upstream portion has considerably higher number of collected macroinvertebrates than the downstream portion. Water strider is the most abundant in the upstream while leech is the most abundant species in the downstream. Based on the different diversity indices of macroinvertebrates shown in Table 3, the species diversity of macroinvertebrates is higher in the upstream portion of the Bigaan River as compared to the downstream portion.

Macroinvertebrates are classified based on their tolerance to pollution. As shown in Table 4, majority of the macroinvertebrates are considered as pollution tolerant and two of these species, the aquatic worn and creeping water bug, were exclusively found in the downstream portion of the river. On the other hand, caddisfly and mayfly, which are both pollution sensitive species, were found only in the upstream portion of the river. The presence and abundance of mayfly and caddisfly indicates that the water quality in the upstream portion of the river is still in good status. Mayfly (Ephemeroptera) and caddisfly (Tricoptera) belong to the EPT taxa which are known to be pollution-sensitive and are composed of aquatic macroinvertebrates commonly used to assess the health status of stream and river. The presence or absence of the EPT taxa indicates if the aquatic environment is polluted or not.

Table 3: Diversity indices of macroinvertebrates in the 2 sampling stations of Bigaan River, Brgy. Gango, Libona, Bukidnon

Diversity Indices	Downstream	Upstream
Taxa_S	7	7
Individuals	190	512
Dominance_D	0.4907	0.3045
Simpson_1-D	0.5093	0.6955
Shannon_H	1.091	1.431
Evenness_e^H/S	0.4252	0.5974

Accordingly, these macroinvertebrates can only be found in streams and river with good water quality due to their low tolerance to pollution (Agouridis et al., 2015) and thus a strong bioindicator of a healthy aquatic environment. Conversely, the absence of mayfly and caddisfly in the downstream portion of the river implies that the quality of the water in the downstream portion is currently deteriorating and could not anymore support the survival of these pollutant-sensitive macroinvertebrates. In the study conducted by Souto et al. (2011), pollution sensitive groups including Ephemeroptera and Tricoptera were associated to the stream in the preserved area and the more tolerant groups were associated in the streams of the urban area.

Table 4: Pollution tolerance of macroinvertebrates found in the 2 sampling stations of Bigaan River, Brgy. Gango, Libona, Bukidnon

Macroinvertebrates	Pollution Tolerance	Down-stream	Up-stream
Aquatic worm	Pollution Tolerant	√	
Creeping water bug	Pollution Tolerant	√	
Golden apple snail	Pollution Tolerant	√	√
Leech	Pollution Tolerant	√	√
Water strider	Pollution Tolerant	√	√
Pyralid caterpillar	Moderately Tolerant	√	
Whirligig beetle	Moderately Tolerant		√
Water penny beetle	Pollution Sensitive	√	√
Caddisfly larvae	Pollution Sensitive		√
Mayfly nymph	Pollution Sensitive		√

As mentioned, the abundance of leech is higher in the downstream portion of the study area. Accordingly, majority of the common leech species as known to be inhabitants of eutrophic, polysaprobic and highly stressed freshwater environments (Lenat, 1993). Not all species of leech have high tolerance against various pollutants but the high level of tolerance of most common leech made all of them classified under the vast category of "highly tolerant organisms" used in biological assessment of freshwaters (Skriver et al., 2000). On the contrary, the high abundance of water strider, also a pollution tolerant species, in the upstream portion does not justify that the area is also polluted. Other factors might have contributed to the high abundance of water strider in the upstream portion and one might include the food source. As a predator, water strider prefers an environment abundant with insects which serves as its main source of food. Between the two sampling stations, the upstream portion of the river offers this type of environment with high abundance of insects as compared to the downstream portion (Table 2); hence, the high abundance of water strider was also observed.

Bioindicators are known to be strongly associated with some characteristics in its environment and any changes that occur in the habitat can be reflected on the distribution of bioindicators. Several studies have been conducted that utilizes macroinvertebrates as bioindicator in the assessment of aquatic ecosystems (Kaye, 2005; Duran, 2006; Haileselasie and Teferi, 2012; Henderson et al., 2012; Tampus et al., 2012; Selvanayagam and Abril, 2015). In this study, variation in the distribution as well as in the abundance of macroinvertebrates between the upstream and downstream portion of Bigaan River might be greatly influenced by the existence of small-scale mining activities in the downstream portion of the river. The mining activities have brought changes in the physical and chemical aspects of the water and causes mercury contamination in the river. Studies on other heavy metals such as in the assessment of lead mine pollution conducted by Mitchell (2009) using macroinvertebrates revealed that increased level of lead in the sampling sites have attributed to the reduction of species diversity.

Furthermore, characterization of the response of benthic macroinvertebrates to heavy metals released from the mines showed that although the concentration of heavy metals is not seriously high, their effects were reflected in the changes in species composition of macroinvertebrates particularly affecting the pollution sensitive EPT taxa and the decreased in total abundance and species richness as the concentration of heavy metals increases (Qu et al., 2010). Likewise, in this present study, although the concentration of mercury detected in the downstream portion of Bigaan River is low and still within the acceptable limit set by DAO-34, this concentration might still be detrimental to the aquatic macroinvertebrates especially for those species that are highly sensitive to pollutants like the EPT taxa. The species composition and total abundance of macroinvertebrates have varied between the two sampling sites wherein the member of Ephemeroptera and Tricoptera taxa were only found in the downstream portion and the abundance of macroinvertebrates in the downstream portion is significantly lower than the upstream portion of Bigaan River.

Aside from mercury contamination, other water quality parameters such as increased total suspended solid and total hardness might have also contributed to the lesser species diversity in the downstream portion of the river. As cited by Chakravorty et al. (2014), high suspended solid not only reduces the rate of photosynthesis but also damages the exposed organs of macroinvertebrates and causes macroinvertebrate dislodgements (Langer, 1980) and is associated with an increased in macroinvertebrate migration (Gamon, 1970). Water hardness, on the other hand, has the capacity to modify the toxicity of heavy metals to aquatic organisms (Khan and Ghosh, 2001). Accordingly, the bioavailability of heavy metals including mercury in freshwater typically decreases as the water hardness increases (USEPA, 1995). Although this claim was not fully established in this study, the increased water hardness in the downstream portion of Bigaan River might possibly explain the low mercury level that is still within the standards set by DAO-34 even though gold mining activities occur in the area.

4. Conclusion

The physicochemical parameters and the diversity and distribution of macroinvertebrates varied between the upstream and downstream portion of Bigaan River in Brgy. Gango, Libona, Bukidnon. The existing small scale mining activities in the area, which caused increase turbidity and mercury contamination in the river, is main identified factor for the observed variation. Assessment of macroinvertebrates as bioindicator reveals that the water quality of the downstream portion of Bigaan River is deteriorating as evidenced by the absence of pollution sensitive Ephemeroptera and Tricoptera taxa. Although the level of mercury contamination is low and within the standard limit, the consequence is still evident indicating that long term exposure to mercury has detrimental effects on the macroinvertebrate communities along the small scale mining area in Brgy. Gango, Libona, Bukidnon.

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