Benthic Macroinvertebrates in Streams Contaminated by Acid Mine Drainage– A Pilot Study from Thailand

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ABSTRACT

Benthic macroinvertebrates were sampled by a D-Frame Dip net (450 µm mesh size) from 3 sites of a stream contaminated with acid mine drainage from a gold mine in Loei Province, Thailand. *Sialis* larvae (Insecta: Megaloptera: Sialidae) were dominant taxa (49%) in the high Arsenic upstream site 1 followed by dipteran larvae (26%), gastropods (15%) and Coleoptera (10%). The less contaminated, downstream site 3 was dominated by Coleoptera (32%), Ephemeroptera nymphs (24%) and *Caridina* (F. Atyidae, O. Decapoda-20%). Seventeen percent of mouthpart deformity of chironomid larvae was also found in site 2. It is preliminary concluded that the extent of contamination with mining waste water has affected both, taxon composition and the proportion of chironomids with deformed mouth parts.

KEY WORDS :

Gold mine
Arsenic
Stream benthos
Mouthpart deformity
Chironomids

INTRODUCTION

Acid mine drainage causes several ecological problems, particularly the acidification of surface freshwater systems and heavy metal concentration (Gerhardt et al., 2004). Streams impacted by acid mine drainage are typically characterized by low pH and high metal concentrations (Warner, 1971; Brady et al., 1986). These factors have substantial biological effects on watercourses (Clarke ,1996; Kleinman, 1990; Kuyucak, 2002; España et al., 2005). In Thailand, exploitation of gold from primary bedrock is practiced in several parts of the country since many centuries. At present, gold exploration has received more attention. Several potential gold areas have been re-investigated in Prachin Buri, Loei and Pichit Provinces. There are two active gold mines in Thailand, namely Chatree gold mine in Pichit Province and Phu TabFa in Loei Province. The Phu TabFa gold mine is operated since 2006. In 2013, acid mine drainage was spilled from a tailing pond of the mine and contaminated the Huai Lex stream which has led to high concentration of heavy metal contaminating even agriculture lands (Muenhoor, 2013). Arsenic (As) concentration in soil and edible snail (*Filopaludina martensi*) in Huai Lex stream exceeded the national standards (Pholweang & Keithmaleesatti, 2014).

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Benthic macroinvertebrates are aquatic organisms that are retained by mesh size equal or greater than 200-500 µm, they inhabit the bottom substrates of freshwater habitats for at least part of their life cycle (Rosenberg & Resh, 1993). The impact of acidic mine drainage on macroinvertebrates has been studied in many countries (Gerhardt et al., 2004; Gray & Delaney, 2010; Svitok et al., 2014; DeNicola & Stapleton, 2016). However, it has never been investigated in Thailand.

The objectives of the present study was to investigate the composition of the benthic macroinvertebrate assemblages in the streams contaminated with gold mine drainage in Loei Province and to examine the frequency of mouthpart deformity of chironomid larvae inhabiting contaminated streams.

MATERIALS AND METHODS

Study sites. Huai Lex is the first order stream adjacent to Phu Tab Fa gold mine. It is a tributary of the Huai Huay stream at Ban Kok Saton, Wang Sapung, Loei Province. Three study sites were selected. The first site (site 1) is located in Huai Lex downstream of the gold mine at 17º22' 0.52"N 101º40'15.68"E, at an altitude of 311m above sea level where it passes through rubber plantation. Its stream bed was covered with thick precipitations of metal hydroxides which turned water and sediment to rust color (Fig. 1). The second site (site 2) is located around 600m downstream of site 1 where the stream passes through rice and soy bean fields before upstream of the confluence with the Huai Huay stream. The substrates of this site were a mixture of gravel and sand, precipitation of metal hydroxide still occurred in this site but it was much less than in site 1. The third sampling site (site 3) is located at 17°21'45.44"N 101°40'5.75"E, 264m above sea level. It was just downstream of confluence of Huai Lex and Huai Huay. Due to a small weir downstream, this site was wider, deeper and the water current was much slower compared to the two upstream sites. The site was additionally characterized by the presence of aquatic macrophytes such as *Hydrilla*, *Colocasia*, *Ipomoea* and *Lemna* in the water channel. During rainy season Huai Huay received water from Huei Lex that caused flooding over the rice field and crop land. Concentrations of cyanide (CN), lead (Pb), mercury (Hg) and As in the water and soil from three studied sites as measured in 2013 are presented in Table 1 (Muenhor, 2013).

Benthic macroinvertebrates sampling. Benthic macroinvertebrates were randomly sampled by using a D frame aquatic net in February 2016. At each sampling site, twenty sweeps were applied along a distance of 50 m. The samples were stored in plastic containers and preserved in 70% ethanol. Benthic macroinvertebrates were identified at least to the genus level using keys of Dudgeon (1999), Sangpradub and Boonsoong (2006) and Yule et al. (2004). Permanent slides of chironomid larvae were prepared following the method of Epler (2011) and were identified to genus level using taxonomic keys cited in Cranston and Dimitriadis (2004) and Cranston (2007). The deformities of the mouth parts in Chironomidae were investigated in each chironomid specimen following Warwick and Tisdale (1988), Warwick (1991), Bird et al. (1995) and Vermeulen (1995). Chironomid mouthpart deformities were identified using an Olympus CH-30 (Japan) standard light microscope at low magnifications (10-40x). The following deformity types were considered as abnormal: missing teeth, extra teeth, fush teeth, Köhn gap, reduced and asymmetric teeth.

Results and Discussion

From the present study, 12 orders and 37 families of benthic macroinvertebrates were identified. Total taxa richness and relative abundance of benthic macroinvertebrates were the lowest in site 1 (9 families, 150 individuals) and higher in site 2 (16 families, 360 individuals) and site 3 (27 families, 547 individuals), respectively (Table 2). Fifteen to 19 orders and 70 to 113 families of benthic macroinvertebrates were reported in undisturbed headwater streams, northeast Thailand (Boonsoong & Sangpradub, 2008; Getwongsa & Sangpradub, 2008 and Uttarak, et al., 2011). Alderfly larvae *Sialis* (O. Megaloptera) was abundant in site 1 where contained 49% of individuals, followed by dipteran larvae (O. Diptera 26%), Gastropoda (15%) and lampyrid larvae (O. Coleoptera 10%), respectively. Diptera (71%) was dominant in site 2 especially F. Chironomidae (55%) and followed by Odonata (16%) and Ephemeroptera (6%), respectively. In site 3, Coleoptera (32%) was dominant, and followed by Ephemeroptera (24%), Decapoda (20%) and Diptera (11%), respectively (Fig. 2). These findings differ from undisturbed streams where Trichoptera, Ephemeroptera and Diptera were usually the three most diverse and abundant orders. The low diversity of benthic macroinvertebrates in site 1 may reflect a response to the toxicity in this site. Based on the measurement of CN and As concentration by Muenhoor (2013), site 1 had a higher concentration of heavy metal in water and soil than those of site 2 and site 3. CN and As in water of all sites exceed the national surface water quality standard as well as As exceeds those limits for soil at all sites. *Sialis* larvae were also found more abundant in site 1, suggesting that *Sialis* larvae were able to tolerate acid mine drainage in a higher extent, which is also supported by the study of Tomkiewicz and Dunson (1977). Moreover, other taxa found in site 1 had tolerance value range from 6-8 (Resh et al., 1996). Ephemeroptera and Trichoptera occurred only in sites 2 and 3. They are sensitive macroinvertebrates which usually inhabit the less impaired sites. However, it was reported that some trichopterans can also tolerate heavy metal in streams up to a certain extent (Malmquist & Hoffsten, 1999) and Caenidae (Ephemeroptera) are also somewhat tolerant (Chessmann & McEvoy, 1998). The results of this study suggest that acid mine drainage affected the benthic macroinvertebrate assemblages in term of taxa richness and abundance. This is in line with findings of Solà et al. (2004), Battaglia et al. (2005) and Gray and Delaney (2010).

Chironomids were dominant in site 2, but only a few chironomids were found in site 1. In the undisturbed Phong River, Loei Province, 18 genera of chironomids were found (Sriariyanuwath & Sangpradub, 2015). It was interesting that the deformed mouthparts of chironomids were found only in site 2 with 17% of deformity (Fig. 3), which is higher than a proposed threshold of 8% indicating disturbance (Nazarova et al., 2004). This result was supported by many researchers who found that sublethal concentrations of heavy metals such as cadmium (Cd), copper (Cu), Pb and zinc (Zn) as well as some endocrine-disrupting chemicals could induce deformities of chironomid mouthparts in the laboratory (Meregalli & Ollevier, 2001; Meregalli et al., 2001; Vermeulen et al., 2000; Martinez et al., 2001; Watts et al., 2003). According to (Niyogi et al., 2013), it was found that leaf and wood breakdown was slower in sites with metal hydroxide precipitation.

Furthermore, the observed effects of mining can impact human health and the local economy. The deformity of chironomids may be used to detect early warning responses of heavy metal contaminated from the mine processing. These results are a preliminary approach on gold mine drainage contaminated streams and its effect on benthic macroinvertebrates. However, further studies extending the sampling size and incorporating replicates and uncontaminated streams for comparison are required.

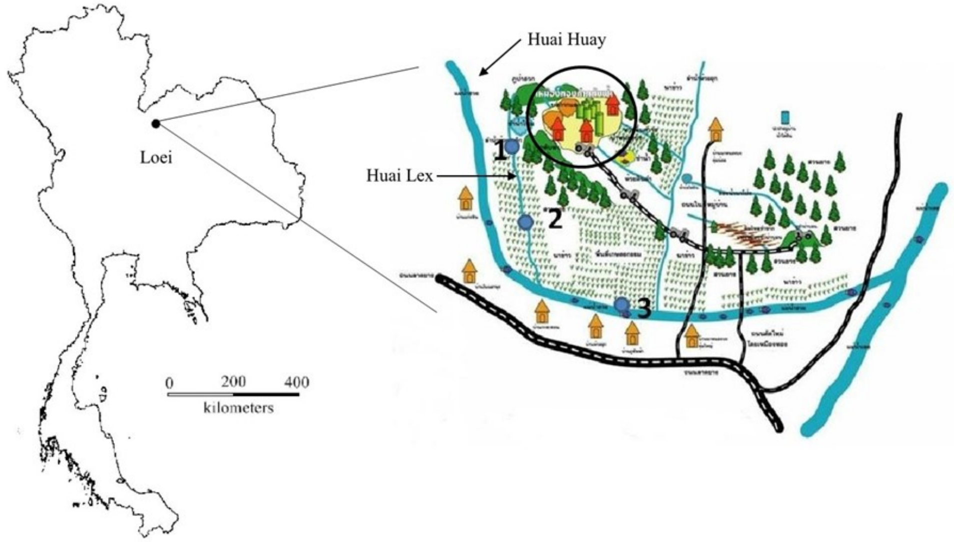

Fig. 1: Location of sampling sites in Huai Lex (sites 1 and 2) and Huai Huay (site 3).

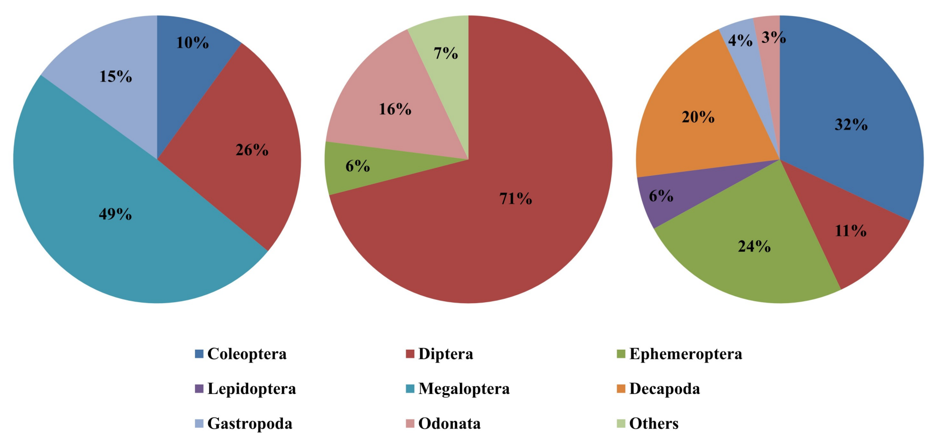

Fig. 2: Taxonomic composition of benthic macroinvertebrate abundances in each sampling site (left: site 1, center: site 2, right: site 3)

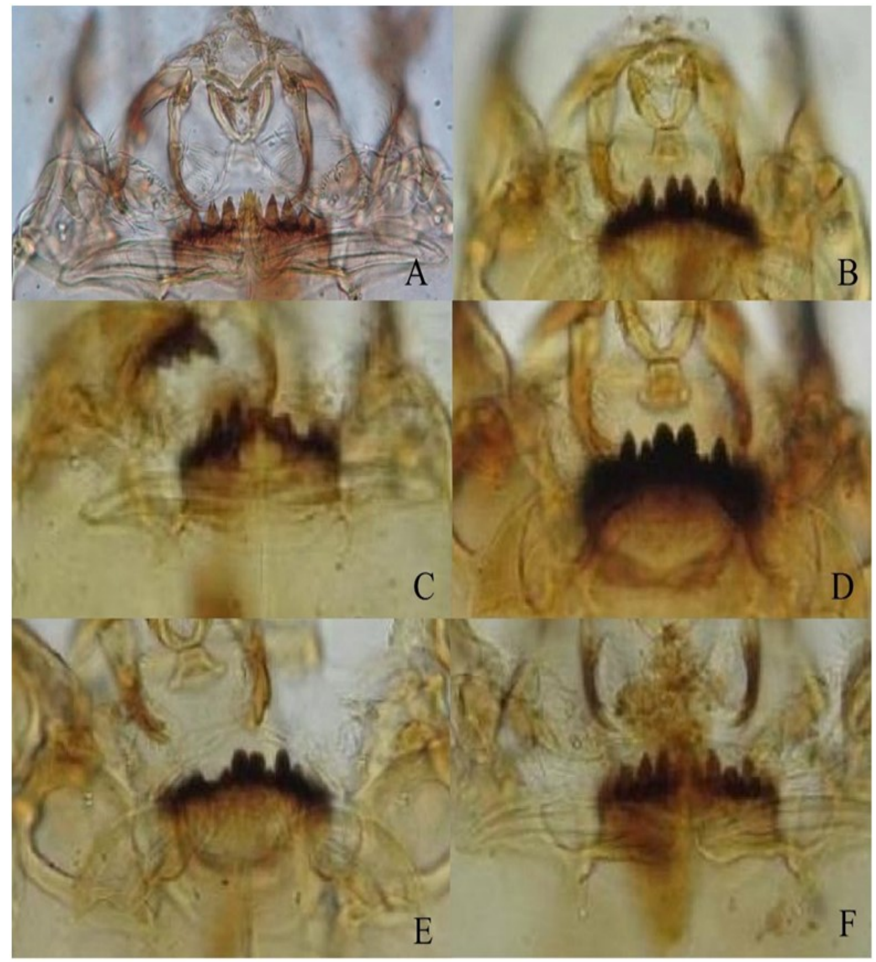

Fig. 3: Normal (A-B) and deformed (C-F) mouthparts of chironomids larvae

Table 1. Heavy metal concentrations in water and soil at the studied sites in 2013 (original data taken from Muenhoor (2013)).

Heavy Metal	Site1		Site 2		Site 3		National standard	
	Water	Soil	Water	Soil	Water	Soil	Surface water quality type 2 (mg/l)	Soil for agriculture and resident (mg/k)
CN	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.005	35
Pb	0.003	17.98	0.001	18.62	0.002	21.93	0.05	750
Hg	0.001	0.554	0.001	0.34	0.002	0.34	0.002	610
As	0.176	48.428	0.181	23.01	0.149	23.60	0.01	3.9

Table 2: Taxa and number of individuals of benthic macroinvertebrates in sampling sites, number of deformed chironomids. Showed in parentheses.

Order	Family/subfamily	Taxon	Site 1	Site 2	Site 3
Pulmonata	Lymnaeidae	*Radix rubiginosa*	7	0	17
Mesogastropoda	Bithynidae	*Wattebledia crosseana*	2	3	0
Mesogastropoda	Bithynidae	*Bithynia siamensis*	2	3	0
Mesogastropoda	Planorbidae	*Helicorbis umbicalis*	12	0	0
Neogastropoda	Buccidae	*Clea helena*	0	0	4
Decapoda	Atyidae	*Caridina*	0	0	108
Collembola		Taxon 1	0	0	1
Coleoptera	Dytiscidae	*Laccophilus*	0	0	11
Coleoptera	Elmidae	Tribe Elmidini	0	0	1
Coleoptera	Hydrophilidae	*Allocotocerus*	0	0	1
Coleoptera	Hydrophilidae	*Helochares* sp.1	0	0	6
Coleoptera	Hydrophilidae	*Helochares* sp.2	0	1	4
Coleoptera	Hydrobiinae	Taxon 2	0	0	6
Coleoptera	Lampyridae	Taxon 3	15	0	0
Coleoptera	Psephenidae	*Eubrianax*	0	0	8
Coleoptera	Scirtidae	Taxon 4	0	0	140
Coleoptera	Staphylinidae	Taxon 5	0	2	0
Diptera	Ceratopogonidae	Taxon 6	12	1	0
Diptera	Ceratopogonidae	*Bezzia*	22	3	0
Diptera	Culicidae	*Culex*	1	50	4
Diptera	Ephydridae	*Brachydeutera*	0	0	1
Diptera	Sarcophagidae	Taxon 7	0	0	3
Diptera	Stratiomyidae	*Odontomyia*	0	3	0
Diptera	Tabanidae	Taxon 8	0	0	1
Diptera	Tipulidae	Taxon 9	1	0	0
Diptera	Chironominae	*Cladotanytarsus*	0	1	0
Diptera	Chironominae	*Chironomus*	0	1	0
Diptera	Chironominae	*Conochironomus*	0	6(3)	0
Diptera	Chironominae	Taxon 10	0	1	0
Diptera	Chironominae	*Polypedilum* sp.1	0	9(5)	0
Diptera	Chironominae	*Polypedilum* sp.2	0	4	0

Cont'd Table 2.

Order	Family/subfamily	Genus/Species	Site 1	Site 2	Site 3
Diptera	Chironominae	*Polypedilum* sp.3	1	14(11)	48
Diptera	Chironominae	*Dicrotendipes*	0	2	0
Diptera	Chironominae	*Stictochironomus*	0	2	0
Diptera	Chironominae	*Kiefferulus*	0	0	2
Diptera	Chironominae	*Tanytarsus*	0	65(7)	0
Diptera	Chironominae	*Paratanytarsus*	0	5(2)	0
Diptera	Chironominae	*Rheotanytarsus*	0	13(1)	0
Diptera	Tanypodinae	Taxon 11	2	11	1
Diptera	Tanypodinae	*Tanypus*	0	23(3)	0
Diptera	Tanypodinae	*Procladius*	0	14	0
Diptera	Tanypodinae	*Clinotanypus*	0	8	1
Diptera	Tanypodinae	*Ablabesmyia*	0	1	0
Diptera	Orthocladinae	*Parapsectrocladius*	0	19(3)	0
Ephemeroptera	Baetidae	*Cloeon*	0	17	131
Ephemeroptera	Caenidae	*Caenis*	0	5	0
Ephemeroptera	Polymitarcyidae	*Povilla*	0	0	1
Hemiptera	Hydrometridae	*Hydrometra*	0	0	1
Hemiptera	Mesoveliidae	*Mesovelia*	0	0	1
Hemiptera	Micronectidae	*Micronecta*	0	3	0
Hemiptera	Naucoridae	*Naucoris*	0	0	2
Hemiptera	Veliidae	*Pseudovelia*	0	0	1
Lepidoptera	Crambidae	*Elophila*	0	0	30
Megaloptera	Sialidae	*Sialis*	73	8	2
Odonata	Coenagrionidae	Taxon 12	0	6	3
Odonata	Gomphidae	*Microgomphus*	0	32	2
Odonata	Libellulidae	Taxon 13	0	0	2
Odonata	Macromiidae	*Macromia*	0	0	1
Odonata	Platycnemididae	Taxon 14	0	21	2
Trichoptera	Calamoceratidae	*Anisocentropus*	0	2	0
Trichoptera	Hydroptilidae	*Oxyethira*	0	1	0
Total Family			**9**	**16**	**27**
Total individuals			**150**	**360**	**547**

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