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The diversity of aquatic insects surrounding the gold mining areas of Central Sulawesi and their relation with mercury levels and water quality

Keanekaragaman serangga air disekitar area tambang emas dan hubungannya dengan kadar merkuri dan kualitas air

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ABSTRACT

Human activities may influence the diversity of aquatic insects in rivers. This study aims to assess the diversity of aquatic insects and their relation with mercury levels and water quality along rivers located near the gold mine in Poboya, Central Sulawesi. The insects were collected at six locations based on human activity levels. At each site, the mercury level of water was measured using atomic absorption spectrophotometry (AAS). In addition, water temperature, acidity, dissolved oxygen, and total dissolved solids were determined. The study recorded 23 species of aquatic insects belonging to 7 orders and 14 families. Mercury levels in the rivers did not exceed the threshold except at two sites and did not affect aquatic insects' diversity. The diversity of aquatic insects, however, tends to decrease downstream. The diversity of aquatic insects, particularly the Ephemeroptera, Plecoptera, and Trichoptera orders, tended to be higher at the higher dissolved oxygen sites.

Key words: Ephemeroptera, Plecoptera, aquatic insect, water pollution

ABSTRAK

Aktivitas manusia dapat mempengaruhi keanekaragaman serangga air di sungai. Penelitian ini bertujuan untuk mengkaji keragaman serangga air dan hubungannya dengan kadar merkuri dan kualitas air di sepanjang sungai di sekitar tambang emas di Poboya, Sulawesi Tengah. Pengumpulan serangga dilakukan di enam lokasi berdasarkan tingkat aktivitas manusia dan jarak ke lokasi tambang emas. Di setiap lokasi, kadar merkuri air diukur menggunakan metode spektrofotometri serapan atom (AAS). Selain itu, diukur juga suhu air, keasaman, oksigen terlarut, dan total padatan terlarut. Sebanyak 23 spesies serangga air yang termasuk dalam 7 ordo dan 14 famili ditemukan selama studi. Kadar merkuri dalam air sungai tidak melebihi ambang batas, kecuali pada dua lokasi dan tidak mempengaruhi keanekaragaman serangga air. Namun, keanekaragaman serangga air cenderung menurun di hilir. Keanekaragaman serangga air khususnya Ordo Ephemeroptera, Plecoptera, dan Trichoptera cenderung lebih tinggi pada lokasi dengan kadar oksigen terlarut dalam air yang lebih tinggi.

Kata kunci: Ephemeroptera, Plecoptera, serangga air, polusi air

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INTRODUCTION

One of Indonesia's local gold mines is located in Poboya, about 7 km east of Palu, the capital city of Central Sulawesi. Poboya is a village with hilly topography and mountain slopes and is traversed by the Poboya watershed with moderate rainfall of 1,500 mm/year (Ruslan & Khairuddin 2010). Initially, this area was a shallot farming area. However, since the discovery of gold deposits around 2009, this area has been transformed into an illegal community gold mining. Since then, the farmers in this area have changed their professions as traditional gold miners. Currently, traditional gold mining activities have decreased and been replaced by a company called PT Citra Palu Minerals (CPM).

During the traditional gold mining in Poboya, they used mercury in amalgamation and disposing of waste containing mercury directly into the water stream. Subsequently, it causes mercury pollution in the river (Purnawan et al. 2013). Poboya gold mine is a concern because it is a buffer zone for the city of Palu and used to be a source of clean water for Palu residents. Human activities in exploiting natural resources along streams or around rivers can harm the environment because they can affect the water's physical, chemical, and biological conditions (Edegbene et al. 2015). Mercury contamination of river water impacts the diversity, abundance, and distribution of aquatic insects.

Research on the diversity of aquatic insects has been widely studied. However, studies on the effects of gold mining activities on aquatic insect diversity are rarely reported. This study is vital since aquatic insects are one of the components that determine the stability of aquatic ecosystems (Rasdi et al. 2012) as predators, decomposers, energy sources for other predators in the food chain (Takhelmayum & Gupta 2015), as well as bio-indicators of water quality (Chakona et al. 2009; Ferianto 2012; Prommi & Payakka 2015). This study aims to determine the composition, distribution, and abundance of aquatic insects in the river around the Poboya gold mine.

MATERIALS AND METHODS

Study sites

The research was carried out along the Pondo River which flows near the Poboya gold mine, Palu, Central Sulawesi, Indonesia and subsequently passes through the Poboya urban village and Palu city from the east (Figure 1). During small-scale traditional gold mining in Poboya, the river was

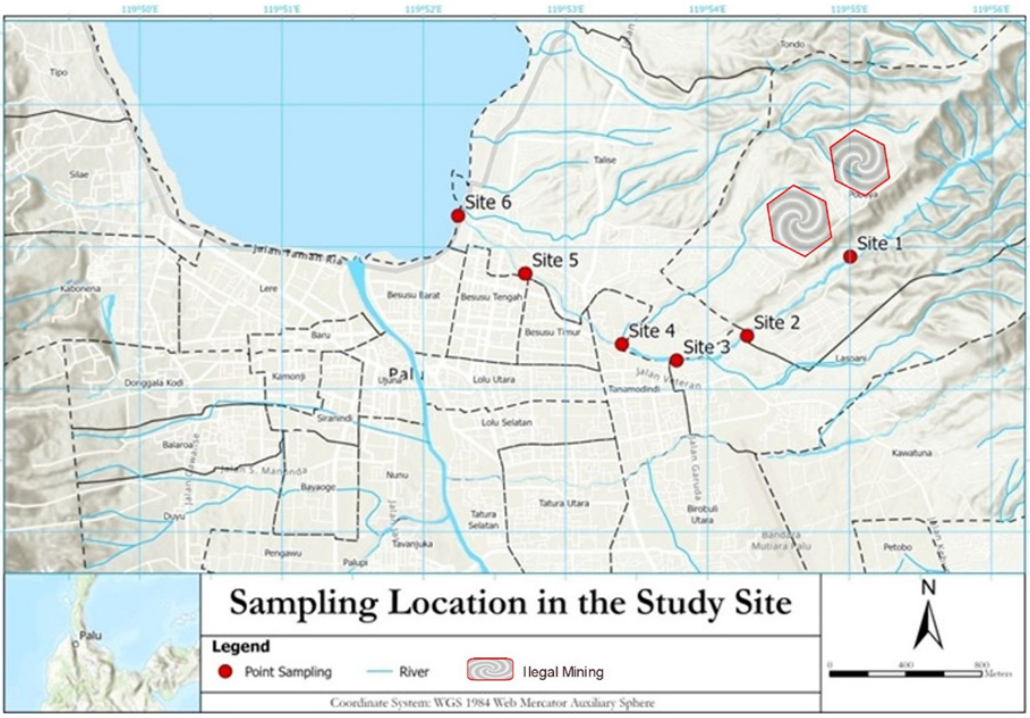

Figure 1. Map of the study area.

Table 1. Description of sampling sites

Location	Long; Lat	Water height (m)	Altitude (m asl)	Description
Site 1	00°53'13.8" 119°54'13.8"	0.3	146	Human activity is low. There are traditional gold panners doing panning activities.
Site 2	00°53'21.4" 119°53'21.4"	0.2	116	At this site, trucks collect water for the gold processing factory (tromol).
Site 3	00°53'47.6" 119°53'47.0"	0.2	81	No human activity at this site.
Site 4	00°53'30.4" 119°53'25.4"	0.5	63	There are human activity waste and sand mining activities at this site.
Site 5	00°53'11.0" 119°52'43.0"	0.7	29	There is garbage disposal activity at this site.
Site 6	00°52'46.7" 119°52'14.8"	0.6	10	There is garbage disposal activity at this site.

a waste disposal site from the gold amalgamation process. Now that illegal mining no longer occurs except at site 1 (Table 1), the river is used for the daily needs of local people and surrounding agriculture. Water samples were collected at six sites located (Table 1 and Figure 1).

Measurement of mercury levels and water quality

Measurement of water mercury levels was carried out in the laboratory of Balai Besar Industri Hasil Perkebunan (BBIHP) Makassar with SNI 6989 78.2011 by using atomic absorption spectrophotometry (AAS). Water temperature, water acidity, dissolved oxygen, and total dissolved solids were measured using a water checker (HORIBA-U-50 Series).

Aquatic insect sampling and identification

Aquatic insects were collected from the stream near the gold mining areas from September 2017 until Mei 2018. They were collected three times following Subramanian & Sivaramakrishnan (2007a). The insects were sampled using a 25 cm × 40 cm Surber sampler equipped with a collecting net. The Surber net was placed in the middle of the river facing the direction of the water current, then sediment and rock in the area of the plot are dredged into the Surber. All insects in the Surber net were taken using a brush and tweezers and then put into a microtube containing 70% alcohol. All samples of aquatic insects obtained were taken to the laboratory for identification by using available aquatic insect identification keys (Subramanian & Sivaramakrishnan 2007b). Unidentified samples were recorded at the morphospecies level.

Data analysis

The Shannon-Wiener index and canonical correspondence analyses (CCA) were used to measure the diversity of aquatic insects and its relationship with mercury levels and water quality, respectively (Hammer et al. 2001).

RESULTS

Diversity of aquatic insects around the Poboya gold mine

The study recorded 23 species of aquatic insects belonging to 7 orders and 14 families. The highest species number and diversity were recorded at site 1 and, moving downstream from site 1 to site 6, both tended to decrease. The composition and abundance of aquatic insects at each site are quite different (Table 2). Ephemeroptera Order is a group that has the largest number of species (8 species) which is included in 3 families, where the Batidae Family dominates with five species. Two of them were found at all sites, while five other species were only found at sites 1 through 5. Plecoptera Order was recorded at site 1. Trichoptera order had five species and was found scattered at stations 1, 2, and 3. Odonata larvae were also found in this study, although the numbers were relatively small. Hemiptera orders were also collected and dominate

Table 2. Diversity of aquatic insects at each site

Orde Family	Species	Sampling site 1	2	3	4	5	6	Total
Ephemeroptera								
Baetidae	*Baetis rhodani*	57	19	96	9	4	0	181
	Baetis sp.1	107	67	79	40	0	0	307
	Baetis sp.2	57	21	33	51	14	0	215
	Acentrella sp.	121	36	68	20	53	4	277
	Centroptilum sp.	29	51	25	34	28	24	215
Heptageniidae	*Heptogenia* sp.	107	49	64	2	52	0	222
	Ecdyonurus sp.	13	27	79	0	0	0	119
Caenidae	*Caenis* sp.	49	25	66	7	0	0	147
Plecoptera								
Capniidae	*Allocap* sp.	57	0	0	0	0	0	57
Trichoptera								
Hydropsychidae	*Hydropsy* sp.1	237	60	0	0	0	0	297
	Hydropsy sp.2	63	9	0	0	0	0	72
	Diplectrona sp.	144	90	36	0	0	0	270
	Chimarra sp.	227	126	75	0	0	0	428
Polycentropodidae	*Polycenthropus* sp.	60	59	54	0	0	0	173
Odonata								
Macromiidae	*Macromia* sp.	47	24	38	45	0	2	168
Hemiptera								
Veliidae	*Rhagovelia* sp.	208	147	179	51	12	0	585
Gerridae	*Gerridae* sp.	57	36	55	0	0	0	148
Coleoptera								
Hydrophilidae	Hydrophilidae sp.1	104	61	90	61	26	0	342
Dytiscidae	*Neoporus* sp.	64	28	69	15	2	0	178
Diptera								
Simuliidae	Simuliidae sp.1	0	0	0	60	50	43	153
Culicidae	*Culiseta* sp.	0	0	0	96	62	116	274
Chironomidae	Chironomidae sp.1	0	0	0	37	75	71	183
	Chironomidae sp.2	0	0	0	102	62	74	238
Total number of individu		1,808	935	1,106	630	436	334	5,249
Total number of species		19	18	16	15	12	7	
Shannon-Wiener (H') index		2.68	2.42	2.55	2.15	2.01	1.37	

by *Rhagovelia* sp. The Diptera species were found at stations 4–6, but not collected at stations 1–3.

Relationship between mercury levels and water quality on the diversity of aquatic insects

The mercury levels and water quality at all sampling stations were varied (Table 3). Mercury concentration was around 0.0004–0.0008 ppm except at sites 2 and 5 which reached 0.0032 and 0.003 ppm, respectively. In general, this mercury level is still lower than the threshold level i.e. 0.001 ppm according to the regulations of The Ministry of Healthy Republic of Indonesia Number 82/2001. However, the mercury concentration at sites 2 and 5 exceeded the threshold levels. The multidimensional scaling analysis results using canonical correspondence analysis (CCA) showing that among variable measured, the presences aquatic insects particularly Ephemeroptera, Plecoptera, and Trichoptera (EPT) species was highly correlated with the dissolved oxygen. While the presence of Chironomids was mainly related with the dissolved solid. Interestingly, mercury levels were not correlated with the diversity of aquatic insects (Figure 2).

DISCUSSION

The study found 23 species of aquatic insects in the river around the mining area in Poboya, Central Sulawesi. The insect diversity at all survey sites tended to decrease moving down river, except for the Diptera Order. Several studies have also reported a decrease in the diversity and abundance of aquatic insects at a distance closer to the river mouth (Candra et al. 2014; Leba et al. 2013; Maramis & Makal 2011). These results are thought to be related to habitat conditions at each location. The rocky and fast-flowing habitat at location 1 is an ideal place for aquatic insects to live. According to Voshell (2009), although aquatic insects can live and adapt to various aquatic habitats, in rocky and swift rivers, aquatic insects can be found with a high number of species and abundance. The nature of the sub-extracts on the riverbed, undisturbed

Table 3. Mercury level and water quality at each site

Sites	Measured variables*				
	Mercury (ppm)	Water temperature (^{o}C)	Water pH	DO (mg/l)	TDS (g/l)
I	0.0004	26.71	5.75	1.14	0.216
II	0.0032	29.71	6.97	0.07	0.231
III	0.0003	31.55	7.21	0.10	0.233
IV	0.0008	30.53	7.27	0.09	0.267
V	0.0034	31.43	7.31	0.07	0.728
VI	0.0014	32.79	6.37	0.05	0.664

*DO: dissolved oksigen; TDS: total dissolved solid.

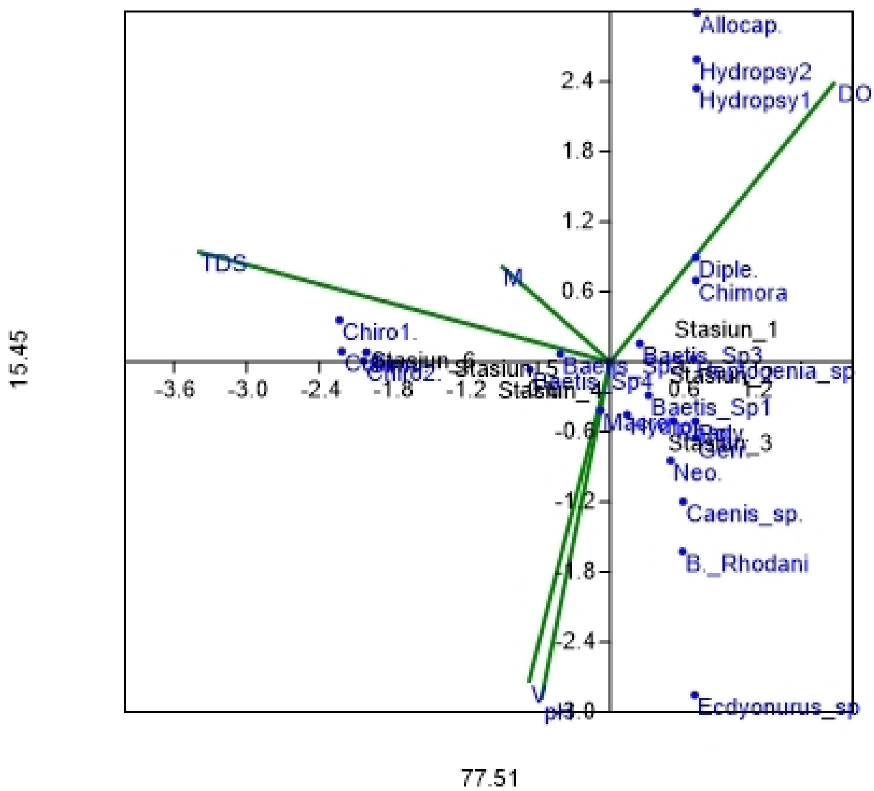

Figure 2. Canonical correspondence (CCA) depicting the effect of various physical and chemical environmental factors on the diversity of aquatic insects (M: mercury; DO: dissolved oxygen; pH: water acidity; TDS: total dissolved solids.

habitat, and clean canopy are also breeding grounds for aquatic insects (Rasdi et al. 2012; Arimoro & Ikomi 2009).

Ephemeroptera was the most diverse and abundant order of aquatic insects recorded in this study, while Plecoptera was the minor group. At the global scale, there are 3000 species of Ephemeroptera, which belong to 400 genera and 42 families (Barber-James et al. 2008). In Turkey, for example, 14 families, 39 genera, 138 species, and five subspecies were reported (Girgin et al. 2010).

Ephemeroptera, Plecoptera, and Trichoptera, commonly abbreviated as EPT, are essential aquatic insect grouping that is very sensitive to changes in the aquatic environment. Therefore, EPT is often used as a bioindicator to study the habitat and water quality of aquatic ecosystems (Rosenberg & Resh 1993). The presence of EPT indicates a habitat has not been heavily polluted (Chun et al. 2017). These groups of insects prefer clear, unpolluted fast flowing streams and are sensitive to water pollution (Subramanian & Sivaramakrishnan 2007a).

In this study, mercury levels were much lower compared to those of previous studies. Purnawan et al. 2013 reported that the river around the Poboya gold mine was contaminated with mercury, exceeding the tolerance threshold, which was around 0.0103–0.183 mg/kg. The decrease in mercury levels in river water after a long time is because there is no gold processing activity that discharges the remaining tailings in the river and also because basically, the solubility of mercury in water is low (Adlim 2016) or in the aquatic environment, metal mercury quickly becomes a gaseous form (Amyot et al. 2005). According to Clever et al. (1985), the solubility of mercury in water is very small. For example, if 1 ton of mercury is thrown into fresh water, only 0.06 g is dissolved. Also, in fast-flowing water, the concentration of mercury is diluted. These features may explain what is happening in the waters of the Poboya River.

In contrast, if mercury enters seawater, it binds to chlorine in the seawater to form organic mercury HgCl bonds. As HgCl, mercury easily enters plankton and moves to other biotas, and accumulates in a food chain (Amyot et al. 2005). In water or sediment, mercury can also become methyl mercury compounds by bacterial activity. Methylmercury is particularly dangerous because it dissolves in fat to accumulate in organisms of various tropic levels. The higher the tropic level in the food chain, the higher the mercury content in the body (Carrasco et al. 2011).

The CCA analysis results showed no effect of the mercury content in the water on the presence of aquatic insects. This is probably related to the low content of the mercury at our study sites with levels that do not differ significantly among sites. However, some previous studies showed that mercury contamination in water due to small-scale community gold mining activities affects the abundance, species richness, and diversity of aquatic insects, especially Ephemeroptera, Plecoptera, and Trichoptera (Chula et al. 2013; Mudyazhezha & Kanhukamwe 2014).

Dissolved oxygen is also known as an environmental factor that influences the presence of EPT (CCA analysis results show that dissolved oxygen levels affect EPT insects). Aquatic insects can be used as an indicator of the quality of a water. Ephemeroptera, Plecoptera, and Trichoptera (EPT) are often found in clean waters and very sensitive to changes in water physics and chemistry (Chun et al. 2017). Apart from the metal content in water, several other environmental factors such as temperature, pH, dissolved oxygen, electrical conductivity, turbidity, sulfate, nitrate -nitrogen, orthophosphate, ammonia-nitrogen, and alkalinity in water also influence the presence of aquatic insects (Prommi et al. 2014). The presence and composition of aquatic macroinvertebrates can also be influenced by human anthropological activities (Malmqvist 2002; Heino 2013; Márquez-García et al. 2009) as these activities can damage the physical and/or chemical environment (Pallottini et al. 2015; Castro et al. 2018; Malmqvist 2002).

CONCLUSION

The study conducted at the river around the Poboya gold mine in Central Sulawesi found 23 species of aquatic insects belonging to 7 orders and 14 families. Ephemeroptera, totaling 32%, dominated the family numbers and abundance of aquatic insects and were recorded at all sites.

These studies also confirmed that mercury levels are still below the threshold and therefore have no relation with aquatic insects' diversity. The dissolved oxygen correlated with the presence and abundance of Ephemeroptera, Plecoptera, and Trichoptera while dissolved solids were associated with Chironomus.

REFERENCES

Adlim M. 2016. Pencemaran merkuri di perairan dan karakteristiknya: Suatu kajian kepustakaan ringkas. *Depik* 5:33–40. DOI: https://doi.org/10.13170/depik.5.1.3968.

Amyot M, Morel FMM, Ariya PA. 2005. Dark oxidation of dissolved and liquid elemental mercury in aquatic environments. *Environmental Science and Technology* 39:110–114. DOI: https://doi.org/10.1021/es035444k.

Arimoro, Francis O, Robert B, Ikomi. 2009. Ecological integrity of upper warri river, niger delta using aquatic insects as bioindicators. *Ecological Indicators* 9:455–61. DOI: https://doi.org/10.1016/j.ecolind.2008.06.006.

Barber-James HM, Gattolliat JL, Sartori M, Hubbard MD. 2008. Global diversity of mayflies (Ephemeroptera, Insecta) in freshwater. *Hydrobiologia* 595:339–350. DOI: https://doi.org/10.1007/s10750-007-9028-y.

Candra Y, Langoy M, Koneri R, Singkoh MFO. 2014. Kelimpahan serangga air di Sungai Toraut Sulawesi Utara. *Jurnal MIPA* 3:74–78. DOI: https://doi.org/10.35799/jm.3.2.2014.5317.

Carrasco L, Barata C, García-Berthou E. Tobias A, Bayona JM, Díez S. 2011. Patterns of mercury and methylmercury bioaccumulation in fish species downstream of a long-term mercury-contaminated site in the lower Ebro River (NE Spain). *Chemosphere* 84:1642–1649. DOI: https://doi.org/10.1016/j.chemosphere.2011.05.022.

Castro DMP, de Sylvain, Callisto M. 2018. Land cover disturbance homogenizes aquatic insect functional structure in neotropical savanna streams. *Ecological Indicators* 84:573–82. DOI: https://doi.org/10.1016/j.ecolind.2017.09.030.

Chakona A, Phiri C, Day JA. 2009. Potential for Trichoptera communities as biological indicators of morphological degradation in riverine systems. *Hydrobiologia* 621:155–167. DOI: https://doi.org/10.1007/s10750-008-9638-z.

Chula PM, Rutebuka E, Yanez PLS. 2013. The effect of illegal small-scale gold mining on stream macro-invertebrate assemblages in the East Usambara Mountains. In: *Conference: Tropical Biology Association*, *(Tanzania, August 2013).* Tanzania: Tropical Biology Association. DOI: https://doi.org/10.13140/RG.2.1.1617.5124.

Chun SP, Jun YC, Kim HG, Lee WK, Kim MC, Chun SH, Jung SE. 2017. Analysis and prediction of the spatial distribution of EPT (Ephemeroptera, Plecoptera, and Trichoptera) assemblages in the Han River watershed in Korea. *Journal of Asia-Pacific Entomology* 20:613–625. DOI: https://doi.org/10.1016/j.aspen.2017.03.024.

Clever HL, Johnson SA, Derrick ME. 1985. The solubility of mercury and some sparingly soluble mercury salts in water and aqueous electrolyte solutions. *Journal of Physical and Chemical Reference Data* 14:631–680. DOI: https://doi.org/10.1063/1.555732.

Edegbene AO, Arimoro FO, Odoh O, Ogidiaka E. 2015. Effect of anthropogenicity on the composition and diversity of aquatic insects of a municipal river in North Central Nigeria. *Biosciences Research in Today's World* 1:55–66.

Ferianto HY. 2012. *Keanekaragaman Serangga Air Sebagai Penduga Kualitas Perairan Pada Sungai Maron Dan Sungai Sempur, Seloliman, Trawas, Mojokerto*. Skripsi. Surabaya: Universitas Airlangga.

Girgin S, Kazanci N, Dügel M. 2010. Relationship between aquatic insects and heavy metals in an urban stream using multivariate techniques. *International Journal of Environmental Science & Technology* 7:653–664. DOI: https://doi.org/10.1007/BF03326175.

Hammer Ø, Harper DAT, Ryan PD. 2001. PAST: Paleontological statistics software package for education and data analysis. *Palaeontologia Electronica* 4:1–9.

Heino J. 2013. The importance of metacommunity ecology for environmental assessment research in the freshwater realm. *Biological Reviews* 88:166–178. DOI: https://doi.org/10.1111/j.1469-185X.2012.00244.x.

Leba GV, Koneri R, Papu A. 2013. Keanekaragaman serangga air di Sungai Pajowa Kabupaten Minahasa, Sulawesi Utara. *Jurnal MIPA* 2:73–78. DOI: https://doi.org/10.35799/jm.2.2.2013.1990.

Malmqvist B. 2002. Aquatic invertebrates in riverine landscapes. *Freshwater Biology* 47:679–694. DOI: https://doi.org/10.1046/j.1365-2427.2002.00895.x.

Maramis RTD, Makal HVG. 2011. Air sebagai indikator biologis cemaran air pada DAS di

Lawongan. *Eugenia* 17:95–103. DOI: https://doi.org/10.35791/eug.17.2.2011.3529.

Márquez-García M. Vila I, Hinojosa LF, Méndez MA, Carvajal JL, Sabando MC. 2009. Distribution and seasonal fluctuations in the aquatic biodiversity of the southern Altiplano. *Limnologica* 39:314–18. DOI: https://doi.org/10.1016/j.limno.2009.06.007.

Mudyazhezha S, Kanhukamwe R. 2014. Environmental monitoring of the effects of conventional and artisanal gold mining on water quality in Ngwabalozi River, Southern Zimbabwe. *International Journal of Environmental Monitoring and Analysis* 2:123–127. DOI: https://doi.org/10.11648/j.ijema.20140202.20.

Pallottini M, Goretti E, Gaino E, Selvaggi R, Cappelletti D, Céréghino R. 2015. Invertebrate diversity in relation to chemical pollution in an Umbrian stream system (Italy). *Comptes Rendus-Biologies* 338:511–520. DOI: https://doi.org/10.1016/j.crvi.2015.04.006.

Prommi T, Payakka A. 2015. Aquatic insect biodiversity and water quality parameters of streams in Northern Thailand. *Sains Malaysiana* 44:707–717. DOI: https://doi.org/10.17576/jsm-2015-4405-10.

Prommi T-O, Laudee P, Chareonviriyaphap T. 2014. Biodiversity of adult Trichoptera and water quality variables in Streams, Northern Thailand. *APCBEE Procedia* 10:292–298. DOI: https://doi.org/10.1016/j.apcbee.2014.10.055.

Purnawan S, Sikanna R, Prismawiryanti. 2013. Distribusi logam merkuri pada sedimen laut di sekitar muara Sungai Poboya. *Nature Science* 2:18–24.

Rasdi MZ, Fauziah I, Ismail R, Hafezan MS, Fairuz K, Hazmi AD, Salmah CMR.2012. Diversity of aquatic insects in Keniam River National Park, Pahang, Malaysia. *Asian Journal of Agriculture and Rural Development* 2:312–328.

Rosenberg DM, Resh VH. 1993. *Freshwater Biomonitoring and Benthic Macroinvertebrates.* London: Chapman & Hall.

Ruslan, Khairuddin. 2010. Studi potensi pencemaran lingkungan dari kegiatan pertambangan emas rakyat Poboya Kota Palu. *Indonesia Chimica Acta* 3:27–31.

Subramanian KA, Sivaramakrishnan KG. 2007a. *Aquatic Insects for Biomonitoring Freshwater Ecosystems-A Methodology Manual*. Bangalore India: Asoka Trust for Research in Ecology and Environment (ATREE).

Subramanian KA, Sivaramakrishnan KG. 2007b. *Aquatic Insects of India-A fieldguide*. Bangalore India: Ashoka Trust for Research in Ecology and Environment (ATREE).

Takhelmayum K, Gupta S. 2015. Aquatic insect diversity of a protected area, Keibul Lamjao National Park in Manipur, North East India. *Journal of Asia-Pacific Entomology* 18: 335–341. DOI: https://doi.org/10.1016/j.aspen.2015.04.002.

Voshell Reese JJR. 2009. Sustaining Americas Aquatic Biodiversity Aquatic Insect Biodiversity and Conservation. Publication, Virginia Cooperative Extension. 420–531.