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Interaction of Organisms in Abandoned Tin Mining Pits: Perspective of Life in Acid Mine Drainage Environment

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ABSTRACT

Acid Mine Drainage (AMD) occurred after mining activity exposes metal sulfides to oxidizing conditions that impact acidic conditions with low pH values in the waters and heavy metals contamination. These conditions have also occurred in abandoned tin mining pits, one of places in Bangka Belitung Archipelago Province. This review aimed to elaborate information of micro- and macro-organism' life in acid mine drainage to be associated with the possibility of life in abandoned tin mining pits. Acidophilic and acidotolerant organisms such as bacterial, phyto- and zooplankton, and some macroorganisms including invertebrate or vertebrate like fishes and also water plants were found in these waters. Their presence developed a symbiosis interaction in aquatic environment. Phytoplankton was an autotroph organism, despite being considered an autotroph organism, many phytoplankton require exogenous organic cofactors and nutrients for their life. These cofactors were often served by heterotroph bacterial to sustain the growth of phytoplankton. Instead, bacterial obtained dissolved organic matter derived from phytoplankton to survive in the aquatic environment. Furthermore, phytoplankton was consumed by zooplankton; zooplankton and/or insect on the water surface were consumed by surface feeder or small fish to big fish in the waters. In addition, water plants also support the interaction of organisms in the water by supplying dissolved oxygen, also anorganic and organic material for their life. The symbiosis and quorum sensing played an important role in structuring the aquatic food web and creating a life in the acidic water-polluted heavy metal in biogeochemical cycle. This review only focused on the role of bacterial in biogeochemical cycles in the acid mining environment. Research or review of other biogeochemical mechanisms was needed to reveal the entire biogeochemical cycles in acid mining waters.



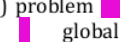


Keywords: acidic water, heavy metal, tin mining pit, biogeochemical, quorum sensing

ABSTRAK

Air Asam Tambang (AAT) terjadi setelah kegiatan penambangan yang mengekspose logam sulfida hingga kondisi oksidasi yang berdampak pada kondisi asam dengan nilai pH rendah di perairan dan kontaminasi logam berat. Kondisi ini juga terjadi pada kolong pascatambang timah yang terbengkalai, salah satunya di Provinsi Kepulauan Bangka Belitung. Review ini bertujuan untuk mengelaborasi informasi kehidupan mikro- dan makro-organisme di air asam tambang untuk dikaitkan dengan kemungkinan kehidupan yang terdapat di kolong pascatambang timah yang ditinggalkan tersebut. Organisme asidofilik dan asidotoleran seperti bakteri, fito- dan zooplankton, dan beberapa makroorganisme termasuk invertebrata atau vertebrata seperti ikan dan juga tumbuhan air ditemukan di perairan ini. Keberadaan organisme ini menghadirkan interaksi simbiosis di lingkungan perairan. Fitoplankton adalah organisme autotrof, meskipun dianggap organisme autotrof, banyak fitoplankton membutuhkan kofaktor organik eksogen dan nutrisi untuk hidupnya. Kofaktor ini sering disediakan oleh bakteri heterotrof untuk mempertahankan pertumbuhan fitoplankton. Sebagai gantinya, bakteri memperoleh bahan organik terlarut yang berasal dari fitoplankton untuk bertahan hidup di lingkungan perairan. Selanjutnya, fitoplankton dikonsumsi oleh zooplankton; zooplankton dan/atau serangga di permukaan air dikonsumsi oleh ikan kecil atau ikan pemakan di permukaan hingga ikan besar di perairan. Selain itu, tumbuhan air juga mendukung interaksi organisme di dalam air dengan menyediakan oksigen terlarut serta bahan anorganik dan organik untuk kehidupannya. Simbiosis dan komunikasi interseluler memainkan peran penting dalam strukturisasi jaring makanan di lingkungan akuatik dan menciptakan kehidupan di air asam yang terkontaminasi logam berat dalam siklus biogeokimia. Review ini hanya berfokus pada peranan bakteri di dalam siklus biogeokimia di dalam lingkungan perairan asam tambang. Penelitian atau review tentang mekanisme biogeokimia lainnya diperlukan untuk mengungkap keseluruhan siklus biogeokimia di perairan asam tambang.

Kata kunci: air asam, logam berat, kolong pascatambang timah, biogeokimia, quorum sensing

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1.   problem 
 global
 (Wang et al., 2021). Acid mine

drainage is a waste from industry or activity of mining (Kaur et al., 2018). Abandoned mines and mine wastes are often acidic, sometimes extremely so and they often contain high concentrations of metals and

possibly other heavy metals and also metalloids. This condition is also found on abandoned mining pits, include such as in Bangka Island and other producers of tin in the world.

Industrial waste and mining activities such as tin are one of the main sources of metal contamination (Guan et al., 2014; Kurniawan, 2016). The activity of tin mining produce metal contaminants (Daniel et al., 2014); Pb, Zn, Cr, Cu, and as in Bestari Jaya, Malaysia; and Fe, Pb, Cu, and Zn detected at tin mining sites in Bangka Island, Indonesia (Henny, 2011; Rosidah and Henny, 2012).

Other ecological changes can also be seen from the change in the acidity value (pH) of soil and water at the post-tin mining site. Characteristics of relatively acidic to neutral pH values (4.8-7.2) (Ashraf et al., 2013) and can be even lower than pH 4 as well as nutritional deficiencies and low dissolved oxygen values (Kurniawan, 2016). Tin mining activity in soil ecosystems leads to low ion exchange capacity, organic matter, total nitrogen, phosphorus availability, macro nutrients, and clay soil content (Oktavia et al., 2014). Mining activities cause ecological imbalances and damage, including physical, chemical, and biological changes within macro- and microecosystems (Ahmad, 2013; and).

Therefore, scientific literature related to AMD water, especially abandoned tin mining pits and its effects on organisms thriving in the heavy metal-contaminated and acidic water, their metabolism in the habitat, and their interactions on biogeochemical mechanism that support their life and succession in the environment. This review focused to role of bacterial in biogeochemical cycle in the acidic water of abandoned tin mining pits.

2. Perspective of Life in Environment

A.

Acid mine drainage (AMD) condition metal (Skuosen et al., 2000). The formation of AMD is a sequence of complex biogeochemical and mineral dissolution processes (Dold, 2014), characterized by acidic effluents with a high content of sulfide mineral and heavy metal ions in water (Pozo-Antonio et al. 2014). A number of sulfide minerals found in the waters acids Acid pH such as pyrite (FeS₂), chalcopyrite (CuFeS₂), galena (PbS), sphalerite ((Zn,Fe)S) (Celebi and Oncel, 2016). These minerals undergo oxidation to produce the final product in the form of H⁺ ions

and).

Many researches have shown that the exposed pyrite in al mining is the main cause of acid mine drainage.

general chemical that describes formation acid is equation. generally weathering that forms . Here is overview of the reactions (Gaikwad and Gupta 2007; Byrne et al. 2012):

$$(1)$$

pyrite involves produces per

$$+ (2)$$

oxidation process)

To convert

(Fe(II)) (Fe(III)) need mol

bacterial iron (II) (III).

and

) in the absence of bacterial,

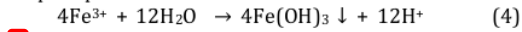
and is several orders of magnitude faster at pH values close to 5. This reaction is called "velocity". The "restriction steps" for overall acid production indicate the order.



(ferrous iron oxidation process)

Ferrous Iron + Oxygen + Acidity → Ferric Iron + Water

The third possible reaction is the hydrolysis of iron. Hydrolysis is a reaction that breaks down water molecules. As a by-product, three moles of acidity are produced. Many metals can be hydrolyzed. The formation of ferric hydroxide precipitates (solids) depends on pH. When the pH is above about 3.5, solids are formed, but below pH 3.5, the solids hardly or at all precipitate.



(ferric iron hydrolysis process)

(III) produced reactions

a periodic, that occurs quickly

entire exhausted.

an oxidizer,



oxidation process)

Equation describes about producing ferric iron as the primary oxidant of pyrite.

(Do 3 2014).

reactions to Cu^{2+} , Zn^{2+} , Ni^{2+} , Cr^{3+} , Pb^{2+} , and other elements in the mining environment cause an increase in the number of H^+ protons that are produced, contribute to an increase in environmental acidity conditions. The more H^+ ions in an environment, the the environment (and , 2007; increase in the value of H^+ also occurs in organic and inorganic materials such as ammonia and carbon dioxide. The acidity caused by the ammonium nitrification process takes place through the reaction of $NH_4^+ + 2O_2 \rightarrow NO_3^- + 2H^+ + H_2O$ and then dissolved nitrate (NO_3^-) (Goulding, 2016). The chemical interaction between carbon dioxide and water produces a weak acid through the reaction of $CO_2 + H_2O \rightarrow H_2CO_3$ and then carbonate ions (HCO_3^-) and protons (H^+) are formed (Stallinga, 2018).

The increase of H^+ ions water and disturbing aquatic organism's life. Increased acidity has a particularly harmful effect on organisms from their early life stages such as fish larvae, impact in their respiration and oxygen consumption, depressing effect on the growth rate and survival rate (Srineeetha et al., 2014; Ndubuisi et al., 2015) and also disturb on photosynthesis of water plants (Long et al., 2017). However, some organisms "extremophiles" can thrive under multiple extremes conditions (Merino et al., 2019).

B. Abandoned Tin Mining Pit in Bangka Belitung Archipelago Province

The existence of former mining pit-like a lake, particularly (in local language called kolong) presents a significant impact from abandoned mining activities (Kurniawan et al., 2020). Abandoned tin mining pits become a new ecological model for studying of biological life, metabolism, and organisms' interaction in this habitat, especially tin producers in the world such as Indonesia, Malaysia, and others. Some studies result information about this environment such as water quality (), heavy metal contamination (); Kurniawan, 2020), microorganism and molecular diversity (Sow et al., 2014a, 2014b), and also (Kurniawan , 2020; morphological view of some abandoned

pits in Bangka Island of Indonesia were shown in Figure 1.

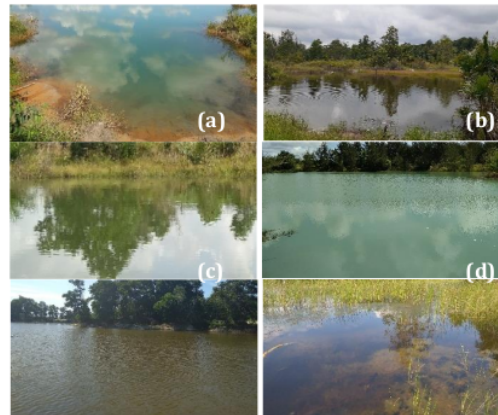


Figure 1 The morphological condition of abandoned tin mining pits in Bangka Island, Indonesia, (a) Station A (age < 13 years); (b) Station B (age 5-15 years); (c) Station C (age); (d) Station D (age); (e) Station E (age); and (f) Station F (age >) (Mustikasari et al., 2020)

Tin mining activities carried out on land in Bangka Belitung Island have led to the formation of pits by a spray mining method. This process is carried out through the stripping stage in the form of dismantling soil layers to a certain depth, spraying stages to disassemble or dissolve soil or rocks containing tin seeds so that they turn into mud, and washing stages to separate lead seeds from other materials through the deposition process (Harahap, 2016). Tin mining activity does not use chemicals, but elements or minerals such as Fe, Sn, Pb, Cu, and so on that cause changes in water quality and potential heavy metal pollutant residues (Kurniawan et al., 2019; Kurniawan and Mustikasari, 2019). The authors have found in the before research some elements, bacteria, and fishes in abandoned tin mining pits, resumed in Table 1.

Tin mining activity doesn't use chemical materials during the exploration process, but effect of mining activity is the elements contained . The consequence of pyrite and other sulfide oxidation can cause severe acidification of mine water, accelerate erosion of basins, promote heavy metal migration and threaten local ecosystems such as aquatic life and human health (Li et al., 2018). Authors observe onshore mining activity impact to ecological changes such as deforestation, biodiversity recuding, water flow damages, decrease of environmental stability, also macro- and microorganism structure alteration. Furthermore, for a long chronosequence, it may drive the changes of organisms' metabolism to survive in the environment.

Table 1. Information of [redacted]

Water Quality ^a	Elements ^b	Bacterials (Phylum) ^b	Fishes ^a
pH (3.71-7.09);	As;	Proteobacteria;	<i>Channa</i> sp.,
Temperature	Co;	Actinobacteria;	<i>Trichogaster</i> sp.,
(31.36-31.70 °C);	Cr;	Chloroflexi;	<i>Puntius</i> sp.,
DO (5.20-7.20 ppm);	Cu;	Firmicutes;	<i>Oreochromis</i> sp.,
COD (10.17-15.4 ppm);	Fe;	Acidobacteria;	<i>Gambusia</i> sp.,
TDS (38.93-98.25 ppm);	Ga;	Planctomycetes;	[redacted],
TSS (3.66-6.0 ppm);	Hf;	Bacteroidetes;	<i>Anabas</i> sp.,
Eh (0.01-0.18 V);	Mn;	Chlorobi;	<i>Betta</i> sp.,
Conductivity	Ni;	Cyanobacteria;	<i>Belontia</i> sp.,
(58.40-143.75 US.cm ⁻¹);	Pb;	Gemmatimonadetes;	<i>Brevibora</i> sp.,
Total Nitrogen	Sn;	Candidate of Phylum; Parcubacteria;	<i>Oryzias</i> sp.,
(0.02-0.069 ppm);	Ta;	Spirochaetes;	<i>Aplocheilichthys</i> sp.,
Total Phosphate	Te;	Thermi;	
(0.013-0.021 ppm)	Th;	Nitrospirae;	
	V;	Verrucomicrobia;	
	Zn	Armatimonadetes;	
		Chlamydiae;	
		Elusimicrobia;	
		Caldiserica;	
		Chaldirithrix;	
		Lentisphaerae;	
		Fibrobacteres	

Sources: ^aKurniawan et al. (2020), ^bKurniawan (2020)

C. Organisms in Acid Mine Drainage-Polluted Heavy Metals

Acid mine drainage (AMD) is a highly acidic wastewater rich in heavy metals and metalloids (Plaza-Cazón et al., 2021). In this condition, only selected organisms can survive and life normally. Known as extremophiles, these organisms breed in habitats that are intolerably hostile or even deadly to other terrestrials. One of them thrive in acidic conditions and some can grow in toxic waste, low nutrient content, and also heavy metals pollution.

[redacted] broadly [redacted] that [redacted] optimally [redacted]

[redacted] (Rampelotto, 2013).

[redacted], oligotrophic ([redacted] in nutritionally limited condition), and metallophilic/metallophilic (resistant to high concentration of metals). In addition, extremophiles involve thermophiles and hyperthermophiles (optimally thrive at high or very high temperatures), psychrophiles (optimally thrive at low temperatures), alkaliphiles (optimally adapted to alkali pH values), barophiles or piezophilic (optimally thrive at high pressure) [redacted] (organisms that require NaCl for growth), [redacted]

[redacted] (thrive [redacted] a [redacted] area) (Rampelotto, 2013; Gupta et al., 2014; Sinha et al., 2014; Zhu et al., 2020).

However, in this review, we only deal with extremophile organisms related with acidic water-polluted heavy metal as well as abandoned tin mining pits conditions, which can categorized as

polyextremophiles due to these [redacted], as an acidophilic [redacted] metallophilic or metallophilic.

Environmental pH values are an important factor in acidophiles identification so they are grouped into two, namely true or extreme acidophiles [redacted] and moderate acidophiles. True acidophiles ([redacted]) can [redacted] a [redacted] of [redacted] and [redacted] some can live at a pH < 1.0 with an optimum pH of growth of < 3.0. Moderate acidophiles are able to live in the wider pH range, which is 3.0-7.2 with an [redacted] optimum pH of growth of 3.0-5.0 (Johnson and [redacted]). The acidophilic group has a fairly wide growth range, but optimum growth takes place between a pH of 1.0 and a pH of 5.0. This characteristic distinguishes from other groups such as neutrophiles that live tolerant in the pH range of 5.0-9.0 with the optimum pH for growth being 7.0 as well as alkaliphilic tolerant live at pH 6.0-12.0 with optimum pH above 9.0 or often between pH 10.0 and pH 12.0 (Gupta et al., 2014; Horikoshi, 2016).

In addition, in this review we use term acidotolerant to describe organisms which can live in acidic condition, while metallophilic to describe organisms which can survive in environment-contaminated heavy metals, especially in abandoned tin mining pit. We tend to agree with Maltman and Yurkov (2019) that explained organisms that can withstand high concentrations of metals (metalloids) are called metallophilic. However, this description can be a bit misleading. The suffix "phile" means that it is highly compatible in the presence of metals (metalloids). This is because even highly resistant microorganisms do not always grow well at such high levels and also it does not require oxyanions to survive. Therefore, term of metallophilic/metallophilic

is not used in this review and a more appropriate term is metallotolerant.

In this review, authors do references approach to elaborate some acidophilic and metallotolerant organisms found in other mining site or extreme environment to reveal potential of these organisms existing which might be found in abandoned tin mining pits. In this perspective, we highlight acidophile-metallotolerant as our term to disclose these organisms. Furthermore, it will becomes information as a guide for researching the presence of these organisms in this water. Some researchers has discovered the ability of some organisms to survive in extreme conditions of acidic and heavy metal contamination where some of them are resumed in Table 2.

All of them develop self-ability to survive so they can play an important role in this environment. Metallotolerant microorganism as well as acidophile have been found to be capable of efficiently accumulating heavy by the mechanisms of acidolysis, transport across cell membrane, complexation, ion exchange, precipitation, physical adsorption, accumulation, chelate, redoxolysis, and leaching which are carried out through physical mechanism, chemical modification or by influencing chemical bioavailability (Rao et al., 2002; Siswati et al., 2009; Damodaran et al. 2011; Harms et al., 2011; Javanbakht et al., 2014; Chaturvedi et al., 2015; Dixit et al., 2015; Dusengemungu et al., 2021).

In principle, acidophile, acidotolerant, and metallotolerant which do acidolysis, they can exchange metal oxide and decrease H^+ ion by metal oxide detachment and react oxygen with water, as shown in the reaction $MeO + 2H^+ \rightarrow Me^{2+} + H_2O$. Protons attach and react to the metal and then reduce the strength of chemical bonds so metal ions are removed from the metal surface (Srichandan et al., 2019). Furthermore, Me^{2+} as a metal cation will be processed as well as microbe capability such as accumulate or precipitate the cation ion become solid, as exemplified in this reaction $Me^{2+} + HO_2C.CO_2H \rightarrow (Me(O_2C.CO_2))_{(s)} + 6H^+$ and $Me^{2+} + SO_4^{2-} \rightarrow MeSO_4_{(s)}$ (Dusengemungu et al., 2021). In addition, they can play oxidation and reduction reactions to use the metal as their nutrition or detoxification of the metal to make sure their environment. For example, they are capable of both reactions, that reduction, and oxidation such as reduce Fe^{3+} with H_2 as an electron donor or oxidize Fe^{2+} with NO_3^- as an electron acceptor (Zhang et al., 2009).

Some of aquatic plants do their role as phytoremediator with rhizofiltration, phytostabilization process of uptaking accumulating from environment (Ali et al., 2020). Phytoextraction (phytoaccumulation) refers to the uptake and

translocation of metal in the environment by plant roots to above-ground plant parts. The plants can harvest and burn metals for energy, and the pollutants can be recovered/recycled from the ashes as needed by phytoextraction process (Erakhrumen, 2017; Chandra et al., 2018; Sukono et al., 2020). Roots play a very important role for rhizofiltration to absorb or adsorb the pollution, resulting in restricted movement of these contaminants in the environment (Abhilash et al., 2009; Benavides et al. 2018; Sukono et al., 2020).

transfer them to atmosphere by (Ghosh and Singh, 2005; Leguizamo et al. 2017; Sukono et al., 2020). Phytostabilization also known as in place deactivation, using plants to reduce heavy metal bioavailability and to restrict the movement of contaminants in the environment (Abhilash et al., 2009; Benavides et al., 2018; Yan et al., 2020).

While, some fishes improve their external morphology of the chorion (the egg envelope) to enter diapause phase, metabolism buffering of acidity, ion regulation and exchange of mitochondria cell by homeostatic mechanism, and biochemical metabolism by metallothionein (MTs) production (Hirata et al., 2003; Lindeque et al. 2010; Hwang et al., 2011; Daurte et al. 2013; Dominguez-Castanedo et al., 2013; Liu et al., 2014; Kurniawan and Mustikasari, 2021).

D. Life in Acidic-Heavy Metals Water: Perspective of Tin Mining Pit

Interactions of organisms play a critical role in existence and prospects of life in acid-heavy metals waters as formed as acid mine drainage. In addition, we elaborated many papers to construct a life in a perspective of tin mining pit based on life approach in the acid mine drainage. Hui (2012) explained the food chain is an important for ecological concept, especially in a life concept, organisms' interaction, nutritional relationships, and energy flow or transfer, which begins with autotrophs (known as the grazing food chain) and which begins with dead organic matter (known as the harmful food chain). Meanwhile, through this theory, we present a concept of thought about a food chain scheme that might occurred in a tin mining pit (Figure 2). The food chain of this habitat offers important informations for studies of the ecological interactions that define energy flows and the relationship of producer and consumer in an ecosystem, directly impact to nutrient cycling and biological life.

An essential part of a food chain is that each organism or their group are of equal importance to the ecosystem and play important role in an environment. We focused to constructed role of some microbes of abandoned tin mining pit, especially phylum of bacterial which affect to its characteristics

and ecological exchange in a biogeochemical process (Figure 3).

Bacteria is a group of microorganisms that have the highest ability of all life forms to adapt to extreme and stressful environments due to the ability to transfer genetic information as a major factor in adaptation to environmental changes. The population genetic diversity also contributes as one of the major factors determining the adaptation ability of a species to environmental variations (Jump et al. 2009). Bacteria, part of microbes can do their activity absolutely in aerobic and anaerobic conditions or facultative between aerobic or anaerobic conditions depending on the environment they are in.

Furthermore, some of them can do photosynthesis process. The photosynthetic bacteria use sunlight to produce energy in a process similar with plants. Instead of using the chlorophyll, they use bacteriochlorophyll compounds to capture the sunlight and do the photosynthesis (Emmyrafedziawati and Mohd Aziz, 2016).

The aerobic phototrophic bacteria are a recently discovered group capable of producing a photosynthetic apparatus like the purple phototrophic bacteria. These bacteria have bacteriochlorophyll (BChl) *a* incorporated into light harvesting (LH) and reaction center (RC) complexes capable of transforming light into electrochemical energy under aerobic conditions (Rathgeber et al., 2004). To date, there are six bacterial phyla namely Cyanobacteria, Proteobacteria, Chlorobi, Chloroflexi, Firmicutes, and Acidobacteria that use (bacterio)chlorophyll-based photosynthetic reaction centers (chlorophototrophs) (Zeng et al. 2014). There are four known phylogenetic groups of anoxygenic phototrophs: the green sulfur bacteria, the green non-sulfur bacteria, the heliobacteria, and the purple bacteria which consist of purple sulfur and purple non-sulfur bacteria (Emmyrafedziawati and Mohd Aziz, 2016). These microorganisms use reduced sulfur (S) compounds as electron donors in the process of anoxygenic photosynthesis (Kushkevych et al., 2021).

Kurniawan (2020) has explained the phyla of bacteria found in acid mine drainage, especially abandoned tin mining pits. We assumed that occurred the biogeochemical process in this habitat that involved bacteria so cause characteristic changes in this environment (Figure 3).

The oxidation of sulfide minerals and heavy metals found in abandoned tin mining water make acidic condition in the water. Biologically, Acidophile bacteria such as Actinobacteria, Firmicutes, and Chloroflexi oxidized sulfide minerals and heavy metals so accelerate acidic forms in abandoned tin mining pit and increase ion H^+ that cause acid condition in this water. While, the physically and chemically oxidation process also occurs to sulfide minerals and heavy metals (Bao et al., 2022) so cause pit water has acidic characteristic.

Chronosequently, within a certain time, organic matter from bacterial, archaea, microfungi, planktonic organisms were degraded and composed in this water. For quite a while, the organic matters and the degrading or composting product of organic matters were accumulated and caused increasing of c-organic. This organic material and its products were used Bacteroidetes as an energy source for their life and biochemical activity, include to decompose organic matters. Bacteroidetes play important role in decomposition process as a key of carbon cycle in an environment (Herzog et al., 2019).

We analyzed that the presence of organic material implicates to two major mechanisms: (1) carboxylic bond ($COOH^-$) of organic matters bound H^+ ions of sulfide minerals and heavy metals and (2) CO_2 and H_2O as decomposition products can be reacted to produce H_2CO_3 , while bicarbonate ion (HCO_3^-) also bound H^+ ions of sulfide minerals and heavy metals. These mechanisms caused H^+ ions in abandoned tin mining water will be decreased and the implication was increasing pH value, changes from acid to be a neutral or base. Vijayakumar et al. (2019) explained that a solution with a high concentration of hydrogen ions have a low pH (acid) and solution with low concentrations of H^+ ions have a high pH concentration (neutral to base).

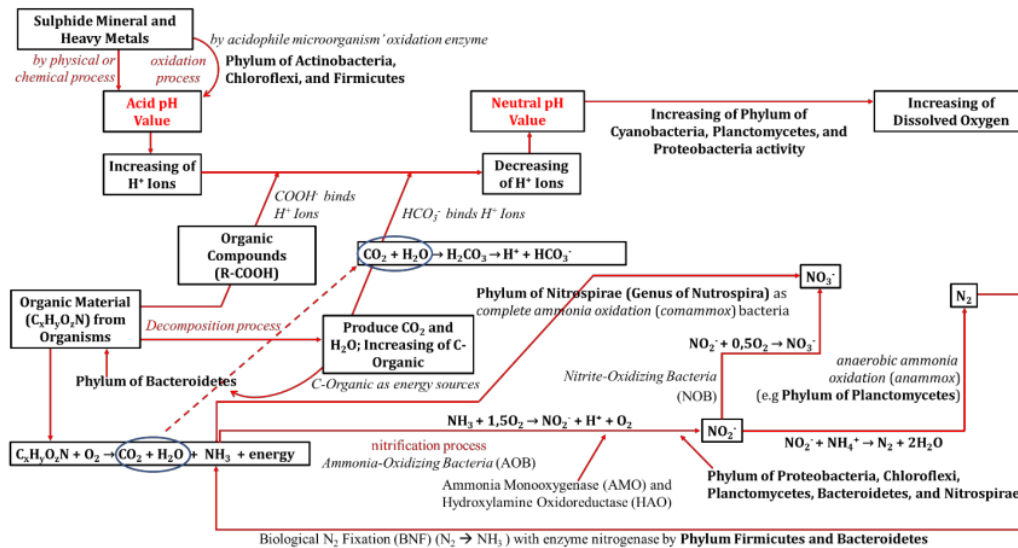
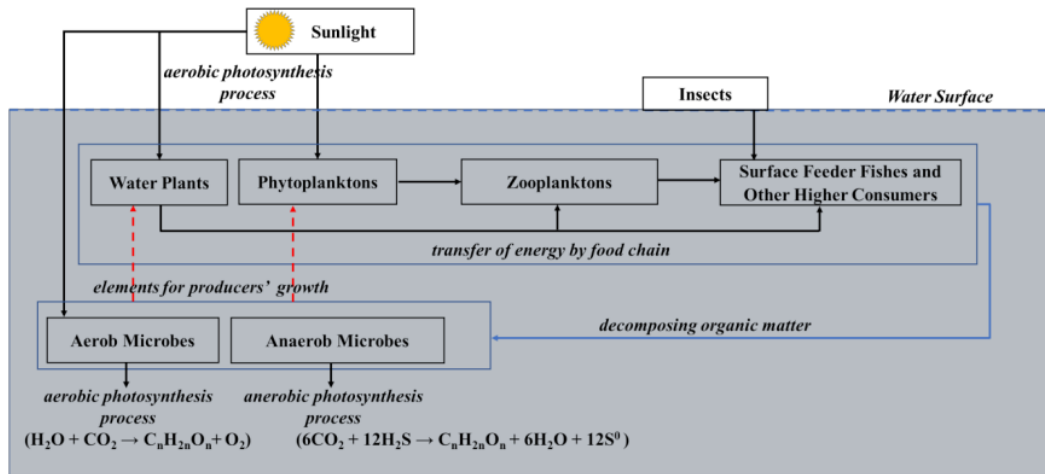
The pH changes contributed to ability of the other bacteria to live in this habitat such as Cyanobacteria, Proteobacteria, and Planctomycetes. The presence of Cyanobacteria as a primary producer contributes to photosynthesis by fixation of inorganic carbon (CO_2) to organic carbon ($(CH_2O)_n$) and releasing oxygen (Prieto-Barajas et al., 2018). Thereby, dissolved oxygen in this habitat will be increase and impact to other organisms, involved bacteria (e.g Proteobacteria and Planctomycetes), plankton, water plants, and fishes.

In addition, degradation organic matter produced ammonia (NH_3) that can be used by group of ammonia oxidizing bacteria (AOB), nitrite oxidizing bacteria (NOB), anaerobic ammonia oxidation, and complete ammonia oxidation (comammox) to produce nitrogen. Guignard et al., (2017) explained the presence of nitrogen impact to increasing of plant and animal abundances; trophic interactions and population dynamics; and ecosystem dynamics and productivity.

Therefore, the presence of bacteria and they work together, called quorum sensing (Kurniawan and Asriani, 2020) can create a habitable zone for many water organisms, from micro to macroorganisms and revive the food or web chains in the environment, include abandoned tin mining water.

Table 2. Acidophile-Metallotolerant Organisms in a Extreme Environment

Organism	Individu	Optimum Parameters		References
		pH	Heavy metal	
Bacterial	Phyla of Proteobacteria and Bacteroidetes	3.1	Pb, Cd, As, Ni, Co, Fe, Cr	Oyetibo et al. (2021)
	Phyla of Chloroflexi, Cyanobacteria, Proteobacteria, Firmicutes, Actinobacteria	4.8	Cu, Zn, Co, Ni, Mn, Fe, Cd, 20 Hg	Arif et al. (2021)
	Phyla of Acidobacteria, Actinobacteria, Amatinomadetes, Bacteroidetes, Chlorobi, Chloroflexi, Crenarchaeota, Cyanobacteria, Firmicutes, Nitrospirae, Nitrospinae, Parcibacteria, Proteobacteria, Planctomycetes	< 3	Ac, Cu	Zhang et al. (2019)
Fungal	<i>Penicillium</i> , <i>Candida</i> , <i>Saccharomycetales</i> , <i>Vishniacozyma</i> , <i>Trichoderma</i> , <i>Didymellaceae</i> , and <i>Cladosporium</i>	5.01	Fe, Cr, Cu, Zn	Kalu et al. (2021)
	<i>Fusarium solani</i>	5,0	Ag	El Sayed and El-Sayed (2020)
Archaea	Phylum Euryarchaeota	2.73-3.4	Fe, As	Bruneel et al. (2008)
	Phylum Euryarchaeota	1.9-2.75	Fe, Ni, Cu, Cr, Mn, Zn, As, Pb	Korzhenkov et al. (2019)
	Phylum Crenarchaeota	3.0	Fe, Mn, Cu	Hao et al. (2010)
Phytoplankton	Genera of Chlorophyta (<i>Chlamydomonas</i> , <i>Scourfieldia cordiformis</i>); Heterokontophyta (<i>Ochromonas</i> , <i>Chromulina</i>); Cryptophyta (<i>Gyathomonas</i>); Euglenophyta (<i>Lepocinclis</i> , <i>Euglena mutabilis</i>). Near-spherical non-motile Chlorophyta (<i>Nanochlorum</i> sp.); Heterokontophyta (<i>Eunotia exigua</i> , <i>Nitzschia</i>); Dinophyta (<i>Gymnodinium</i> , <i>Peridinium umbonatum</i>); and Cryptophyta (<i>Rhodomonas minuta</i>)	2.3-2.9	Fe	Lessmann et al. (2000)
	Class of Chlorophyceae (<i>Mougeotia</i> sp., <i>Spirogyra</i> sp., and <i>Chlamydomonas</i> sp.); Ulvophyceae (<i>Klebsormidium</i> sp.); Euglenophyceae (<i>Euglena</i> sp.); Bacillariophyceae (<i>Pinnularia</i> sp., <i>Eunotia</i> sp., <i>Navicula</i> sp., and <i>Cyclotella</i> sp.); Chlorophyceae (<i>Characium</i> sp.); Chrysophyceae (<i>Dinobryon</i> sp.); Ulothricophyceae (<i>Oedogonium</i> sp. and <i>Ulothrix</i> sp.) and Trebouxiophyceae (<i>Chlorella</i> sp.)	2.1-6.3	As, Cr, Cu, Fe, K, Mg, Mn, Ni, Co, Zn, Cd, Pb	Gomes et al. (2021)
	Rotifer (<i>Rotaria</i> sp., <i>Asplanchna priodonta</i> , <i>Aspelta cincinnator</i> , <i>Brachionus</i> sp., <i>Cephalodella</i> sp., <i>Colurella colurus</i> , <i>Elosa worallii</i> , <i>Kellicottia longispina</i> , <i>Keratella</i> sp., <i>Lecane</i> sp., <i>Polyarthra dolichoptera</i> , <i>Testudinella patina</i> , <i>Trichocerca</i> sp.)	2.7-4.9	Pb, Cd, Cu, Zn, Cr, Ni, Mn, Fe	Pociecha et al. (2018)
Fish	<i>Capoeta fusca</i>	5	Hg	Mansouri and Baramaki (2011)
	<i>Channa striatus</i>		Cu, Zn, Pb	Jalal et al. (2013)
	<i>Cyprinus carpio</i> and <i>Pelteobagrus fluvidraco</i>		Cr, Cu, Cd, Pb	Rajeshkumar and Li (2018)
	<i>Oxyeleotris marmorata</i> and <i>Rasbora lateristriata</i>	6.56-6.80	Cd, Cu, Fe, Pb, Zn	Syandri et al. (2015)
	<i>Aplocheilus panchax</i> and <i>Anabas testudineusi</i>	3.81-7.79	Sn, Hf, Cu, Fe	Mustikasari et al. (2020); Mustikasari and Agustiani (2021)
	<i>Trichogaster pectoralis</i> and <i>Anabas testudineusi</i>	6.86	Fe	Herliyanto et al. (2014)
	<i>Gambusia affinis</i>	6.247	Cd, Cr, Cu, [redacted]	Franssen (2009)
	<i>Esomus malayensis</i> , <i>Trichogaster pectoralis</i> , <i>Oreochromis mossambicus</i> , <i>Megalops cyprinoides</i>	5.69-6.03	[redacted] Zn, [redacted] Cr, [redacted] Cd	Widad and Abdullah (2013)
<i>Hampala microlepidota</i> , <i>Barbonymus schwanefeldii</i> , <i>Mystacoleucus marginatus</i> , <i>Hemibagrus nemurus</i> , <i>Cyclocheilichthys apogon</i> , and <i>Oreochromis niloticus</i>	-	Cu, [redacted] Pb, Ni, [redacted]	Baharom and Ishak (2015)	
<i>Puntius schwanefeldii</i> , <i>Ompok bimaculatus</i> , <i>Cyclocheilichthys apogon</i> , <i>Osteochilus hasseltii</i> , <i>Notopterus notopterus</i> , <i>Chana micropeltes</i> , <i>Puntius bulu</i> , <i>Labiobarbus festiva</i> , <i>Osteochilus melanopleura</i> , <i>Hampala macrolepidota</i> , <i>Chela oxygastroides</i> , <i>Mystus nigriceps</i> , <i>Thynnichthys thynnoides</i> , <i>Barbichthys laevis</i> , <i>Helostoma temmicki</i>	5.8-6.4	Cu, [redacted] Zn, Cd	Ahmad and Shuhaimi-Othman (2010)	
Aquatic Plant	<i>Eleocharis dulcis</i> , <i>Cyperus odoratus</i> , <i>Hydrilla verticillata</i> , <i>Ipomea aquatic</i> , <i>Pistia stratiotes</i>	4.56-6.09	Fe, Mn	Herniwanti et al. (2013)
	<i>Azolla filiculoides</i>	2	Cr	Babu et al. (2014)



4. Conclusion

We have disclosed about the interaction of organisms in abandoned tin mining pits by the perspective of life in acid mine drainage environment. We believed some bacterial of abandoned tin mining water as part of acid mine drainage played important role in biogeochemical process to change water quality and create a food or web chains by a creating habitable environment for all organisms, including

micro- to macroorganisms. Some groups of bacterial played important role in organic matter cycle and another played in anorganic cycle of biogeochemical mechanisms. This review was only limited to the role of bacterial in abandoned acid mining waters. Further researches were needed to explain about the food chain and energy transfer that occurs in these waters.

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Conflict of Interest

The author declares that there is no conflict of interest in this publication.

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