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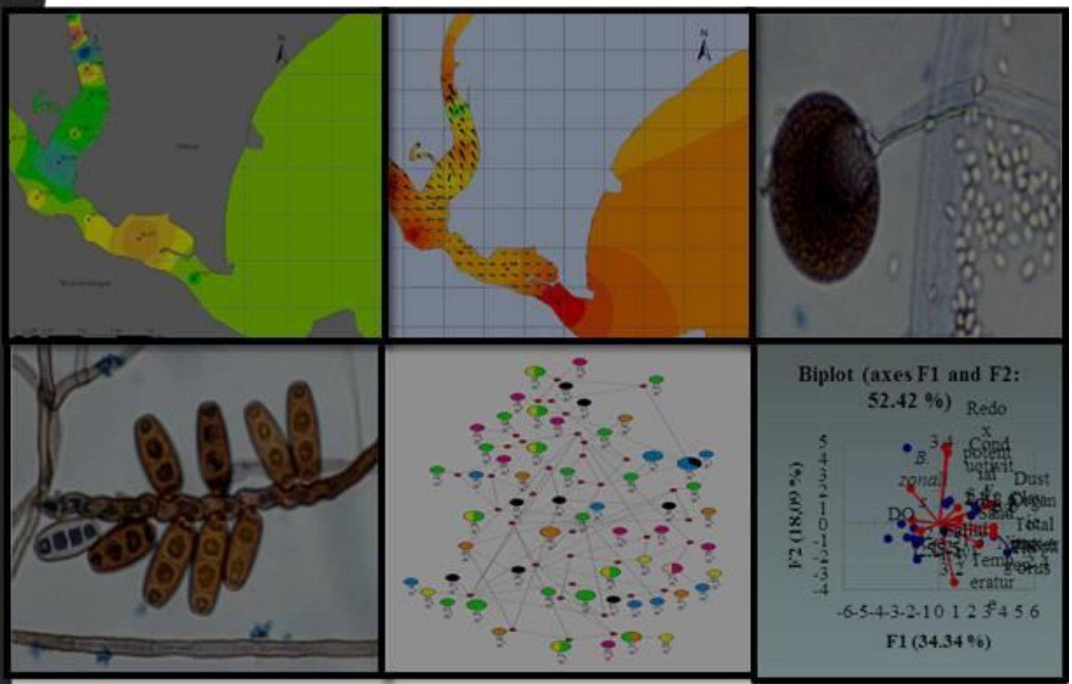

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The Phosphorus and Sulphur Distribution and Culturable Bacterial in Time Chronosequence of Ex-Tin Mining Ponds

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ABSTRACT

The tin mining had caused ecological changes that can be occured to macro- and microecosystem. This article aims to study the pattern distribution of element of phosphorus (P) and sulphur (S) and also to identify culturable bacterial that were isolated form ex-tin mining ponds in time chronosequence. The elemets of P and S were detected by X-Ray Fluorescence (XRF) and the bacterials was isolated in medium agar and biochemistry identification by microbact. The concentration of element of P and S showed the average of P concentration increased in time chronosequnce of ex-tin mining ponds, whereas the average of S concentration showed dynamic pattern. In ex-tin mining pond with age < 1 year the average concentration of P was 33,725 mg.L-1 and S was 311,45 mg.L-1. In ex-tin mining pond with age 5-10 years were P (59,8 mg.L-1) and S (451,75 mg.L-1). In ex-tin mining pond with age > 15 years were P (67,44 mg.L-1) and S (386,125 mg.L-1). While, the culturable bacterials were *Kurthia* spp; *Actinobacillus equuli*; *Bacillus amyloliquefaciens*; *Bacillus* spp; *Micrococcus* sp; *Enterobacter gergoviae*; *Veillonella* sp; *Enterobacter aerogenes*; *Moraxella bovis*; *Nitrobater* spp; and *Enterobacter agglomerans*.

Keywords: *phosphorus, sulphur*, *tin mining*, *culturable bacteria*

1. Introduction

Tin mining activity had contributed to ecological problems. The soil changes by tin mining activity caused a degradation of soil composition, structure, quality, and physical or biological characteristics, and changes of macro and microorganisms in their natural habitats (Kurniawan et al., 2016). The other problem was a formation of ex-tin mining ponds and consequently, the ponds become a reservoir of water.

The characteristics of waters showed acidic pH value and often highly acidic (pH < 4) (Kolmert and Jhonson, 2001), low dissolved oxygen (Ashraf et al., 2011), heavy metals accumulation (Daniel et al., 2014), and low cation exchange capacity, organic matter, nitrogen, phosphorus, macronutrient, and also clay content in soil texture (Oktavia et al., 2014). This condition caused the waters can not be used for primary activities.

A recovery of natural succession even takes a long time. Thefore, information about lush of the waters, especially phosphorus and sulphur were an important part to explained the thropic level and acidic value of waters in time chronosequence. It can be used to determine the eco-management of ex-tin mining ponds.

In additon, an understanding of bacterial' life in ex-tin mining ponds were also important. It can explained bacterial' response to the environmental changes caused by the tin mining chronosequence. The understanding of bacterial's life in ex-tin mining becomes an important focus to investigated adaptation capacity of them during ecological changes process or microbial succession pattern in change through time.

This studi about culturable bacterial aims to identify their characteristic of biochemistry. Further, the characteristics can indicate their capability and it can be used as a successor and bioremediator agent to recover water quality quickly.

2. Material and Methods

The study stations were located in Bangka Regency, Bangka Belitung Archipelago Province of Indonesia. The study areas were encoded as Station A (pond in age < 1 year), Station B (pond in age 5-10 years), and Station C (pond in age > 15 years).

The coordinate of Station A were 01°59' S in points 36,0"; 36,2"; 36,4"; 36,5"; 36,6" and 106°06' E in points 36,5"; 36,9"; 37,3"; 37,4"; 37,5". The coordinate of Station B were 01°59' S in points 41,3"; 41,4"; 41,5"; 42,4"; 42,5" and 106°06' E in points 39,2"; 39,5"; 41,4"; 42,7"; 43,1". The coordinate of Station C were 01°55' S in points 40,9"; 58,9"; 59,1"; 59,2"; 59,5" and 106°06' E in points 19,5"; 19,7"; 19,9"; 22,4"; 29,2".

In the each of research stations points, the water sampling was done to water samples < 4m in depth (encoded Station A.1; Station B.1; and Station C.1) and the composite sampling were done to water and sediment samples > 4m in depth (encoded Station A.2; Station B.2; and Station C.2).

The parameters of research include element concentration of phosphorus (P) and sulphur (S) in waters and also characteristic of biochemistry from culturable bacterial. The elements concentration of samples were measured by X-Ray Fluorescence (XRF) that calibrated by three light spreader metals of copper (Cu), molybdenum (Mo), and aluminum (Al). While, the isolation of culturable bacterial was done in medium agar and analysis gram, motility, catalase, oxidase, glucose, ornithine, indole, citrate, and voges-proskauer (VP) were identificated by microbact™ 12A and 24E (Oxoid, UK) Identification Kits (Septiama et al., 2008; Osuntokun et al., 2018).

3. Results and Discussion

2.1 The concentration of phosphorus and sulphur

The concentration of element of P and S in time chronosequence of ex-tin mining ponds showed the average of P concentration increased from Station A to Station B and Station C, whereas the average of S concentration increased from Station A to Station B and then decreased in Station B. The average of P concentration were 33,725 mg.L-1 (Station A), 59,8 mg.L-1 (Station B), and 67,44 mg.L-1 (Station C). While, the average of S concentration were 311,45 mg.L-1 (Station A), 451,75 mg.L-1 (Station B), 386,125 mg.L-1 (Station C) (**Table 1**).

The understanding of both element of P and S in ex-mining activity was important. The element of P can indicated thropic level, whereas element of S can produced acide mine drainage by oxidation sulfide minerals.

The ex-mining ecosistems were deficient in nutrients, include P (Huang et al., 2011). However, the chronosequence ranging in time of ex-tin mining ponds contributed to the ecological change. The age of ecosystem had correspondences with ecological succession that were followed by changes of nutrient cycling and physico-chemical characteristics (Moreno-de las Heras et al., 2008). The element of P concentration in Table 1 showed increasing pattern that can indicated the change of ecosystem in eutrophication level because the presence of P in a ecosystem caused eutrophication (Sibrell et al., 2009; Abdel-Raouf et al., 2012).

Table 1. Concentration of P and S in time chronosequence of ex-tin mining ponds

No.	Elements	Density (g/cm^3)	Concentration (mg.L-1)					
			Station A		Stasion B		Stasion C	
			A.1	A.2	B.1	B.2	C.1	C.2
1.	Phosphorus (P)	1,823	12,2	55,25	25,7	93,9	88,3	46,58
2.	Sulphur (S)	1,96	60,8	562,1	163	740,5	471	301,25

Notes: *Station A (pond in age < 1 year), Station B (pond in age 5-10 years), and Station C (pond in age > 15 years). The station code (A.1, B.1, and C.1) showed water samples < 4m in depth and the station code (A.2, B.2, and C.2) showed composite samples (water and sediment > 4m in depth).*

The eutrophication can indicated positive changes of ex-tin mining ponds ecosystem. The presence of phosphate becomes one of indicator for eutrophication and a parameter to predicted biomass abundance. The mobilization of phosphate in water-sediment interphase contributed to physic-chemical factors of waters (Maher et al., 2002; Quirós, 2003; Mahadevaiah et al., 2007; Topcu and Pulatsu, 2014; Lei et al., 2017). Indirectly, the physic-chemical changes can impacted to organism' life, especially microorganisms as first life in the ecosystem. The microorganism' life can implicated to succession and water quality change there.

The element of S can produced acid condition in mine ecosystem (RoyChowdhury et al., 2015). The mining wastewaters typically contain metal sulfide minerals, particularly the pyrite (FeS_2) was oxidized in contact with oxygen and water become an acid mine drainage (Chun-bo et al., 2007). The overall, pyrite oxidation by reaction respectively (Descotes et al., 2002):

$$FeS_2 + 7/2\ O_2 + H_2O \rightarrow Fe^{2+} + 2\ SO_2 + 2\ H^+$$
$$FeS_2 + 14\ Fe^{3+} + 8\ H_2O \rightarrow 15\ Fe^{2+} + 2\ SO_2 + 16\ H^+$$

The element of P concentration in Table 1 showed increasing from Station A to Station B and decreasing in Station C. This pattern can indicated oxidation process in Station B was higer than Station C and then this process implicated on pH value change. The element of S in form SO_4^{2-} was a significant factor in acid mine drainage, besaide metals such as Al, As, Fe, K, Mg, Mn, Na, and Zn (Campaner et al., 2014). The consequence of pH value change contributed to dissolved organic and anorganic materials (Akan et al., 2013; Kuriata-potasznik et al., 2016), water solubility from nitrogen and amonia (Luo et al., 2015), oxygen depletion (Hou et al., 2013), and other parameters of water that impacted to biology activity.

The change of P and S in waters can indicated ecological composition and structure quality and also physical characteristics. Indirectly, they contributed to biological changes, either macro- and micro ecosystems change (Vyas and Pancholi, 2009; Giri et al., 2014; Lad et al., 2015). The biological changes include organisms and microbial communities structure (Grant et al., 2007).

2.2 The culturable bacterial

The bacterial was isolated in medium agar had an oppurtunity to studied characteristics of biochemistry. There were eight genus of bacteria that Actinobacillus, Bacillus, Enterobacter, Kurthia, Micrococcus, Moraxella, Nitrobater, and Veillonella (**Table 2**).

The change of ex-tin mining waters can impacted microorganisms diversity like methane-oxidizing bacteria (MOB), ammonia-oxidizing bacteria (AOB), and arsenic-resistant bacteria (ARB) (Jareonmit et al., 2010; Valverde et al., 2011; Sow et al., 2014a; Sow et al., 2014b) or other microorganisms like archea that were called acidophile (Navarro et al., 2013). They had a capability to respond alterations quickly in an ecosystem and the potential property can be used to predict and detect environment changes (Paerl et al., 2003; Niemi and McDonald, 2004; Moscatelli et al., 2005; Lau and Lennon, 2012). There was a significant correspondence between microorganism communities and ecological factors (Vishnivetskaya et al., 2011). The changes of ecological along time chronosequence can drived size, activity, diversity, structure, composition, and capabilty of microbial (Liao and Xie, 2007; Wang et al., 2007; Chodak et al., 2009; Banning et al., 2011; Bier et al., 2015).

Further, their resistance and resilience in acid mine drainage, include a metals contamination, indirectly can contributed to the ecological changes (Xie et al., 2011; Shade et al., 2012). The acidophile showed an ability to survive in acid condition like ex-tin mining. They can used residues of mining as nutition, carbon, and nitrogen source with mixotrophy as chemoheterotroph and photoautotroph (Hao et al., 2010).

Some of them were *Alcaligenes* spp., *Arthrobacter* spp., *Bacillus* spp., *Corynebacterium* spp., *Azotobacter* spp., *Pseudomonas* spp. *Rhodococcus* spp., *Aspergilus niger*, *Flavobacterium* spp., *Mycobacterium* spp., *Methanogens*, *Nocardia* spp., *Methosinus* sp., *Pleurotus ostreatus*, *Rhizopus arrhizus*, *Stereum hirsutum*, *Phormidium valderium*, and *Ganoderma applantus* (Girma, 2015).

In this research, *Actinobacillus* sp, *Bacillus* sp, *Enterobacter* sp, *Kurthia* sp, *Micrococcus* sp, *Moraxella* sp, *Nitrobater* sp, and *Veillonella* sp were isolated form the ecosystem and they were culturabled in medium agar. However, they were not representation of all microorganisme in ex-tin mining ponds ecosystem. The culturable bacterials were only 1-10% can be isolated in the laboratory (Lutton et al., 2013). Therefore, bacterial identification by the sequencing confirmation of 16S rRNA genes were needed to identify the culturable bacterials.

Table 2. Characteristic of culturable bacteri in time chronosequence of ex-tin mining ponds

Bio-chemistry Ident.	Biochemistry characteristics and species bacteria																				
	Station A								Stasion B								Stasion C				
	A.1			A.2					B.1				B.2				C.1		C.2		
Code*	a	b	c	d	e	f	g	h	i	j	k	l	m	n	o	p	q	r	s	t	u
Gram	+	-	+	+	+	+	-	-	-	-	-	+	+	-	-	+	-	-	-	-	-
Motility	-	-	-	-	-	-	+	-	+	+	-	-	+	-	-	-	-	-	-	-	+
Catalase	+	+	+	+	+	+	-	+	-	-	+	+	+	-	-	+	+	-	+	-	-
Oxidase	-	+	+	+	-	+	-	-	-	-	+	-	-	+	+	-	+	+	+	+	-
Glucose	-	+	-	-	-	-	+	-	+	+	-	+	+	+	+	-	-	+	-	+	+
Ornithine	+	-	-	+	-	-	+	+	+	+	-	-	-	-	-	+	-	-	-	-	-
Indole	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
Citrate	+	+	-	-	-	-	+	-	+	+	-	-	-	-	-	-	-	-	-	-	+
VP	-	-	+	-	-	+	+	-	+	+	-	-	+	+	+	-	-	+	-	+	+

Notes: *Station A (pond in age < 1 year), Station B (pond in age 5-10 years), and Station C (pond in age > 15 years). The station code (A.1, B.1, and C.1) showed water samples < 4m in depth and the station code (A.2, B.2, and C.2) showed composite samples (water and sediment > 4m in depth).*

*) (a) *Kurthia* spp; (b) *Actinobacillus equuli*; (c) *Bacillus amyloliquefaciens*; (d) *Bacillus* spp; (e) *Micrococcus* sp; (f) *Bacillus amyloliquefaciens*; (g) *Enterobacter gergoviae*; (h) *Veillonella* sp; (i) *Enterobacter aerogenes*; (j) *Enterobacter aerogenes*; (k) *Moraxella bovis*; (l) *Bacillus* spp; (m) *Bacillus* spp; (n) *Nitrobater* spp; (o) *Nitrobater* spp; (p) *Kurthia* spp; (q) *Moraxella bovis*; (r) *Nitrobacter* spp; (s) *Moraxella bovis*; (t) *Nitrobacter* spp; (u) *Enterobacter agglomerans*

Furthermore, the metagenoms analysis become method to explore information about potential bacterial that were needed. The metagenomic analysis was a *culture-independent genomic* analysis of microorganism' communities. The analysis by polymerase chain reaction (PCR) amplification of 16S rRNA genes can be used to identify unculturable microorganisms and represented more than 99% of the microorganism in an environments (Schloss and Handelsman, 2003). By metagenoms analysis, diversity of potential bacterials will be known.

2.3 The relationship of bacteria with P and S

Phosphorus and sulphur in an environment was closely related to microorganism' life cycle because they were needed for cell activity and growth. On the other side, microorganism' activity can contributed to dynamic of P and S. Therefore, there was an interaction both of them in an environment.

In ex-tin mining ponds, the concentration of element of P and S showed concentration increasing in time chronosequnce of ex-tin mining ponds, whereas the average of S concentration showed dynamic pattern. These conditions contributed to genus of bacteria there, where gram positive bacteria were more found in ponds with age < 1 year, whereas gram negative were more found in ponds with age > 15 years.

Sulphur was among the most abundant elements on the environment and mainly present as pyrite (FeS_2) as a result of sulphide oxidation (Tan et al., 2007; Muyzer and Stam, 2008). This condition contributed to acidic pH value as acid mine drainage (AMD). The increasing of P in the ponds may caused by ecological changes as sedimentation, cation and anion exchange, pH value changes, reduction-oxidation, composting, etc along chronosequence in time.

The element P was used by the microorganism for an adaptation. In fact, in time chronosequence' effect impacted to gram negative bacterials were more than gram positive bacterials. Further, they activity caused concentration of S was decreased. This interaction indicated that gram negative bacterials had a potential activity as a sulphur reducer to redused sulphur from the environment. The sulphate-reducing bacteria (SRB) can converted sulphate ions (SO_4^{-2}) into sulphide (S^{-2}) (Sakamoto et al., 2012) and they used sulphate as a terminal electron acceptor in cell activities such as the degradation of organic compounds and also an important role in both the sulphur and hydrocarbon cycles in wastes and some environment contaminants (Dar et al., 2007; Plugge et al., 2011; Hussain et al., 2016).

4. Conclussion

Tin mining caused macroecosystem changes and indirectly influenced microecosystem. The phosphorus and sulphur value and also microorganism' life in ex-tin mining ponds can be indicators that indicated the ecological changes. Distribution of P and S element had a relationship with diversity of microorganism, specially bacteria. Furthermore, in time chronosequence of ex tin mining ponds also contributed to ecological changes.

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Reference

Abdel-raouf, N., Al-homaidan, AA., Ibraheem, IBM. 2012. Microalgae and wastewater treatment. Saudi Journal of Biological Sciences 19(3): 257-275.

Akan, JC., Audu, SI., Mohammed, Z., Ogugbuaja, VO. 2013. Assessment of heavy metals, pH, organic matter and organic carbon in roadside soils in Makurdi Metropolis, Benue State, Nigeria. Journal of Environmental Protection 4(6): 618-628.

Ashraf, MA., Maah, MJ., Yusoff, I. 2011. Analysis of physio-chemical parameters and distribution of heavy metals in soil and water of ex-mining area of Bestari Jaya, Peninsular Malaysia. Asian Journal of Chemistry 23(8): 3493-3499.

Banning, NC., Gleeson, DB., Grigg, AH., Grant, CD., Andersen, GL., Brodie, EL., Murphy, DV. 2011. Soil microbial community successional patterns during forest ecosystem restoration. Applied and Environmental Microbiology 77(17): 6158-6164.

Bier RL., Voss, KA., Bernhardt, ES. 2015. Bacterial community responses to a gradient of alkaline mountaintop mine drainage in central appalachian streams. ISME Journal 9(6): 1378-1390.

Campaner, VP., Luiz-silva, W., Machado, W. 2014. Geochemistry of acid mine drainage from a coal mining area and processes controlling metal attenuation in stream waters, Southern Brazil. Anais da Academia Brasileira de Ciências 86(2): 539-554.

Chodak, M., Pietrzykowski, M., Niklińska, M. 2009. Development of microbial properties in a chronosequence of sandy mine soils. Applied Soil Ecology 41(3): 259-268.

Chun-bo H, Hong-xun Z, Zhi-hui B, Qing H, Bao-guo Z. 2007. A novel acidophile community populating waste ore deposits at an acid mine drainage site. Journal of Environmental Sciences 19(4): 444-450.

Daniel, VN., Chudusu, ES., Chup, JA., Pius, ND. 2014. Variations of heavy metals in agricultural soils irrigated with tin water in Heipang District of Barkin Ladi, Plateau State, Nigeria. International Journal of Science and Technology 3(5): 255-263.

Dar, SA., Yao, L., Van Dongen U., Kuenen, JG., Muyzer, G. 2007. Analysis of Diversity and Activity of Sulfate-Reducing Bacterial Communities in Sulfidogenic Bioreactors Using 16S rRNA and *dsrB* Genes as Molecular Markers. Applied and Environmental Microbiology 73(2): 594-604.

Descostes, M., Beaucaire, C., Mercier, F., Savoye, S., Sow, J., Zuddas, P. 2002. Effect of carbonate ions on pyrite (FeS_2) dissolution. Bulletin de le Societe Geologique de France 173(3): 265-270.

Giri, K., Mishra, G., Pandey, S., Verma, PK., Kumar, R., Bisht, NS. 2014. Ecological degradation in northeastern coal fields: Margherita Assam. International Journal of Science, Environment and Technology 3(3): 881-884.

Girma, G. 2015. Microbial bioremediation of some heavy metals in soils: an updated review. Indian Journal of Scince Research 6 (1): 147-161.

Grant, RJ., Muckian, LM., Clipson, NJ., Doyle, EM. 2007. Microbial community changes during the bioremediation of creosote-contaminated soil. Letters in Applied Microbiology 44(3): 293-300.

Hao, C., Wang, L., Gao, Y., Zhang, L., Dong, H. 2010. Microbial diversity in acid mine drainage of Xiang Mountain sulfide mine, Anhui Province, China. Extremophiles 14(5): 465-474.

Hou, D., He, J., Lu, C., Sun, Y., Zhang, F., Otgonbayar, K. 2013. Effects of environmental factors on nutrients release at sediment-water interface and assessment of trophic status for a typical Shallow Lake, Northwest China. The Scientific World Journal 2013(2013): 1-16.

Huang, L., Tang, F., Song, Y., Wan, C., Wang, S., Liu, W., Shu, W. 2011. Biodiversity, abundance, and activity of nitrogen-fixing bacteria during primary succession on a copper mine tailings. FEMS Microbiology Ecology 78 (3): 439-450.

Hussain, A., Hasan, A., Javid, A., Qazi, JI. 2016. Exploited application of sulfate-reducing bacteria for concomitant treatment of metallic and non-metallic wastes: a mini review. Biotech 6(119): 1-10.

Jareonmit, P., Sajjaphan, K., Sadowsky, MJ. 2010. Structure and diversity of arsenic-resistant bacteria in an old tin mine area of Thailand. Journal of Microbiology and Biotechnology 20(1): 169-178.

Kuriata-potasznik, A., Szymczyk, S., Skwierawski, A., Gli´nska-lewczuk, K., Cymes, I. 2016. Heavy metal contamination in the surface layer of bottom sediments in a flow-through lake: a case study of Lake Symsar in Northern Poland. Water 8(8): 1-15.

Kurniawan, A. 2016. Microorganism communities response of ecological changes in post tin mining ponds. Journal of Microbiology and Virology 6(1): 17-26.

Lad, RJ., Samant, JS. 2015. Impact of bauxite mining on soil: a case study of bauxite mines at Udgiri, Dist-Kolhapur, Maharashtra State, India. International Research Journal of Environment Sciences 4(2): 77-83.

Lau, JA., Lennon, JT. 2012. Rapid responses of soil microorganisms improve plant fitness in novel environments. PNAS Early Edition 109(35): 14058-14062.

Lei, Y., Song, B., Van Der Weijden, RD., Saakes, M., Buisman, CJN. 2017. Electrochemical induced calcium phosphate precipitation: importance of local pH. Environmental Science & Technology 51(19): 11156-11164.

Liao, M., Xie, XM. 2007. Effect of heavy metals on substrate utilization pattern, biomass, and activity of microbial communities in a reclaimed mining wasteland of red soil area. Ecotoxicology and Environmental Safety 66(2): 217-223.

Luo, X., Yan, Q., Wang, C., Luo, C., Zhou, N., Jian, C. 2015. Treatment of ammonia nitrogen wastewater in low concentration by two-stage ozonization. International of Journal Environmental Research and Public Health 12(9): 11975-11987.

Lutton, E., Schellevis, R., Shanmuganathan, A. 2013. Culture-dependent methods increase observed soil bacterial diversity from Marcellus shale temperate forest in Pennsylvania. Journal of Student Research 2(1): 9-16.

Mahadevaiah., Kumar, MSY., Galil, MSA., Suresha, MS., Sathish, MA., Nagendrappa, G. 2007. A simple spectrophotometric determination of phosphate in sugarcane juices, water, and detergent samples. E-Journal of Chemistry 4(4): 467-473.

Maher, W., Krikowa, F., Wruck, D., Louie, H., Nguyen, T., Huang, WY. 2002. Determination of total phosphorus and nitrogen in turbid waters by oxidation with alkaline potassium peroxodisulfate and low pressure microwave digestion, autoclave heating or the use of closed vessels in a hot water bath: comparison with kjeldahl digestion. Analytica Chimica Acta 463(2): 283-293.

Moreno-de las Heras, M., Nicolau, JM., Espigares, T. 2008. Vegetation succession in reclaimed coal-mining slopes in a mediterranean-dry environment. Ecological Engineering 34(2): 168-178.

Moscatelli, MC., Lagomarsino, A., Marinari, S., De Angelis, P., Grego, S. 2005. Soil microbial indices as bioindicators of environmental changes in a poplar plantation. Ecological Indicators 5(3): 171-179.

Muyzer, G., Stams, AJM. 2008. The ecology and biotechnology of sulphate-reducing bacteria. Nature Reviews Microbiology 6 (6): 441-454.

Navarro CA, Bernath DV, Jerez CA. 2013. Heavy metal resistance strategies of acidophilic bacteria and their acquisition: importance for biomining and bioremediation. Biological Research 46(4): 363-371.

Niemi, GJ., McDonald, ME. 2004. Application of ecological indicators. Annual Review of Ecology, Evolution, and Systematic 35(2004): 89-111.

Oktavia, D., Setiadi, Y., Hilwan, I. 2014. Sifat fisika dan kimia tanah di hutan kerangas dan lahan pasca tambang timah Kabupaten Belitung Timur. Jurnal Silvikultur Tropika 5(3): 149-154

Osuntokun, OT., Jemilaiye, TA., Thonda, AO. 2018. Phenotypic identification and antibiogram profile of citrobacter species. Journal of Clinical Research and Pharmacy 1(1): 1-6.

Paerl, HW., Dyble, J., Moisander, PH., Noble, RT., Piehler, MF., Pinckney, JL., Steppe, TF., Twomey, L., Valdes, LM. 2003. Microbial indicators of aquatic ecosystem change: current applications to eutrophication studies. FEMS Microbiology Ecology 46(3): 233-246.

Plugge, CM., Zhang, W., Scholten, JCM., Stams, AJM. 2011. Metabolic flexibility of sulfate-reducing bacteria. Frontiers in Microbiology 2(81): 1-8.

Quirós, R. 2003. The relationship between nitrate and ammonia concentrations in the pelagic zone of lakes. Limnetica 22(1-2): 37-50

RoyChowdhury, A., Sarkar, D., Datta, R. 2015. Remediation of acid mine drainage-impacted water. Current Pollution Reports 1(3): 131-141.

Sakamoto, IK., Maintinguer, SI., Hirasawa, JS., Adorno, MAT., Varesche, MBA. 2012. Evaluation of microorganisms with sulfidogenic metabolic potential under anaerobic conditions. Brazilian Archives of Biology and Technology 55(5): 779-784.

Schloss, PD., Handelsman, J. 2003. Biotechnological prospects from metagenomics. Current Opinion in Biotechnology 14(3): 303-310.

Septiama., Sugianti, B., Aritonang, AH., Shatrie, DN., Barleani, AA., Noor, RP., Wahyuni, I., Hapsari, I., Fakhriza, I., Kusbiandany, S., David, PHS., Gunardi, AS., Arbay, EA., Trisniyati., Firma. 2008. Metode standar pemeriksaan HPIK golongan bakteri. Pusat Karantina Ikan. Departemen Kelautan dan Perikanan

Shade, A., Peter, H., Allison, SD., Baho, DL., Berga, M., Bürgmann, H., Huber, DH., Langenheder, S., Lennon, JT., Martiny, JBH., Matulich, KL., Schmidt, TM., Handelsman, J. 2012. Fundamentals of microbial community resistance and resilience. Frontiers in Microbiology 3(417): 1-19.

Sibrell, PL. 2009. Removal of Phosphorous from agriculture wastewaters Using Adsorption Media Prepared From Acid Mine Drainage. Water Research 43(8): 2240-2250.

Sow, SLS., Khoo, G., Chong, LK., Smith, TJ., Harrison, PL., Ong, HKA. 2014a. molecular diversity of the ammonia-oxidizing bacteria community in disused tin-mining ponds located within Kampar, Perak, Malaysia. World Journal of Microbiology and Biotechnology 30(2): 757-766.

Sow, SLS., Khoo G., Chong, LK., Smith, TJ., Harrison, PL., Ong, HKA. 2014b. Molecular diversity of the methanotrophic bacteria communities associated with disused tin-mining ponds in Kampar, Perak, Malaysia. World Journal of Microbiology and Biotechnology 30(10): 2645-2653.

Tan, G., Shu, W., Hallberg, KB., Li, F., Lan, C., Huang, L. 2007. Cultivation-dependent and cultivation-independent characterization of the microbial community inacid mine drainage associatedwith acidic Pb/Zn mine tailings at Lechang, Guangdong, China. FEMS Microbiology Ecology 59(1): 118-126.

Topcu, A., Pulatsu, S. 2014. Phosphorus fractions and cycling in the sediment of a shallow eutrophic pond. Journal of Agricultural Sciences 2014(20): 63-70

Valverde, A., González-Tirante, M., Medina-Sierra, M., Santa-Regina, I., García-Sánchez, A., Igual, JM. 2011. Diversity and community structure of culturable arsenic-resistant bacteria across a soil arsenic gradient at an abandoned Tungsten–tin mining area. Chemosphere 85(2011): 129-134.

Vishnivetskaya, AT., Mosher, JJ., Palumbo, AV., Yang, ZK., Podar, M., Brown, SD., Brooks, SC., Gu, B., Southworth, GR., Drake, MM., Brandt, CC., Elias, DA. 2011. Mercury and other heavy metals influence bacterial community structure in contaminated Tennessee streams.

Applied and Environmental Microbiology 77(1): 302-311.

Vyas, A., Pancholi, A. 2009. Environmental degradation due to mining in South Rajasthan: a case study of Nimbahera, Chittorgarh (India). Journal of Environmental Research and Development 4(2): 405-412.

Wang, YP., Shi, JY., Wang, H., Lin, Q., Chen, XC., Chen, YX. 2007. The influence of soil heavy metals pollution on soil microbial biomass, enzyme activity, and community composition near a copper smelter. Ecotoxicology and Environmental Safety 67(1): 75-81.

Xie, J., He, Z., Liu, X., Liu, X., Nostrand, JDV., Deng, Y., Wu, L., Zhou, J., Qiu, G. 2011. Geochip-based analysis of the functional gene diversity and metabolic potential of microbial communities in acid mine drainage. Applied and Environmental Microbiology 77(3): 991-999.