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Research Article

Assessment of water quality of the ex-sand mining sites in Pasir Sakti Sub-District, East Lampung for tilapia (*Oreochromis niloticus*) culture

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Abstract

Sand mining activities in Pasir Sakti Sub-District, East Lampung Regency, have changed the landscape and the allotment of land around it. The former sand mining area now becomes large puddles that are not utilized. This study aimed to analyze the suitability of water quality in ex-sand mining areas for tilapia (*Oreochromis niloticus*) culture. Observations were carried out at three stations in January-October 2019. Water quality measurements were performed to check water depth, clarity, temperature, current, dissolved oxygen, pH, salinity, nitrate, phosphate, iron, sulfate, and phytoplankton density. Analysis of suitability for aquaculture was carried out using weighting and scoring methods. Based on the results of the suitability analysis, the scoring result of the sand mining land for *O.niloticus* culture was in the range of 64% -68%. This score is classified as marginally suitable. The parameters with low scores are clarity, dissolved oxygen, temperature, pH, ammonia, phosphate, and iron (Fe) concentration. Meanwhile, salinity, nitrate, sulfate, and phytoplankton density indicate conditions that are suitable for aquaculture. Therefore, severe treatment is needed to improve water quality to make it ideal for *O.niloticus* culture.

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Introduction

Mining activities may frequently cause environmental problems, namely ecological damage due to negative impacts in the form of the amount of land damaged after mining activities are carried out (Sari and Buchori, 2015; Rizqan et al., 2016; Gavriletea, 2017). One of the areas that have an enormous sand mining potential is Pasir Sakti Sub-District, East Lampung Regency, Lampung Province. According to Supardan et al. (2006), sand is considered a treasure that is stored in the land of Pasir Sakti Sub-District. The sand mining activities that began in 2004 has provided economic benefits for residents (Firdaus, 2012). They got the income from sand excavation activities, sand trading, and selling their gardens and lands to traders or sand mining companies. But over time, sand mining activities are now causing problems for the residents. According to the Department of Marine Affairs and Fisheries of East Lampung Regency, the area of ex-sand mining in Pasir Sakti Sub-District reached 8,000 ha. According to PT. Jaya Pacific Propertindo, the potential of sand in the Rawa Sragi area (Pasir Sakti Sub-District and surrounding areas) reaches 30,000 ha, with sand deposits reaching 1.2 billion m^3. Based on measurements using the Google Earth feature, the total area of the lake from ex-sand mining area is estimated at 1,200 ha.

The waters in the ex-sand mining area in the Pasir Sakti Sub-District is currently in the form of lake/puddles and unutilized (Hasani et al., 2021a; Hasani et al., 2021b). However, based on the Decree of The Minister of Maritime and Fisheries Affairs of the Republic of Indonesia, Pasir Sakti Sub-District is an aquaculture area in Lampung Province. This sub-district is known as one of the fishery commodities producers in Lampung Province. Therefore, it would be a huge benefit if the unutilized waters from ex-sand mining areas can be used for aquaculture activities.

The ex-sand mining land with specific characteristics is the potential for aquaculture (Octorina et al., 2013; Octorina et al., 2017). However, water quality in this area is not optimum (Octorina et al., 2017; Hasani et al., 2021), acidic (Firdaus, 2012), and high heavy metal content (Darmayanti et al., 2000; Kurniawan, 2018) requires special treatments to be utilized for aquaculture. The purpose of this study was to scientifically analyze the suitability of the ex-sand mining waters in Pasir Sakti Sub-District for tilapia (*O. niloticus*) culture.

Materials and Methods

Study sites

Water quality observations were conducted from January to December 2019. Water samples were taken from three stations (nine points) which considered to represent the characteristics of the location of the sand mine area. Coordinates of stations were recorded by using the *Global Positioning System* (GPS). Station 1 is located in the north (Mulyosari Village) at 5°30'26"S and 105°46'25"E, which is a relatively narrow and fairly old sand excavation area. Station 2 is located in the middle (Rejomulyo Village) at 5°31'30"S 105°46'17"E. Station 3 in the south (Boundary of Rejomulyo village and Kedung Ringin Village) with coordinates of 5°33'06"S and 105 ° 46'29"E. These stations are the most extensive ex-mining location (Figure 1).

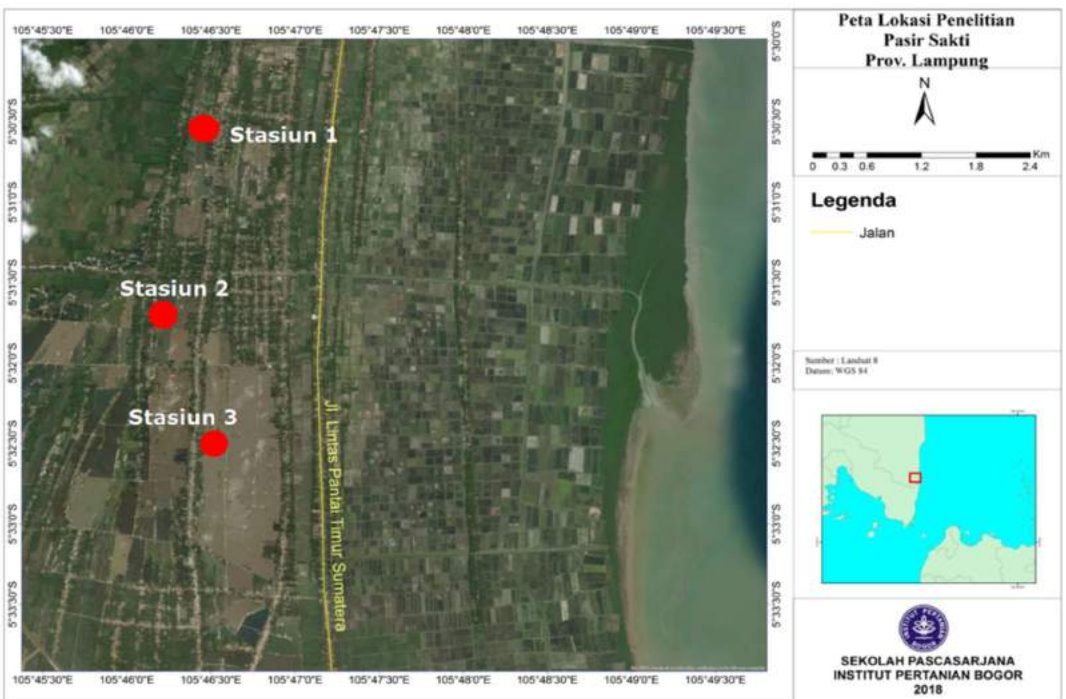

Figure 1. Map of the observation station: Station I (Mulyosari Village), Station 2 (Rejomulyo Village) and Station 3 (the boundary of Rejomulyo Village and Kedung Ringin Village).

Water quality measurement

Physico-chemical parameters of the waters were measured in-situ, together with water and phytoplankton sampling. Water quality data that cannot be measured in-situ was tested in a laboratory. Samples were taken using a Van Dorn water sampler. The parameters observed were temperature, clarity, depth, current, pH, salinity, dissolved oxygen, phosphate, nitrate, sulfate, Fe, and phytoplankton diversity. Water samples were analyzed at the Integrated Laboratory and Technology Innovation Center of the University of Lampung, regarding APHA (2012). Fe concentration was measured refers to the EPA 2007 (5th Revision) method (APHA 2012), using Inductively Coupled Plasma-Atomic Emission

Spectrometry (ICP-AES). Meanwhile, sulfate (SO_4^{2-}), ammonia (NH_3), nitrite (NO_2-N), nitrate (NO_3-N), and phosphate (PO_4) were measured by using the spectrophotometry method with ascorbic acid (APHA, 2012). Phytoplankton samples were taken using plankton net number 20 from the bottom of the water to the surface (Hasani et al., 2012; Muhtadi et al., 2020). Phytoplankton samples were immediately given a Lugol's iodine solution 3% (3 mL per 100 mL sample) (Bellinger and Siege, 2010) and then stored in a coolbox with a temperature of ± 4°. Phytoplankton identification was performed by using a microscope with a magnification of 100 times. The obtained plankton was identified using the identification books of Yamaji (1976), Tomas (1997), Bellinger and Siegee (2010). Phytoplankton calculations were performed by using the Sedgwick-rafter counting chamber. The density of phytoplankton per liter was calculated using the formulation of APHA (2012); Hasani et al. (2012); Muhtadi et al. (2020)

Waters suitability analysis for fish culture

Water suitability analysis for *O. niloticus* culture was carried out with a land/water suitability matrix using weighting and scoring methods (modification of Ministry of Maritime and Fisheries Affairs of the Republic of Indonesia, 2011; Yulainto et al., 2017; Anggraini et al., 2018), through the following stages:

1. Suitability Score (A), as shown in the third column of the matrix. This scoring used weighting for each water quality parameter. The aim is to differentiate the score of suitability level by using the scoring method. Suitability scores are defined as follows: Very Suitable with a score of 5; Fairly Sufficient with a score of 3, and not suitable with a score of 1 (Table 1).

Table 1. The matrix of water quality parameters assessment for tilapia (*O. niloticus*) culture suitability.

Parameters	Range	Score (A)	Weight % (B)	(A x B)	Reference
Clarity (m)	> 5 >3 – 4.9 < 2.9	5 3 1	5	25	Beveridge (1991); Hastari et al. (2017)
Dissolved Oxygen (mg/L)	4-7 3-4 dan 7.5-8 <3 dan >9	5 3 1	10	50	Boyd, (1990); Kordi and Tancung (2010); Lucas et al. (2018)
Salinity (‰)	< 0.5 1-5 >5	5 3 1	5	25	Boyd (1990); Kordi and Tancung (2010)
Temperature °C	28 -32 20-27 and 32.5-33 <20 and >33	5 3 1	5	25	El-Sayed and Kawanna (2008); Kordi and Tancung (2010); Hidayati et al. (2019)
pH	6.5-8.5 5-6.4 and 8.6-9 <5 and >9	5 3 1	10	50	El-Sherif and El-Feky (2009); Kurinawan (2012); Lucas et al. (2018)
Nitrate (mg/L)	0,9 1.0 – 2.0 >2.0	5 3 1	10	50	El-Sayed, (2006); Setiadi et al. (2018).
Ammonia (mg/L)	<0.1 0.1 – 0.2 >0,2	5 3 1	10	50	Popma and Lovshin (1996); El-Sayeed (2006); Hastari et al. (2017)
Phosphate (mg/L)	> 0.2 – 0.5 0.1-0.19 dan 0.51-0.6 <0.2 dan >0.6	5 3 1	10	50	Hastari et al. (2017)
Fe (mg/L)	< 0.4 0.5 – 10 > 10	5 3 1	15	75	CCREM (1987) in Effendi (2003); EPA (2002)
SO_4 (mg/L)	< 80 80 – 400 > 400	5 3 1	15	75	Kutty (1987); Menezes et al. (2017)
Phytoplankton (cells/L)	> (1.5 x 10^4) and < (5 × 10^5) (2 x 10^3) – (1.5 x 10^4) and (5 × 10^5 – 10^6) (2 x 10^3) and > (1 x10^8)	5 3 1	5	25	Yulianto et al. (2017)
Total		**5**	**100**	**500**	

Notes: modification from the Ministry of Maritime Affairs and Fisheries of Indonesia (2011); Radiarta et al. (2004); Pramono et al. (2005); Hastari et al. (2017). Note: Scores (5: good; 3: moderate; 1: less). The score is ∑ (n; i = 1) = A × B.

2. The weight of the parameter (B), was presented in the fourth column of the matrix; each water quality parameter was provided with a different weight due to different role in supporting the life of aquaculture biota. Water quality parameters with a significant role will get a higher value than parameters with lower impact.
3. Score (AxB) was calculated by multiplying score (A) with a weight (B) for first parameters to n-parameters,
4. Furthermore, the total score from each parameter was used to determine the suitability level of land aquaculture based on water quality characteristics (Ministry of Maritime and Fisheries Affairs of the Republic of Indonesia, 2011); Muhaemi et al. (2015); Hastari et al. (2017); Yulianto et al. (2017):

$$\text{Suitability Score} = \frac{\text{Score}}{\text{Maximum Total Score}}\ x\ 100\ \%$$

Based on the suitability score, the level of assessment is classified into several classes, as follows:

- S1: highly suitable with a score of 85-100%. This indicates that the water does not have a limiting factor for fish culture activities,
- S2: moderately suitable (score of 75-84%). There are only minor limiting factors for users and they only need a little treatment.
- S3: marginally suitable (score of 65-74%). This score means that the water has serious limiting factors for aquaculture activities. Therefore, serious treatments are needed to improve water quality for aquaculture activities.
- Class N: not suitable with value/score <65%. This means that the water cannot be used for aquaculture activities due to the permanent barrier or limiting factor.

Results and Discussion

Sand mining activities in Pasir Sakti Sub-District, East Lampung Regency, from 2004-2017, have changed the shape of the landscape in that area (Figure 2). These activities have left the land in the form of lakes/puddles with the size of thousands of hectares. Based on measurements using Google Earth, the ex-sand mining area stretches for approximately 10 km (North to South) and width between 0.5-1.5 km (East to West). The utilization of this area has its own challenges because the water in this area tends to have specific water and soil quality.

Waters quality

The ex-sand mining area in Pasir Sakti Sub-District is now abandoned in the form of huge lakes/puddles, with a depth of approximately 1.4-5.25 m. In general, there are several parameters that are still within the quality standards for the *O. niloticus* culture using floating fish cages. Water temperature in the waters of the ex-sand mining area ranged from 29.3-36.5^{o}C with an average of 32.13^{o} C on Station 1, and 32.34^{o} C on station 2 and 32.61^{o} C on station 3. These conditions have exceeded the quality standard for aquaculture activities. According to Kordi and Tancung (2010), the optimum temperature range for fish in tropical waters is between 28-32°C.

Figure 2. Ex-sand mining area in Pasir Sakti Sub-District, East Lampung which has not been utilized for aquaculture activities.

While the optimum temperature for *O. niloticus* ranged from 24 to 32°C (El-Sayed and Kawana, 2008). Generally, in addition to high average temperatures of water, temperatures at the study site also showed significant range variations. These conditions occurred because the area is located in a coastal area with low altitude and sandy soil. According to Effendi (2003), the temperature is strongly influenced by seasonal, altitude, land elevation of sea levels. The result showed that the water clarity level in the three stations is not suitable for *O. niloticus* culture. Water clarity level in the ex-sand mining area shows a range of 65.0-140.0 cm with an average of 93.23 cm on Station 1, 22.0-98.40 cm with an average of 69.10 cm on Station 2 and 48.50-115.00 with an average of 90.09 cm on Station 3. This condition is not suitable to support aquaculture activities, especially in floating fish cages. Based on the water suitability value for aquaculture activities, water clarity level <2.9 m is classified as not good for aquaculture; water clarity level of > 3–4.9 m is classified as quite good, while water clarity level > 5 m is classified as very good (Hastari et al., 2017). The low clarity level is presumably caused by high suspension particles and dissolved particles in the form of small grains of sand. This caused the water becomes coloured and turbid. The low clarity level will affect the survival of phytoplankton, the photosynthesis process and the fish sight (Hasani et al., 2012). The depth of the water in the ex-sand mining area ranged from 1.40-5.25 m with an average depth of 3.271 m. This condition indicates that the depth of the lake/puddles at ex-sand mining area is too shallow for aquaculture activities (Kordi and Tancung, 2010; Hastari et al., 2017; Anggraini et al., 2018). Water depth is closely related to the location of the floating fish cage. The floating fish cage should not be deployed in waters that are too shallow or too deep. Waters that are too shallow will be vulnerable to the accumulation of waste from the leftover feed and fish metabolism (Kordi and Tancung, 2010). Meanwhile, waters that are too deep (> 40 m) will cause trouble in the deployment of floating fish cages that will require a significant cost (Hastari et al., 2017).

The result showed that the water current in ex-sand mining waters area ranged from 1.19 to 60.0 cm/s (average 22.78 cm/s). The current in this area is categorized as low. However, water currents play an important role in water circulation the distribution of dissolved solid and oxygen. According to Affan (2012), currents play an important role in water circulation; in addition to carriers of dissolved and suspended solids, currents also affect the amount of oxygen solubility in water. Current strength can reduce fouling organisms in floating fish nets. Dissolved oxygen (Table 2) in ex-sand mining waters were ranged from 4.11-8.8 mg/L with an average of 6.98 mg/L (Station 1), 6.59 mg/L (Station 2), and 6.98 mg/L (Station 3).

According to water quality standards of the Government Regulation of the Republic of Indonesia No. 82 the year 2001 (class II), the range of dissolved oxygen for fish culture activities is > 4 mg/L (Tatangindatu et al., 2013). Thus, the concentration of dissolved oxygen in the water in the ex-sand mining area of Pasir Sakti Sub-District is classified as excellent or suitable for aquaculture activities in floating fish cages. Salinity also showed a proper range for aquaculture activities with the value of 0.00 ‰.

Table 2. Water quality parameters of ex-sand mining area in each station.

No	Parameters	ST 1 (Mulyosari)		ST 2 (Rejomulyo)		ST3 (Rejomulyo-Kd. Ringin)	
		Range	Averages	Range	Averages	Range	Averages
1	Temperature (°C)	29.3-35.4	32.13	30.1-36.5	32.34	31.6 - 35	32.61
2	Depth (cm)	140.0-525.0	327.06	135.0-320.0	211.56	230.0-354.0	295.56
3	Clarity(cm)	65.0-140.0	93.23	22.0-98,.40	69.10	48.50-115.00	90.09
4	Current (sm/s)	1.19-60.0	22.78	2.12-60.50	18.87	5.15-71.70	29.26
5	Odor	No	No	No	No	No	No
6	TSS (mg/L)	5.33-33.33	17.904	6.27-54.57	21.728	4.00-46.67	21.932
7	TDS (mg/L)	50.33-110.00	75.310	50.00-990.67	277.165	50.30-130.00	100.498
8	pH	3.4-7.4	6.10	5.7-7.6	6.64	6.6-7.525	7.03
9	Salinity (‰)	0.00	0.00	0.00	0.00	0.00	0.00
10	Dissolves Oxygen (mg/L)	4.35-8.5	6.98	4.11-8.8	6.59	4.27-8.5	6.98
11	PO_4-P(mg/L)	0.001-0.077	0.0247	0.002-0.111	0.046	0.002-0.082	0.026
12	NO_3-N (mg/L)	0.316-2.697	1.282	0.277-3.484	1.724	0.244-2.932	1.350
13	NH_3-N (mg/L)	0.074-2.479	0.770	0.039-1.248	0.468	0.072-1.032	0.392
14	SO_4 (mg/L)	30.397- 90.428	56.616	12.933-68.939	34.588	35.767-67.211	48.303
15	Fe (mg/L)	0.159-2.766	1.284	0.558-5.898	3.012	0.227-2.026	0.923
16	Pyitoplankton (cells/L)	51,648-490,812	188,314	45,698-788,022	339,407	55,091-445,247	204,729
17	Macrophyte	*Salvinia* sp, Lotus (small)		*Eichorrnia* sp. (rarely), Salvinia sp		*Salvinia* sp, Lotus (small), *Thypa* sp	

pH measurements in ex-sand mining waters were ranged from 3.4 - 7.6 with an average pH of 6.10 (Station 1), 6.64 (Station 2), and 7.03 (Station 3). This condition tends to be acidic and fluctuated. Therefore, pH is something that should be considered in terms of fish culture development in the ex-sand mining area in Pasir Sakti Sub-District, East Lampung Regency. While a proper pH for fish growth ranged from 6.5-9.0 with an optimal range of 7.5–8.7 (Kordi and Tancung, 2010). Acording to Kurniawan (2012) and Triswiyana et al. (2019), optimal range of pH for tilapia culture are 6.5 – 8.0.

Other chemical parameters examined in this study are ammonia (NH_3), nitrate (NO_3), phosphate (PO_4), sulfate (SO_4) and iron (Fe). The result showed that ammonia concentrations were ranged from 0.104-1.479 mg/L (with an average of 1.066 mg/L at Station 1, 0.632 mg/L at Station 2 and 0.545 mg/L at station 3). Phosphate concentrations were ranged from 0.001-0.111 mg/L (with an average of 0.0247 mg/L at Station 1, 0.046 mg/L at Station 2 and 0.026 mg/L at Station 3). Nitrate concentrations were ranged from 0.244-3.484 mg/L (with an average of 0.835 mg/L at Station 1). Sulfate concentrations were ranged from 12.933-90.428 mg/L (with an average of 56.617 mg/L at station 1, 34.588 mg/L at station 2, and 48.303 at station 3); while Fe concentration were ranged from 0.159 to 5.898 mg/L (with an average of 1.284 mg/L at Station 1, 3.012 mg/L at Station 2 and 0.923 mg/L at Station 3).

Nitrate and sulfate concentrations show a proper range for aquaculture activities. Nitrate concentrations that are good for aquaculture activities are <1.0 mg/L (Setiadi et al., 2018). In comparison, sulfates levels in the natural freshwater range from 2-80 mg/L (Effendi, 2003).

Furthermore, the result of phosphate, ammonia and Fe indicated that water conditions in ex-sand mining waters areas need some kind of treatment before it can be used for *O. niloticus* (Hastari et al., 2017; Anggraini et al., 2018). Fortunately, phytoplankton density indicates that ex-sand mining waters are suitable for aquaculture activities (Yulianto et al., 2017). The density of phytoplankton in the ex-sand mining waters area in the Pasir Sakti Sub-District showed a range of 51,648-788,022 cells/L with an average density of 188,314 cells/L at Station 1,339,407 cells/L at Station 2 and 204,729 cells/L at station 3.

Suitability of water quality for aquaculture

Water suitability analysis was carried out using modified matching and scoring methods. This method is referring to the method from the Ministry of Maritime Affairs and Fisheries of the Republic of Indonesia (2011); Pramono et al., 2005; Radiarta et al., 2014; Hastari et al. (2017) and Yulianto et al. (2017). This method is presented in Table 1. The parameters considered in this study are water clarity, temperature, current, dissolved oxygen (DO), pH, salinity, Nitrate (NO_3-N), Phosphate (PO_4-P), iron (Fe) concentration and Sulfate (SO_4). The results of the suitability calculation of the ex-sand mining area for *O. niloticus* culture with floating fish cages are presented in Table 3. The result of suitability analysis with matching and scoring method showed a suitability level of 64% for Station 1 (Mulyosari Village); 68% at Station 2 (Rejomulyo Village), and 68% at Station 3 (Rejomulyo and Kedung Ringin Border Village).

Table 3. Suitability assessment of ex-sand mining area for tilapia (*O. niloticus*) culture by stations.

Parameter	Empiric value			Score (A)			Weight (B)	Maximum Score	Score (A x B)		
	St 1	St2	St3	St 1	St2	St3			St 1	St2	St3
Brightness (cm)	93.23	69.203	90.089	1	1	1	5	25	5	5	5
Dissolved Oxygen (mg/L)	6.984	6.587	6.983	5	5	5	10	50	50	50	50
Salinity (‰)	0.000	0.000	0.000	5	5	5	5	25	25	25	25
Temperature (°C)	32.133	32.336	32.606	3	3	3	5	25	15	15	15
pH	6.098	6.636	7.027	3	5	5	10	50	30	50	50
Nitrate (mg/L)	0.282	1.724	1.350	3	3	3	10	50	30	30	30
Ammonia (mg/L)	0.770	0.468	0.392	1	1	1	10	50	10	10	10
phosphate (mg/L)	0.025	0.046	0.027	1	1	1	10	50	10	10	10
Fe (mg/L)	1.284	3.012	0.923	3	3	3	15	75	45	45	45
SO_4 (mg/L)	56,617	34.588	48.303	5	5	5	15	75	75	75	75
Phytoplankton (cells/L)	188,314	339,407	204,729	5	5	5	5	25	25	25	25
Total score							**100**	**500**	**320**	**340**	**340**
Suitability score (%)									**64.00**	**68.00**	**68.00**

Notes: St 1: Mulyosari Village; St 2: Rejomulyo Village; St 3: Boundary of Rejomulyo-Kedung Ringin Villages.

Based on this value, it can be concluded that the water quality from all stations in the ex-sand mining area is classified as S3 class or marginally suitable for *O. niloticus* culture. This condition means that the water in the ex-sand mining area has severe limiting factors for fish culture using floating fish cages (Radiarta *et* al., 2014; Hastari et al., 2017, Yulianto et al., 2017). The low suitability score is mainly influenced by several parameters, namely: clarity, dissolved oxygen, temperature, pH, ammonia, phosphate, and Fe concentrations. Furthermore, other parameters such as salinity, nitrate, sulfate, and phytoplankton density showed a suitable condition for aquaculture. Therefore, if the waters in the ex-sand mining area are to be used as a location for aquaculture activities, severe treatments are needed to improve water quality - especially for parameters with a low score

Conclusion

Water quality suitability score in the ex-sand mining area for *O. niloticus* culture is classified as class S3 or marginally suitable. This condition is mainly influenced by the parameters of clarity, dissolved oxygen, temperature, pH, ammonia, phosphate, and iron (Fe) concentration. Therefore, serious treatment is needed to improve water quality to make it suitable for *O. niloticus* culture activities using the floating fish cage method.

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