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Ornamental Carp Fish Cultured in Settling Pond after Revegetation of Ex-Silica Mining Area

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ABSTRACT

This study looked at a settling pond at an ex-silica mine located in Sukabumi, Indonesia. The settling pond was built in order to reduce the effect of acid mine drainage. Acid mine drainage is the main pollutant at the open pit mining and it can contaminate aquatic biota. In order to utilise the settling pond, ornamental fish was cultured. The objective of this research was to analyse the possibility of aquaculture for ornamental fish in the settling pond ex-silica mining area. For this purpose, three species of ornamental fish of koi carp (*Cyprinus carpio*), gold fish (*Carassius auratus*) and comet carp (*Carassius auratus auratus*) at the settling pond were compared with control pond outside the mining area. We measured their specific growth rate and survival rate for 10 weeks. Results showed that specific growth rate indicated by length and weight for all species was higher at the settling pond compared with the control pond. In contrast, the survival rate percentage of all the three species was higher than those of the control pond, i.e. 48.5-93 % at the settling pond vs. 94.5-96% at the control pond. Meanwhile, the specific growth rate of weight was 0.92-1.88 % day^{-1} at the settling pond and 0.34-0.61 % day^{-1} at the control pond, while the length was 0.70-1.02 % day^{-1} at the settling pond and 0.31-0.63 % day^{-1} at the control pond. These indicated

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that the three species of ornamental fish can be cultured at the settling pond even at low survival rate condition.

Keywords: Acid mine drainage, ornamental fish, plankton, settling pond, specific growth rate, water quality

INTRODUCTION

Mining is an exploitation of non-renewable resources with significant impacts on the environment, such as alteration in landscapes, flora and fauna, soil structure, pattern of surface and deep soil water flow. An unfortunate outcome of this activity is acidic water. Due to its very low pH value, together with exposure to remaining metals and reactions with rain water, aquatic biota can be contaminated by high acidity which can also dissolve metal. The water becomes too toxic for aquatic organisms, and harm the ecosystem (Simate & Ndlovu, 2014). Vegetation alteration due to mining also affects metal, chemical and physical properties, which mobilise and transport them into soil and settling ponds (Huot et al., 2015). According to Brain (2017), mining operations change water quality and quantity in the Andes.

Fish farming is one of the efforts to make use of ex-mining area settling ponds. Several research has also confirmed the feasibility of fish farming in ex-mining ponds. For instance, Pangas catfish (*Pangasius pangasius*) and catfish (*Clarias batrachus*) are widely cultivated in ex-mining ponds in Bangka Belitung Islands, Indonesia (Bidayani, 2007) and coal ex-mining ponds in Kalimantan Timur, Indonesia (Pagoray & Ghitarina, 2016). Mozambique tilapia, known locally known as mujair (*Oreochromis mossambicus*), has also been farmed in lead-contained ponds with weight and length growth rates of 0.453% and 0.223% respectively (Yulaipi & Aunurohim, 2013). In a similar condition, daily growth rate of catfish (*Clarias gariepinus*) was 11.17% (Prasetiyono, 2015). Blue tilapia (*Oreochromis aerus)* was also reportedly grown in settled pond containing heavy metal copper (Straus, 2003), while rainbow trout (*Oncorhynchus mykiss*) can be grown in mining acidic water without any physiological stress symptoms (Viadero & Tierney, 2003). However, to the best of author's knowledge, there is still limited information on ornamental fish farming in the settling pond of ex silica mining area. Therefore, this study analyses the potential of ornamental fish farming in the settling pond of an ex-silica mine.

METHODS

The research was conducted at a settling pond of an ex-mine. One of the silica quarries managed by a mining company is located in Sukabumi District of West Java Province Indonesia with an area of approximately 69 hectares. This company stopped its mining activities in 2013. The company has since tried restoring the ecosystem post-mining through reclamation and revegetation of their ex-mining area and it was designed to become a plantation forest. After three years planting the area, 38, 900 trees have been grown there. Twenty species of trees have been planted with by Pinus merkusii as the dominant tree species. Some cover crops have also been planted to cover the soil surface. Some kind of fertiliser was utilised in order to supply nutrient that is essential for plantation growth. There is a settling pond located in the middle of the ex-mining area. In this settling pond three species fish of ornamental carp were cultured and the specific growth rate and survival rate of those fish observed.

Experiments were carried out for four months (from March to June, 2017) in 5000 m^2 settling pond of ex-silica mining in Sukabumi and the control pond of 500 m^2 fish farming in Bogor, Indonesia. Three kinds of ornamental fish used in the study were koi carp (*Cyprinus carpio*) with average length of 8.5 ± 0.32 cm and weight of 19.7 ± 1.07 g, 5.17 ± 0.40 cm long goldfish (*Carassius auratus*) weighed 6.71 ± 0.60 g, and 5.36 ± 0.36 cm long comet carp (*Carassius auratus auratus*) weighed 6.40 ± 0.70 g, respectively. Fish was maintained in 1.5 m x 1 m x 1 m hapa, 100 fish per hapa, for 10 weeks. Each hapa contained only one kind of ornamental species. The experiment was run in triplicates of each ornamental species, with a total of 9 hapas in each settling pond and control pond. The fish were fed daily, once every morning and afternoon, with commercial pellet Hi-Pro-Vite 788-2 (Indonesia) at 5% of biomass weight.

Fish sampling for length and weight measurement (30 number of fishes) as well as water quality, was done once every two weeks, while visual observation was done daily. Fish body weight was measured using electronic balance Kris Chef EK935OH (Indonesia) and fish body length was measured using Vernier caliper. Sampling for plankton abundance measurement was done by filtration 100 litres of surface water using 45 µm sized plankton net. Filtered water was put into 30 ml sample bottle before preservation using 3─5 drops of Lugol. Plankton abundance was expressed as individuals per litre. Temperature was measured using thermometer, while dissolved oxygen and pH were measured using DO-meter TOA-DO20 (Japan) and pH meter TOA-HM30 (Japan), respectively. Alkalinity, turbidity, TAN, nitrite, and nitrate were measured using Spectrophotometer Optima-SP300 (Japan) with regard to APHA (1989). Plankton microscopic observation was conducted in Laboratory of Aquaculture Environment of Bogor Agricultural Institute. Perimeters analysed were daily specific growth rate and survival rate, plankton abundance (phytoplankton and zooplankton), and water quality (temperature, dissolved oxygen (DO), pH, alkalinity, turbidity, total ammonia nitrogen (TAN), nitrite and nitrate).

The specific growth rate (SGR) and survival rate (SR) were calculated according to Huisman (1987):

$$\text{SGR weight} = [(\ln W_t - \ln W_0)/t] \times 100$$

Where W_0 and W_t are the initial and final weight of the fish (g), respectively, and t is the culture period in days.

SGR length = [(ln L_t─ln L_0)/t] x 100

Where L_0 and L_t are the initial and final length of the fish (cm), respectively, and t is the culture period in days.

SR (%) = N_t/N_0 x 100

Where N_0 and N_t are the initial and final number of fish, respectively.

RESULTS

Daily weight and length growth rate of all fish were found to increase, both in the settling and control ponds, indicating that the settling pond aquatic environment can be utilised for ornamental fish farming. Specific growth rate (SGR) of ornamental fish, both in weight and length, in the settling pond was higher than that of the control. The specific growth rate of weight was 0.92-1.88 % day^{-1} at the settling pond and 0.34-0.61 % day^{-1} at the control pond respectively, while the length was 0.70-1.02 % day^{-1} at the settling pond and 0.31-0.63 % day^{-1} at the control pond respectively. Specific growth rate (SGR) and survival rate (SR) of ornamental fish in this study are shown in Table 1.

Table 1
Specific growth rate (SGR) and survival rate (SR) of ornamental fish

No	Location	Koi carp	Gold fish	Comet carp
		SGR weight (% day^{-1})		
1	Settling Pond	0.92 ± 0.05	1.61 ± 0.47	1.88 ± 0.15
	Control Pond	0.61 ± 0.37	0.34 ± 0.13	0.58 ± 0.07
		SGR length (% day^{-1})		
2	Settling Pond	0.70 ± 0.33	0.97 ± 0.4	1.02 ± 0.46
	Control Pond	0.63 ± 0.36	0.31 ± 0.17	0.42 ± 0.15
		SR (%)		
3	Settling Pond	93.00 ± 0.00	48.50 ± 0.71	61.00 ± 1.41
	Control Pond	94.50 ± 0 .71	95.00 ± 0.00	96.00 ± 0.71

Phytoplankton abundance and zooplankton in the ex-mining area settling pond and control pond can be seen in Figure 1, while dominant compositions of phytoplankton and zooplankton in the ex-mining settling pond and control pond are shown in Figure 2 and 3 respectively. Water quality is shown in Table 2.

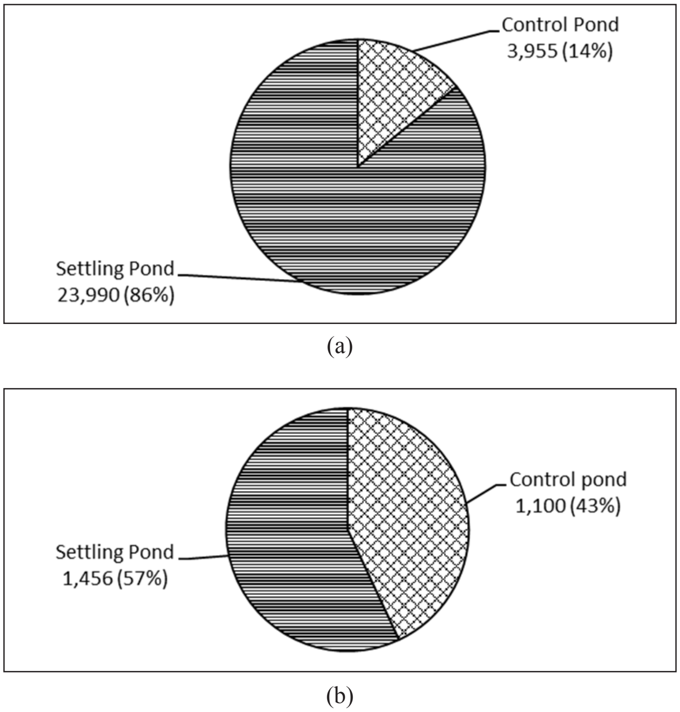


Figure 1. Phytoplankton (a) and zooplankton (b) abundance (individual L^{-1}) in the settling pond and control pond

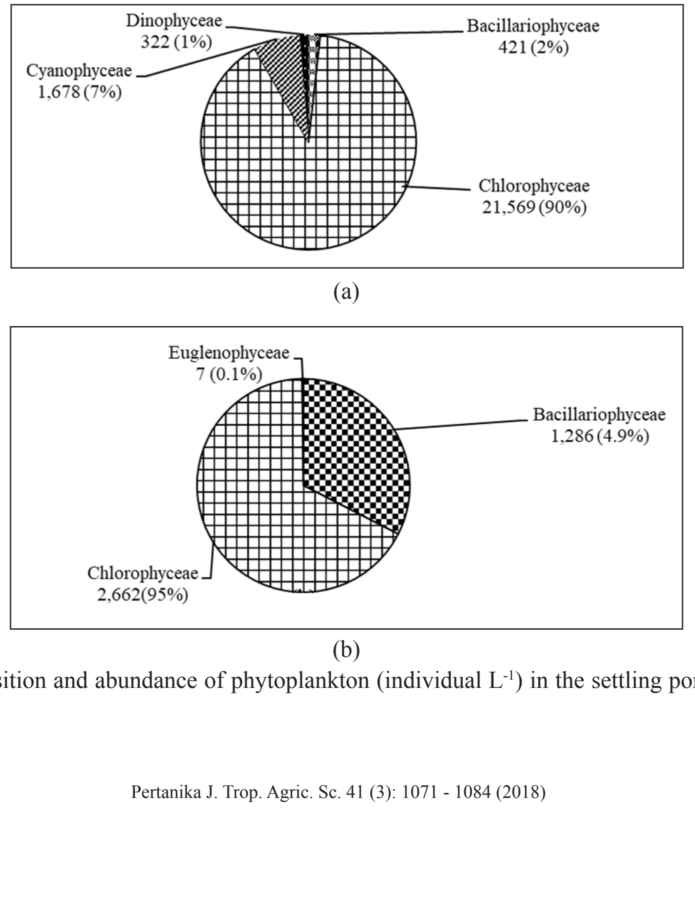
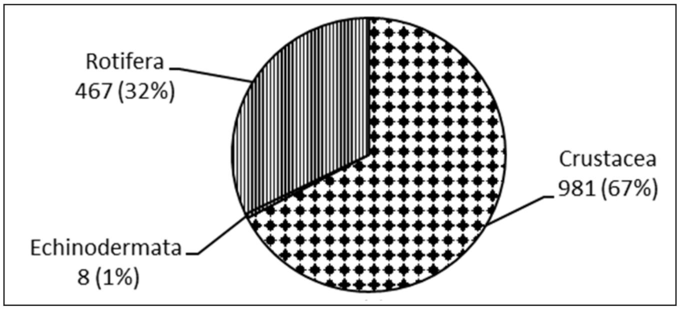
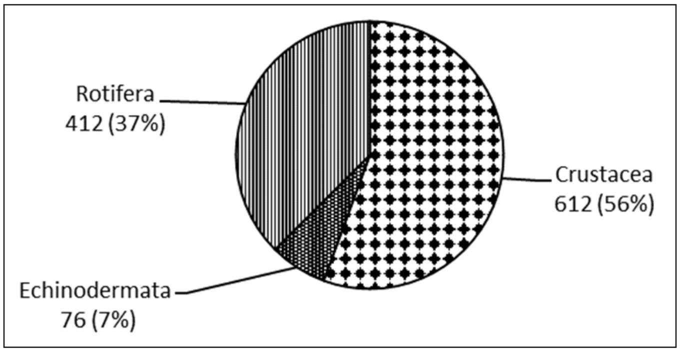


Figure 2. Composition and abundance of phytoplankton (individual L^{-1}) in the settling pond (a) and control pond (b)



(a)



(b)

Figure 3. Composition and abundance of zooplankton (individual L^{-1}) in the settling pond (a) and control pond (b)

Table 2
Water quality in the settling pond and control pond

	Settling pond	Control pond
Temperature (^{o}C)	27.2-29.2	26.5-27.9
DO (mg L^{-1})	6.1-7.8	6.0-7.1
pH	7.08-7.93	6.80-7.67
Alkalinity (mg L^{-1})	28.83-104.16	22.42-70.47
Turbidity (NTU)	20.5-108.0	21.0-53.0
TAN (mg L^{-1})	0.003-0.642	0.001-0.620
Nitrite (mg L^{-1})	0.005-0.457	0.008-0.424
Nitrate (mg L^{-1})	0.167-1.434	0.117-0.670

DISCUSSION

The highest rate obtained by comet fish (*Carassius auratus auratus*) of settling pond SGR length and weight of 1.02 ± 0.86 % day^{-1} and 1.88 ± 0.15 % day^{-1}, respectively, while the lowest was obtained by control goldfish at 0.31 ± 0.17 % day^{-1} and 0.34 ± 0.13 % day^{-1} respectively (Table 1). Previous research on goldfish (*Carassius auratus*) maintained in controlled container (tank, aquarium) fed with commercial feed resulted in the SGR of 1.56 ± 0.02 day^{-1} (Bandyopadhyay et al., 2005), whereas those of monoculture goldfish was 5.21 ± 0.31% day^{-1} (Jha et al., 2006b), those of 0.08 fish L^{-1} density was 1.97 ± 0.014% day^{-1} (Niazie et al., 2013), compared to the control of 1.07 ± 0.03% day^{-1} (Wang et al., 2015). The SGR of goldfish fed four times day^{-1} was 0.499 ± 0.025% day^{-1}, while those obtained by twice a day feeding was 0.472 ± 0.009% day^{-1} (Priestley et al., 2006). According to Popovic et al. (2016), prussian carp (*Carassius gibelio*) grows rapidly and it can tolerate water pollution. SGR of koi carp (*Cyprinus carpio* var *koi*) farmed in a density of 0.1 fish L^{-1} was 4.38 ± 0.03% day^{-1} (Jha & Barat, 2005a), whereas those of fish maintained without water circulation was 3.92 ± 0.03% day^{-1} (Jha & Barat, 2005b). The koi fish fed with commercial feed was 3.66 ± 0.05% day^{-1} lower than the natural feed of 5.09 ± 0.14% day^{-1} (Jha et al., 2006a), while those of monoculture was 5.45 ± 0.09% day^{-1} (Jha et al., 2006b). Based on the research, ornamental fish growth rate in this study was relatively low, which was probably caused by settling and control pond water content and quality difference to those of the controlled farming media such as in the aquarium or fish tank. Fish growth is affected by age of fish, adult fish grows slower than fry and juvenile fish (Rahardjo et al., 2011). In this study, we used adult fish, so its growth was relatively slower.

Meanwhile, the SGR difference of both length or weight in settling and control pond was probably caused by availability of natural feed in those ponds. Growth is correlated with the ability to obtain food and environmental adaptation, thus food as energy source becomes one of the main factors. Energy is mainly used for metabolism, the demand which needs to be fulfilled first, with the remaining used for growth (Goddard, 1995; Jobling, 1994). Farming performances in the form of growth and survival rate, biomass, and feed conversion ratio are highly dependent on feed (Martinez-Cordova et al., 2014). A research by Mladineo et al. (2010) on sea bass (*Dicentrarchus labrax*) showed that fish maintained in recirculated system with algal addition (RAS+HRAP) had a higher growth rate of 0.3 ± 0.1% day^{-1} than without algal of 0.23 ± 0.1% day^{-1}. Ornamental fish in this study was fed with commercial feed and supported by aquatic natural source, such as plankton. It was reported that plankton plays an important role in fish as feed source (Feuga, 2000).

It can be seen that settling pond had higher phytoplankton and zooplankton abundance of 23, 989 individual L^{-1} (86%) and 1456 individual L^{-1} (57%) than the control (Figure 1), thus fish in the settling pond had higher access to natural feed than those of the control. In the area around the settling pond there was revegetation activity which used fertiliser. The nitrogen and phosphorus of fertiliser drifted through the surface run off into the settling pond. The results of Jha et al. (2004) showed that plankton abundance increased 5 times in fertilised tanks compared with those not fertilised. In both the settling and control ponds, phytoplankton abundance was dominated by Chlorophyceae (Figure 2) indicating healthy aquatic condition (Barinova & Krupu, 2017). According to Wu et al. (2014), chlorophyte index is usable for bio-assessment of water quality. Indicators of polluted water is usually dominated by Bacillariophyceae as in the waters of the ex-gold mining area (Priyono, 2012), in estuarine Creek Nigeria (Onyema, 2007) and in a Moroccan shallow reservoir (Belokda et al., 2017). Phytoplankton acts as a primary producer for zooplankton presence as a function of food source. It was also reported in other research that zooplankton abundance directly correlated to growth rate (de Souza, 2015). High-zooplankton aquatic region is able to produce better fish growth (Jha & Barat, 2005b; Jha et al., 2006b). The growth of koi carp increased by about 1.3 times on zooplankton abundance increased approximately 5 times (Jha et al., 2004). Zooplankton observed in this research was dominated by crustacean (Figure 3), good natural feed source for fish. A report noted that koi generally likes crustaceans, such as cladocera (daphnia, moina, bosmina) and copepoda (cyclops, diaptomus, nauplii), which were found in koi gut (98.02%) from its composition, while those of goldfish was 96.55% (Jha et al., 2006b). Koi fish culture in concrete tanks containing cladocera and copepods of 1286.63 numbers L^{-1} (79.29%) resulted in the highest SGR of 5,14% ± 0.03 % day^{-1} (Jha et al., 2004). Settling pond has an abundance crustacean higher at 67%, while 57% at control, supporting better growth in the settling pond. Cladocerans is usable for bio-indicator of water quality (Montemezzani et al., 2017).

Survival rate of ornamental fish in settling pond was lower than those of control, with the highest of settling pond obtained by koi carp at 93.0 ± 0.00% and the lowest by goldfish of at 48.5 ± 0.71%. In the control pond, the highest survival rate was obtained by comet carp 96.5 ± 0.71% and the lowest by koi carp of 94.5 ± 0.71%. The survival rate is determined by water quality as certain aquatic condition is needed for optimum fish growth. Jha and Barat (2005b) reported 95.21 ± 1.03% survival rate of koi maintained in daily water exchange, ensure better water quality, much higher than those of otherwise of 60.43 ± 2.39%. The SGR of corydoras (*Corydoras aeneous*) maintained in 30% day^{-1} water exchange had a survival rate of 87% (Diatin et al., 2014), while those of 50% day^{-1} water exchange had a higher rate of 97% (Diatin et al., 2015).

In this study, data for water quality are presented in Table 2. It can be seen that temperature, DO, and pH in the settling and control ponds were in feasible range for ornamental fish farming, as koi, goldfish, and comet need to live in neutral pH of 7.0 (Petrovicky, 1988) or 6.5-7.6 (Axelrod et al., 1988), temperature of 24-28^{o}C (Petrovicky, 1988) and minimum dissolved oxygen of 3 mg L^{-1} (Boyd, 2001). The low survival rate of ex-mining settling pond was probably caused by too high alkalinity rate and turbidity. Minimum alkalinity concentration for fish farming is 20 mg L^{-1} (Wedemeyer, 1996), while lower rate will cause fish physiological stress (Bhatnagar & Devi, 2013). The most suitable alkalinity for fish is around 50 mg L^{-1} (Boyd, 2007), 100–150 mg L^{-1} (Wedemeyer, 1996) and 50-200 mg L^{-1} (Bhatnagar & Devi, 2013). In this study, the alkalinity rate of settling pond (28.83-104.16 mg L^{-1}) was relatively higher than the control pond (22.42-70.47 mg L^{-1}). Previous research conducted on koi fish farming indicated that the alkalinity rate of 35.14 ± 0.77 mg L^{-1} led to a survival rate of 93.363 ± 0.89% (Jha & Barat, 2005a), while lower survival rate of 60.43 ± 2.39 % was recorded at 146.25 ± 11.02 mg L^{-1} alkalinity rate (Jha & Barat, 2005b). Goldfish farming at 33.92 ± 1.40 mg L^{-1} alkalinity rate generated 91.41% survival rate (Jha et al., 2006b). Lime leaching can increase alkalinity (Bhatnagar & Devi, 2013). Revegetation activity around the settling pond uses ameliorant soil containing lime to increase soil pH. This material is supposed to come into the settling pond through surface run off, so the value of alkalinity in the settling pond has a wide range.

Turbidity represents organic and inorganic matters; both suspended, or dissolved. In this study, turbidity of ex-mining settling pond was at 20.5-108.0 NTU range, slightly lower than the control of 21.0-53.0 NTU. Previous research in tin ex-mining settling pond reported 300 NTU turbidity (Henny, 2010), higher than those of coal mining of 42-271 NTU (Pagoray & Ghitarina, 2016). Feasible turbidity concentration for fish farming ranged between 25 and 50 NTU (Ozbay & Boyd, 2003), less than 20 mg L^{-1} (Wedemeyer, 1996). Other studies mentioned 30-80 NTU (Bhatnagar & Devi, 2013), 0.9-132.3 NTU in pond (Xu & Boyd, 2016), and 50.7 ± 5,5 NTU for carp fish in freshwater reservoir (Akhurst et al., 2017). Turbidity is influenced by the resultant effect of several factors, such as suspended clay particles, dispersion of plankton organisms, and particulate organic matter (Bhatnagar & Devi, 2013). The high turbidity in the settling pond was due to the high plankton abundance, whereas in the control pond its abundance was relatively low. More specifically, the phytoplankton abundance in the settling pond was 6 times higher than that of the control pond (Figure 1). Relatively high alkalinity and turbidity rate presumably indicate lower survival rate in the settling pond.

Toxic parameter of water quality for fish is ammonia (Ebeling et al., 2006) that is harmful even in very low concentration (Crab et al., 2007; Hu et al., 2013), and thus generally recognised as pollutant (Yang et al., 2011). According to Lamoljo et al. (2009) there was a relationship between concentration of N and the nutrient from fertiliser. In this research location, the change of N concentration in water was associated with the applications of fertiliser. Research showed that the total ammonia nitrogen (TAN) value of settling pond was at 0.003-0.642 mg L^{-1}, and this was similar to that of the control at 0.003-0.620 mg L^{-1}. Ammonia toxicity level also depends on fish species and size (Stickney, 2005). According to Boyd (2008), TAN concentration above 2 mg L^{-1} is potentially dangerous at pH above 8. Total nitrogen of carp (*Cyprinus carpio*) maintained in freshwater reservoir was 1.74 ± 0.26 mg L^{-1} (Akhurst et al., 2017). Acute ammonia concentration for common carp (*Cyprinus carpio*) was at LC_{50} 96 h, pH 7.46-7.53, was 0.76-1.26 mg L^{-1} (Abbas, 2006), at LC_{50} 96 h of crucian carp (*Carassius auratus*) was 0.511 ± 0.007 mg L^{-1} (Yang et al., 2010), while at EC_{50}s was 0.1997 mg L^{-1} (Yang et al., 2011).

The nitrite level of the settling pond was 0.005-0.457 mg L^{-1} lower than the control pond at 0.008-0.424 mg L^{-1}. Sensitivity against nitrite is determined by fish size and age (Kroupova et al., 2016; Zhang et al., 2012), species, sex (Zhang et al., 2012), pH, dissolved oxygen, and temperature (Kroupova et al., 2005). Bigger size or older fish is more tolerant to nitrite (Zhang et al., 2012). Nitrite concentration of 0.7 mg L^{-1} in common carp (*Cyprinus carpio*) induced retards growth (Kroupova et al., 2016). Nitrate concentrations of settling and control ponds were 0.167─1.434 mg L^{-1} and 0.117─0.670 mg L^{-1} respectively. Nitrate is relatively not toxic for fish, however the maximum nitrate concentration that is safe for fish farming is 50 mg L^{-1} (Kroupova et al., 2005; Yusoff et al., 2011). At 0.211 ± 0.048 mg L^{-1} nitrite concentration and nitrate at 0.608 ± 0.96 mg L^{-1}, approximately 40% of koi would not survive (Jha & Barat, 2005b) while mortality rate was around 32% at 0.014 ± 0.005 mg L^{-1} nitrite and 0.095 ± 0.012 mg L^{-1} nitrate (Jha et al., 2006a). The values of TAN, nitrite and nitrate in the settling ponds were still within tolerable limits for ornamental fish farming; however, if the concentration increased it could have inhibited the growth and survival of fish.

CONCLUSION

Ornamental fish maintained in the settling pond an ex-silica mine had higher specific growth rate of length and weight than those of the control pond, but lower survival rate. All the three ornamental fish types can be maintained in the ex-silica mining area settling pond. The settling pond of ex-silica mining which had been closed for mining activity, can be utilised for fish culture. It can become a model for utilisation of settling ponds of other ex-mining areas.

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