JIPK. Volume 15 No 1. April 2023
Sinta 1 (Decree No: 158/E/KPT/2021)

e-ISSN:2528-0759; p-ISSN:2085-5842
Available online at https://e-journal.unair.ac.id/JIPK

JIPK
(JURNAL ILMIAH PERIKANAN DAN KELAUTAN)
Scientific Journal of Fisheries and Marine

Short Communication

The Combination of Dolomite and Hydrated Lime with Different Compositions in Sulfuric Acid Soil for Fish Culture Ponds

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OPEN ACCESS

ARTICLE INFO

Received: July 22, 2022
Accepted: August 15, 2022
Published: Sept 27, 2022
Available online: January 29, 2023

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Keywords:
Soil pH
Bottom Soil Pond
Liming Combination
Aquaculture

Abstract

The application of liming material should consider the amount and quality of chemicals related to cost expenditure and target of expected soil properties since it is usually done with an incorrect number's estimation and expected soil-water quality which produces unsuccessful results. This study aimed to analyze the effect of different percentages from each combination of dolomite and hydrated lime (DH); DH1 (75:25), DH2 (50:50), and DH3 (25:75), which used five replications to the soil and water quality. The soil samples were taken from the earthen pond of semi-intensive tilapia fish (*Oreochromis niloticus*) culture in Lat Bua Luang, Rangsit, Thailand, placed into 50 plastic pots (volume = 1.5 L), and mixed with lime of different compositions. Based on the results, the mixture of dolomite and hydrated lime (DH) increased the soil and water pH into the desirable ranges (7.4-8.6). The alkalinity of DH treatments was not higher than that of the single dolomite (DA) or hydrated lime (HA). However, the value was still sufficient (>75 mg/L as $CaCO_3$) to buffer water quality changes. Several depletions of the toxic materials (total aluminum, iron, and manganese) caused by sulfuric acid from pyrite (FeS2) oxidation had been observed in combination treatment, especially in DH1. On the contrary, the essential base cations, calcium, and magnesium increased beyond the single treatment, either dolomite (DA) or hydrated lime (HA). A combination of dolomite and hydrated lime (DH1) as an alternative treatment to remedy aquaculture ponds in acid-containing soil is suggested in terms of efficiency and possible cost-effectiveness.

Cite this as: Fitrani, M., Wudtisin, I., & Kaewnern, M. (2023). The Combination of Dolomite and Hydrated Lime with Different Compositions in Sulfuric Acid Soil for Fish Culture Ponds. *Jurnal Ilmiah Perikanan dan Kelautan*, 15(1):170–178. http://doi.org/10.20473/jipk.v15i1.37719

1. Introduction

Many literatures have detailed the utilization of liming materials on soil and water in aquaculture schemes. However, the proper application is still necessary to be studied because pond sediment characteristics in several areas need specific management related to the amount and kind of lime needed. The pond's changes, particularly earthen ponds, depend on the base unsaturation and exchange acidity; consequently, a particular liming requirement must be adjusted (Boyd, 1995).

Liming is used to neutralize soil's acidity and increase the water's hardness and total alkalinity (Boyd, 2017; Sá *et al*., 2021). In the case of sulphuric acid soils, where pyrite is present, it results in ultra-low pH (<3) upon drying, causing adverse effects on aquaculture. An enormous amount of liming is required and probably costs a considerable amount (Boyd, 1995). However, fish culture can supplement local people's income under appropriate management strategies with cost-effective techniques, particularly with soil and water, in the reclaimed sulphuric acid areas. The proper method will reduce the total cost during the preparation and the farming period. Various research has found that liming could improve the pH of sulphuric acid-containing soil and water (Lyle-Fritch *et al*., 2006; Mahmood and Saikat, 1995; Pine and Boyd, 2011; Sammut, 1996; Sonnenholzner and Boyd, 2000). Each chemical of different kinds indicated improved sediment in pond and water properties and increased fish culture production. Agriculture limestone and lime materials, burn lime (CaO), and hydrated lime ($Ca(OH)_2$) are common chemicals applied to the bottom of soil ponds. Nevertheless, as compared to $CaCO_3$ or $CaCO_3MgCO_3$, the use of calcium hydroxide $Ca(OH)_2$ was more effective in increasing the soil and water pH, and likewise the total alkalinity (Sá *et al*., 2021), with a smaller amount (Fitrani *et al*., 2020). Hydrated lime $Ca(OH)_2$ is a better liming option compared to agricultural limestone (Sá *et al*., 2021). It may be caused by its greater molecular weight compared to limestone which in turn generates a greater base concentration (Boyd, 1995).

Frequently, $Ca(OH)_2$ has also been applied to the bottom of the pond to kill the pathogenic organism. Nonetheless, hydrated lime's fast reaction will cause the pH to increase above ten which is dangerous for aquatic organism. Its cost may be more expensive, and the availability is limited in some areas compared to agricultural limestone. Therefore, this research aims to study the lime requirement by using a combination of hydrated lime $Ca(OH)_2$ and dolomite ($CaCO_3MgCO_3$) to improve the soil and water properties of the sulfuric acid-containing earth. This study is necessary as an alternative method to overcome the fishpond's severe acidity problem and improve fish production cost-effectiveness.

2. Materials and Methods

2.1 Sample Preparation

The soil samples were taken from the earthen pond of semi-intensive tilapia fish (*Oreochromis niloticus*) culture in Lat Bua Luang, Rangsit, Thailand. Sediment samples were spread thinly on a plastic tray and exposed to the air for two weeks to ensure that the iron pyrite had oxidized. Further, dried soils were pulverized to pass a 20-mesh (0.85-mm apertures) sieve. The original dried soil sample contained 4.77±0.12% organic carbon and a pH of 2.69±0.36. Total aluminum and iron, respectively, were 49.4 mg/kg and 20.9 mg/kg, while the total calcium and magnesium were 2.54 mg/kg and 4.11 mg/kg.

2.2 Experimental Design

Dried soil samples were placed into 50 plastic pots (volume = 1.5 L) and mixed with lime with different compositions (Table 1). The treatment used was based on pre-experiment results that used 50 t ha^{-1} of dolomite $CaMg(CO_3)_2$ and 2.3 t. ha^{-1} of hydroxide lime $Ca(OH)_2$, which presented the highest soil and water pH (>7). The calcium carbonate equivalent of each lime was 102.83% for dolomite and 100.82% for hydroxide lime. Distilled water was added to the soil (1.5:1) and stirred. Laboratory analysis was performed on the soil and samples after the seventh and fifteenth day. All samples were incubated indoors for 15 days. Water was added after the first sampling. The combination of liming has been applied to achieve the desirable soil pH target, specifically for aquaculture (7.4-8.6), based on the results investigated by Attanandana and Vacharotayan (1986), Boyd (1995), Boyd and Tucker (2014), Foth (1990) and Wurts and Durborow (1992).

2.3 Soil and Water Analysis Methods

Soil pH was analyzed using 10 g of a pulverized soil sample with 10 ml of distilled water measured with a pH meter according to Boyd (2003). Soil particle-size distribution analysis uses a hydrometer method (Weber and Gokel, 1977). A texture class was assigned based on a percentage of sand, silt, and clay using a soil triangle (Boyd and Tucker, 2014). Soil organic matter (SOM) was analyzed by sulphochromic oxidation in acid, and organic carbon (OC) was measured by the Walkley-Black method with sulfuric acid (H_2SO_4) and potassium dichromate ($K_2Cr_2O_7$) oxidation procedure (Nelson and Sommers, 1996). Exchangeable acidity (Al^{3+} and Fe^{3+}) was analyzed using orthopenatroline and measured through spectrophotometry. The cations Mg^{2+} and Ca^{2+} were displaced from exchange sites with 1.0 N HCl and measured through titration with standard ethylene

Table 1. Composition of dolomite and hydrated lime used in combination treatments

Treatments (Code)	**Chemical material**	**Dosage (t. ha^{-1})**	**% Combination and code**		
			DH1	DH2	DH3
DH	Dolomite (DA)	50	75	50	25
	Hydrated lime (HA)	2.3	25	50	75

Table 2. Mean values ± SD of soil pH resulted from dolomite (DA) and hydrated lime (HA). and combination of dolomite and hydrated lime (DH)[1]

Variables	**Single chemical**	**Combination Dolomite and hydrated lime (DH)**		
Soil pH	Dolomite (DA)	DH1	DH2	DH3
Day-7	7.36±0.03^{c}	7.26±0.02^{b}	7.21±0.02^{a}	7.17±0.02^{a}
Day-15	7.29±0.01^{a}	7.46±0.01^{b}	7.62±0.01^{d}	7.53±0.02^{c}
	Hydrated lime (HA)	DH1	DH2	DH3
Day-7	7.34±0.03^{c}	7.26±0.02^{b}	7.21±0.02^{a}	7.17±0.02^{a}
Day-15	7.42±0.02^{a}	7.46±0.01^{b}	7.62±0.01^{d}	7.53±0.02^{c}

[1] The data corresponded to the mean of five replicates. Different superscripts ($^{a.\ b.\ c}$) in the same row indicate that the means. significantly. differ ($p < 0.05$) among combination treatments by ANOVA.

Table 3. Means ± standard deviation of total alkalinity resulted in dolomite (DA) and hydrated lime (HA) combination (DH)[1]

Total Alkalinity (mg/L as $CaCO_3$)	**Dolomite**	**Hydrated lime**	**Lime combination (DH)**		
			DH1	**DH2**	**DH3**
Day-7	244.8±7.15	235.2±10.73	219.2±4.38	280.8±22.87	223.20±19.06
Day-15	342.4±14.31	356.8±7.15	190.4±13.14	217.6±10.04	180.8±17.53

[1] The data corresponded to the mean of five replicates.

Table 4. Mean values ± SD of soil organic carbon (OC) resulted from dolomite (DA) and hydrated lime (HA). and combination of dolomite and hydrated lime (DH)[1]

Variables	**Single chemical**	**Combination Dolomite and hydrated lime (DH)**		
OC (%)	Dolomite	DH1	DH2	DH3
Day-7	1.38±0.10^{a}	2.23±0.03^{c}	1.84±0.07^{b}	1.84±0.07^{b}
Day-15	1.62±0.08^{a}	2.04±0.15^{b}	1.68±0.01^{a}	1.69±0.01^{a}
	Hydrated lime	DH1	DH2	DH3
Day-7	2.30±0.08^{c}	2.23±0.03^{b}	1.84±0.07^{a}	1.84±0.07^{a}
Day-15	2.27±0.05^{c}	2.04±0.15^{b}	1.68±0.01^{a}	1.69±0.01^{a}

[1] The data corresponded to the mean of five replicates. Different superscripts ($^{a.\ b.\ c}$) in the same row indicate that the means. significantly. differ ($p < 0.05$) among combination treatments by ANOVA.

diaminetetraacetic acid (EDTA) titration. Water pH was measured with a portable pH meter (EcoSense pH100A, YSI) when the sample was collected (Silapajarn *et al*., 2004). Total alkalinity was obtained by titrating \ the water samples with a 0.02 N H_2SO_4 standard solution up to the pH 4.5 endpoint.

2.4. Statistical Analysis

Descriptive statistics have been used to calculate the mean and standard deviation. The data has been analyzed in a one-way variance analysis (ANOVA) by SPSS version 27 (IBM Corp., 2020) to verify significant differences among treatments. When it was detected ($p < 0.05$), the post hoc Tukey HSD means comparison test was used.

3. Results and Discussion

The soil particle distributions showed that every combination of dolomite and hydrated lime (DH) was categorized as sandy clay loam (SCL). However, the percentage of each size class differs. The DH group consisted of more than 50% sand and > 20% of clay. It was similar to the single dolomite (DA) treatment and hydrated lime (HA). Sandy clay loam texture was suitable for aquaculture (Boyd *et al*., 2002), since it has lower permeability than sandy soils. According to Boyd *et al*. (1999), this type of soil also has good nutrient retention capacity and good physical and chemical potential because the smaller particle size results in greater solubility and adsorptive potential.

Based on chemical soil analysis, the mixture of dolomite and hydrated lime (DH) indicated a significant (p<0.05) increase in dried soil pH and a decrease in organic carbon percentage (Table 2). The soil pH rapidly improved beyond seven within a week of the liming mixture application (day 7), yet the increase had just achieved the desirable soil pH (7.4–8.6) in the following two weeks (day 15). The highest dried soil pH (7.62±0.01) resulted from the DH2 (50:50), followed by the DH3 (25:75), and the lowest pH (7.46±0.01) was DH1 (75:25). Those values were higher than the single liming treatment, resulting from strictly dolomite (7.36±0.03) or hydrated lime (7.34±0.03). It was presumably due to the content of both calcium (Ca^{2+}) and magnesium (Mg^{2+}) being more effective in the DH combination than the other two chemicals.

The combination of liming material, dolomite, and hydrated lime (DH) significantly influenced the increase (p<0.05) of the water pH during the experiment. Initially, the water pH resulting from the sample without any liming application was 3. However, the water pH increased (>6.8) since the DH treatment's first day (Figure 1). It differed from the study result of Sá *et al*. (2021), which showed that the water pH increased after three days of experiment. Water pH generated from each combination group became relatively stable after day 15. Although the increase was not as high as the single hydrated lime application (HA) value, the water pH reached the expected value on day 15 (DH3). The data detected a slower response in the DH treatments than the single hydrated lime (HA), but it reacted faster than the single dolomite (DA). The reduction of dolomite by at least 25% showed a higher soil and water pH than 100% dolomite treatment. In contrast, the values did not exceed the pH generated from 100% of the hydrated lime for the water pH.

The present study showed that the lime combination enhanced the water alkalinity to above 200 mg/L as $CaCO_3$ within a week (Table 3). However, the measurable values dropped after day 15, although the concentrations were still in the desirable ranges (>75 mg/L as $CaCO_3$). The highest alkalinity was found in the DH2 treatment, followed by DH1 and DH3 which did not show a significant difference (p>0.05). The alkalinity which resulted from the mixture of dolomite and hydrated lime (DH) was not better compared to the single use of dolomite or hydrated lime. Total alkalinity was still considered sufficient for freshwater aquaculture if the concentration of $CaCO_3$ was at least 50 mg/L (Boyd and Tucker, 2014). Alkali acts as a buffer to protect fish from abrupt pH changes caused by changes in CO_2 concentrations related to the relative rates of photosynthesis and respiration (Boyd and Tucker, 1998).

Every combination treatment showed the depletion of organic carbon within seven days of the experiment (<2.5%) (Table 4). Following day 15, the higher organic substance was only found in DH1 (2.04±0.15%), while DH2 and DH3 did not present much difference (p>0.05) compared to the single dolomite application. In contrast with the single hydrated lime treatment, the organic carbon resulting from the combination of DH was smaller on day 7 and reduced again on day 15. The present study showed that the most significant depletion of organic carbon had been detected in both DH2 and DH3, followed by DH1. It describes that the combination of DH treatment is better than the single hydrated lime to reduce the organic carbon percentage in the sulfuric acid soil. The amount of organic carbon from the combination of DH in the experiment can be recommended for aquaculture activity (Boyd, 1995).

Based on the main variables observed, soil and water pH, total alkalinity, and organic carbon percentage, it can be concluded that the DH combinations positively impact the improvement of the sulfuric acid soil properties. The data showed that 50:50 composition of dolomite and hydrated lime (DH2) had the highest pH, soil or water pH, and alkalinity. The DH2 also resulted

Table 5. The mean values ± SD of the soil base and acid-forming cations. total sulfur (TS). total phosphorus (TP). cation exchange capacity (CEC) and C/N ratio resulted in sample with single dolomite. hydrated lime. and combination of DH1[1]

Variables	Dolomite		Hydrated lime		Combination of DH1	
	Day-7	Day-15	Day-7	Day-15	Day-7	Day-15
TCa (mg/Kg)	134.07±6.85	149.72±11.37	96.68±14.15	120.07±5.44	121.21±1.02	139.76±10.3
TMg (mg/Kg)	56.28±2.73	61.28±2.74	3.62±3.9	3.51±0.29	41.21±0.13	44.77±2.43
TFe (mg/Kg)	3.28±0.09	3.59±0.38	14.20±1.42	13.70±0.62	8.69±1.45	9.85±0.57
TAl (mg/Kg)	9.19±0.59	1.05±0.06	44.45±2.68	36.38±5.63	23.11±1.69	9.91±0.34
TMn (mg/Kg)	51.13±3.58	59.63±4.37	222.06±20.11	257.63±10.25	1.28±0.07	1.37±0.03
TS (mg/Kg)	1.65±0.04	1.05±0.04	3.93±0.24	3.88±0.06	2.16±0.16	2.38±0.04
TP (mg/Kg)	12.94±2.0	36.13±6.6	296.78±34.15	318.6±14.17	116.87±17.26	93.49±59.6
CEC (Cmol$_c$/Kg)*	3.9	4	17.9	18.7	11.8	9.4
C/N ratio*	5.5	11.5	28.5	28.5	20.33	17.33

[1] The data corresponded to the mean of three replicates. except (*). Total of calcium (TCa). magnesium (TMg). iron (TFe). aluminium (TAl). manganese (TMn).

Table 6. Mean values ± SD of the bases and acid-forming cations in water sample with single dolomite. hydrated lime. and combination of DH1[1]

Variables	Times	Dolomite	Hydrated lime	DH1 combination
TCa (mg/L)	D-7	605.52±70.88	529.58±93.31	663.87±107.2
	D-15	486.63±42.59	425.37±24.15	531.03±38.9
TMg (mg/L)	D-7	188.46±35.62	105.12±16.05	205.36±13.0
	D-15	183.51±8.25	131.34±6.31	215.56±10.4
TFe (mg/L)	D-7	2.10±0.51	1.85±0.24	0.95±0.4
	D-15	0.86±0.28	2.09±0.30	1.16±0.15
TAl (mg/L)	D-7	2.81±0.75	1.96±0.37	1.36±0.2
	D-15	1.05±0.06	0.96±0.11	8.77±1.3
TMn (mg/L)	D-7	2.56±0.69	2.29±0.50	4.57±0.3
	D-15	1.52±0.45	5.99±0.67	2.32±0.1
Orthophosphate (mg/L)	D-7	0.011±0	0.013±0	0.01±0.0
	D-15	0.012±0	0.026±0	0.01±0.01

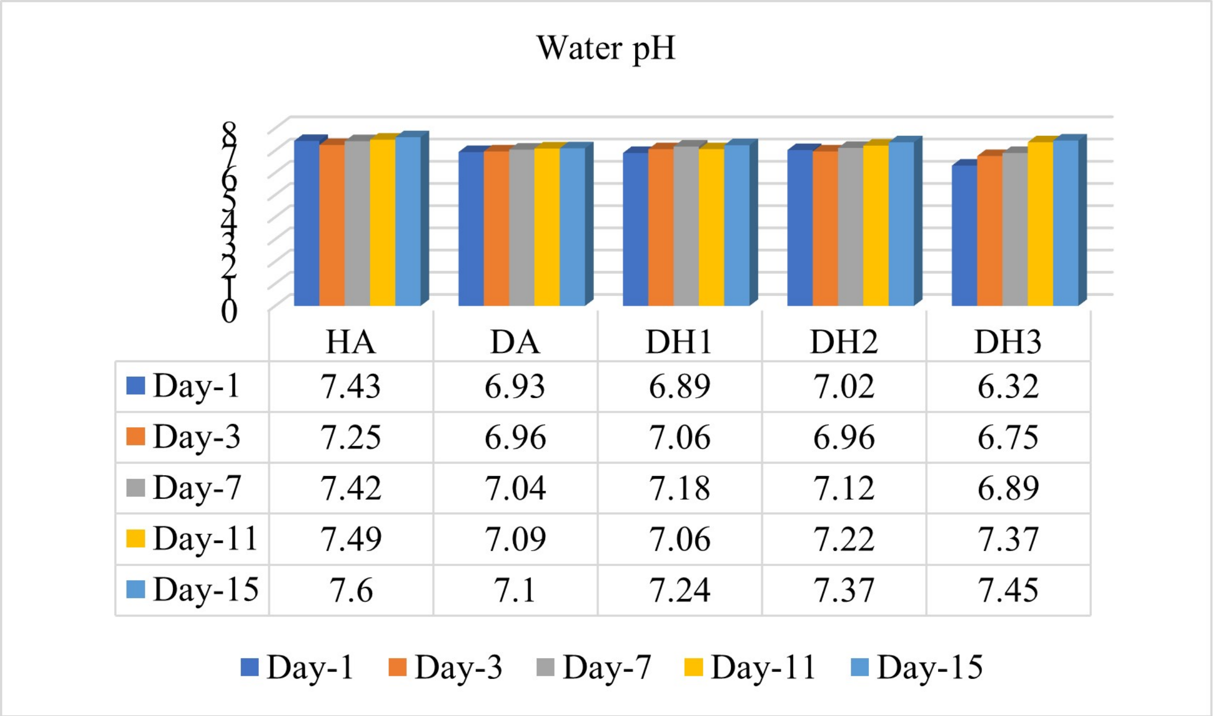
[1] The data corresponded to the mean of three replicates. Total of calcium (TCa), magnesium (TMg), iron (TFe), aluminum (TAl), and manganese (TMn).

in the lowest percentage of organic carbon. Nonetheless, to reveal the DH combination's effect on soil and water's supporting variables, the DH1 application has been chosen for further analysis. The reason is that the most used liming material by farmers is dolomite ($CaCO_3MgCO_3$). However, the sulfuric acid-containing soil should be reconsidered since a considerable amount was needed. Thus, further analysis aims to study the other effects of substitution of at least 25% dolomite with the hydrated lime (Table 5).

The combination of DH1 (75% of dolomite with 25% of hydrated lime) resulted in a higher soil C/N ratio (17.33) as compared to the single dolomite (11.5) on day 15 (Table 5). However, the value was lower than that of the single hydrated lime application (28.5). The values resulting from DH1 describe a faster decomposition in DH1 treatment compared to the hydrated lime, but it tends to be slower than the single dolomite. Nevertheless, the C/N ratio shown in the DH1 treatment was lower than the critical ratio (20-25) for the freshwater aquaculture systems (Anand *et al*., 2013). The value describes the insufficient carbon content to support the heterotrophic bacteria for mineralization. Those are similar to Stelzer *et al*. (2014). Due to the nitrogen content, it was not balanced by the amount of carbon in the sediment. McCarty *et al*. (2007) stated that denitrification was affected by the availability of carbon in wetlands, since it is an essential element of nitrogen cycling. The C/N ratio of organic residue inputs also altered soil microbial community composition and structure (Xue *et al*., 2018). Microorganisms can grow rapidly during organic matter decomposition (Benner, 2011) and an imbalance of C:N:P may limit denitrification (Herrman *et al*., 2008; Hossain and Rahman, 2017). A similar result had been shown by Stelzer *et al*. (2014) who expressed that the soil sample containing <2-5% of organic carbon had a smaller C/N ratio.

The total calcium and magnesium concentration in soil influenced the pH through the cation exchange mechanism (Boyd and Daniels, 1994; Masuda and Boyd, 1994). In the present study, the data indicated that the DH1 produced a slightly lower soil cation exchange capacity (CEC <10 meq/kg), as described in Sonnenholzner and Boyd (2000). That value indicates the insufficient capacity of a soil sample to store cationic nutrients. The DH1 had a lower CEC than the hydrated lime (9.4 meq/Kg). On the contrary, a higher result was detected if compared to dolomite (4.0 meq/Kg). Nonetheless, DH1 combination and dolomite (DA) values showed a higher number of cations, such as Ca^{2+} and Mg^{2+}, than the hydrated lime (HA) treatment.

A similar result was found in both treatments of the DH1 and dolomite (DA). The combination of DH1 supplied an abundance of both calcium and magnesium. The application of DH1 also indicated less concentration of acid-forming cations (Al. Fe. and Mn) and total sulfur in the sediment sample than the use of hydrated lime. The data implies how the considerable content of base cations resulting from the DH1 could replace large acid cations and inactivate the toxic substances in the soil sample. The data did not show a massive difference



	HA	DA	DH1	DH2	DH3
■ Day-1	7.43	6.93	6.89	7.02	6.32
■ Day-3	7.25	6.96	7.06	6.96	6.75
■ Day-7	7.42	7.04	7.18	7.12	6.89
■ Day-11	7.49	7.09	7.06	7.22	7.37
■ Day-15	7.6	7.1	7.24	7.37	7.45

Figure 1. Water pH fluctuation using dolomite (DA), hydrated lime (HA), and its combinations (DH)

in those forming acid cations between the two sampling periods. representing the sample's capability to buffer the chemical that might alter.

The changes in reduction-oxidation in soil were the factor that reduced the availability of phosphorus. A similar statement was found in Boyd *et al.* (1994) that an increase in a liming application significantly impacted soil pH and phosphorous. At high pH and base cations soil, phosphorus quickly reverts to more minor soluble phosphate compounds. Hence, it impacted the concentration of orthophosphate in the water. In the present study, the DH1 and single dolomite treatment presented lower rates of total phosphorous. In contrast, the sample with hydrated lime showed a higher total phosphorous content during the experiment.

It is possible that the high value relates to a larger number of acid-forming cations, particularly aluminum and manganese, compared to dolomite or a combination of DH1. Although there are phosphorous in each treatment, the concentration of orthophosphate maybe low in the water sample. This may have been caused by a characteristic of phosphorous where it is strongly adsorbed by the soil and becomes unavailable (Boyd and Teichert-Coddington, 1994). As revealed by Boyd *et al.* (1994) and Fageria *et al.* (2003), phosphorous might be less soluble in acid soil because of Fe and Al phosphate content during flooding. Aside from this, orthophosphate concentration is also influenced by the abundance of calcium. Liming application increases the level of soil calcium and limits soil phosphorous availability (Norman and Beyrouty, 2000). Thus, the single dolomite treatment (DA) presents the tiny orthophosphate in the present study.

The present study revealed that the DH1 combination had an abundant concentration of calcium and magnesium in water samples. The data revealed a higher content of calcium and magnesium than dolomite or hydrated lime (Table 6). The application of DH1 also resulted in a small concentration of acid-forming cations except for aluminum. The total aluminum concentration resulting from the DH1 was higher than other treatments. Boyd (1995) stated that base concentrations in the water are sourced from the soil's content. It was probably due to the fact that base cations in DH1 are easily released than those in dolomite. It may also be related to the higher value of cation exchange capacity in the DH1 than dolomite which indicates the lower capacity to hold the cations.

A substantial number of essential ions from the DH1 treatment impacted the total iron, aluminum, and manganese concentration reduction in the water samples (Table 6). The data implies that the practical content of base cations, resulted from the DH1, replaced many acid cations and inactivated the toxic substances in water. A significant difference was found in total aluminum, which showed a higher concentration of DH1 than the dolomite and hydrated lime. However, those results do not indicate an exact concentration of heavy metals that may harm the water organism since they were measured in amount. Moreover, a high-water pH obtained by DH1 indicates that the reaction of the toxicity of those chemical substances would be minimal in the water.

4. Conclusions

. The DH1 treatment was done strictly to reveal the interaction of dolomite and hydrated lime in reducing toxic materials caused by sulfuric acidsulphuric acid. However, in terms of the expected primary parameter observed (pH and alkalinity) and cost expenditure, the DH2 (50:50) or DH3 (25:75) is more recommended to optimize the aquaculture ponds in acid-containing soil than the use of DH1 treatment.

Acknowledgments

The authors would like to show our appreciation to Mr. Ratchamongkol Kajornwudtisak, Miss. Nutchaporn Thongdoncham, and Nurhidayah Hanum, for their help during the research activities, and also the Faculty of Fisheries, Kasetsart University, Thailand, for facilities and support.

Authors' Contributions

The contribution of each author is as follows, Mirna F; collected the data, drafted the manuscript, and designed the figures. Idsariya W and Methee K; devised the main conceptual ideas and critical revision of the article. All authors discussed the results and contributed to the final manuscript.

Conflict of Interest

The authors declare that they have no competing interests.

Funding Information

This research was funded by the Indonesian Endowment Fund for Education Ministry of Finance (LPDP-Budi).

References

Anand, T., Blakrishnan, G., Padmavathy, P., Rani, V., & Chandran, A. (2013). Influence of C/N ratio on the heterotrophic activity of model brackish water system. *International Journal of Fisheries and Aquatic Studies*, 1(3):12-21.

Attanandana, T., & Vacharotayan, S. (1986). Acid sulfate soils: their characteristics, genesis, amelioration and utilization. *Southeast Asian Studies*, 24(2):154-180.

Benner R. (2011). Biosequestration of carbon by heterotrophic microorganisms. *Nature Reviews Microbiology*, 9(75):1.

Boyd, C. E. (1995). Bottom soils, sediment and pond aquaculture. New York: Springer.

Boyd, C. E. (2003). Bottom soil and water quality management in shrimp ponds. *Journal of Applied Aquaculture*, 13(1-2):11-33.

Boyd, C. E. (2017). Use of agricultural limestone and lime in aquaculture. *CAB Reviews*, 12(015):1-10.

Boyd, C. E., & Daniels, H. V. (1994). Liming and fertilization of brackishwater shrimp ponds. *Journal of Applied Aquaculture*, 2(3-4):221-234.

Boyd, C. E., Hargreaves, J. A., & Clay, J. W. (2002). Codes of practice and conduct for marine shrimp aquaculture. USA: Consortium.

Boyd, C. E., Wood, C. W., Thunjai, T., Rowan, M., & Dube, K. (1999). Pond soil characteristics and dynamics of soil organic matter and nutrients. *Pond Dynamics/Aquaculture CRSP Annual Technical Report*, 1-12.

Boyd, C. E., Tanner, M., Madkour, M., & Masuda, K. (1994). Chemical characteristics of bottom soils from freshwater and brackishwater aquaculture ponds. *Journal of the World Aquaculture Society*, 25(4):517-534.

Boyd, C. E., & Teichert-Coddington, D. (1994). Pond bottom soil respiration during fallow and culture periods in heavily-fertilized tropical fish ponds. *Journal of the World Aquaculture Society*, 25(3):417-423.

Boyd, C. E., & Tucker, C. S. (1998). Pond aquaculture water quality management. New York: Springer.

Boyd, C. E., & Tucker, C. S. (2014). Handbook for aquaculture water quality. Alabama: Craftmaster Printers, Inc.

Fageria, N. K., Slaton, N. A., & Baligar, V. C. (2003). Nutrient management for improving lowland rice productivity and sustainability. *Advances in Agronomy*, 80:63-152.

Fitrani, M., Wudtisin, I., & Kaewnern, M. (2020). The impacts of the single-use of different lime materials on the pond bottom soil with acid sulfate content. *Aquaculture*, 527:735471.

Foth, H. D. (1990). Fundamentals of soil science (8th ed.). New York: John Willey & Sons.

Herrman, K. S., Bouchard, V., & Moore, R. H. (2008). An assessment of nitrogen removal from headwater streams in an agricultural watershed, northeast Ohio, USA. *Limnology and Oceanography*. 53(6):2573-2582.

Hossain, M. B., & Rahman, M. (2017). Ocean acidification: an impending disaster to benthic shelled invertebrates and ecosystem. *Journal of Noakhali Science and Technology University*, 1(1):19-30.

Lyle-Fritch, L. P., Romero-Beltrán, E., & Páez-Osuna, F. (2006). A survey on use of the chemical and biological products for shrimp farming in Sinaloa (NW Mexico). *Aquacultural Engineering*, 35(2):135-146.

Mahmood, N., & Saikat, S. Q. (1995). On acid sulfate soils of the coastal aquaculture ponds of Bangladesh. *Pakistan Journal of Marine Sciences*, 4(1):39-43.

Masuda, K., & Boyd, C. E. (1994). Phosphorus fractions in soil and water of aquaculture ponds built on clayey, Ultisols at Auburn, Alabama. *Journal of the World Aquaculture Society*, 25(3):379-395.

McCarty, G. W., Mookherji, S., & Angier, J. T. (2007). Characterization of denitrification activity in zones of groundwater exfiltration within a riparian wetland ecosystem. *Biology and Fertility of Soils*, 43:691-698.

Nelson, D. W., & Sommers, L. E. (1996). Total carbon, organic carbon, and organic matter. In D. L. Sparks, A. L. Page, P. A. Helmke, R. H. Loeppert, P. N. Soltanpour, M. A. Tabatabai, C. T. Johnston, & M. E. Summer (Ed.), Methods of soil analysis: part 3 chemical methods. (pp. 961-1010). Madison: Soil Science Society of America, Inc.

Norman, R. J., & Beyrouty, T. H. (2000). B. R. Wells Rice Research Studies 1998. Arkansas: University of Arkansas.

Pine, H. J., & Boyd, C. E. (2011). Magnesium budget for inland low-salinity water shrimp ponds in Alabama. *Journal of the World Aquaculture Society*, 42(5):705-713.

Sá, M. V. C., Cavalcante, D. H., & Lima, F. R. S. (2021). Total buffering capacity of CaCO3-undersaturated and saturated waters buffered with agricultural limestone or hydrated lime and its importance to the liming of shrimp culture ponds. *Aquaculture*, 536:736455.

Sammut, J. (1996). Amelioration and management of shrimp ponds in acid sulfate soils: key researchable issues. *Australian Centre for International Agricultural Research*, Songkhla, 102-106.

Silapajarn, K., Boyd, C. E., & Silapajarn, O. (2004). An improved method for determining the fineness value of agricultural limestone for aquaculture. *North American Journal of Aquaculture*, 66(2):113-118.

Sonnenholzner, S., & Boyd, C. E. (2000). Chemical and physical properties of shrimp pond bottom soils in Ecuador. *Journal of the World Aquaculture and Society*, 31(3):358-375.

Stelzer, R. S., Scott, J. T., Bartsch, L. A., & Parr, T. B. (2014). Particulate organic matter quality influences nitrate retention and denitrification in stream sediments: evidence from a carbon burial experiment. *Biogeochemistry*, 119:387-402.

Weber, W. P., & Gokel, G. W. (1977). Synthesis of ethers. In W. P. Weber & G. W. Gokel (Ed.), Phase transfer catalysis in organic synthesis. (pp. 73-84). Berlin: Springer.

Wurts, W. A., & Durborow, R. M. (1992). Interactions of pH, carbon dioxide, alkalinity and hardness in fish ponds. *Southern Regional Aquaculture Center*, 464:1-4.

Xue, P. P., Carrillo, Y., Pino, V., Minasny, B., & McBratney, A. B. (2018). Soil properties drive microbial community structure in a large scale transect in South Eastern Australia. *Scientific Reports*, 8(11725):1-11.