Application of fishpond sediment and water to increase the efficiency of phosphorus fertilization in land integrating agriculture and fishery

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Abstract. The utilization of water from Mount Salak by farmers in addition to agriculture activities is also for fishponds that are widely spread among agricultural lands. The phosphate from fishpond sediment and water flowing to the river was supposed contributing to the enriched phosphate in the Jakarta Bay. The use of fishpond sediment and water in agricultural land was expected to decrease the load of phosphate to the river and increase the efficiency of phosphorus (P) fertilization by decreasing P sorption and increasing the release of P. The fishpond sediment with the rates of 0, 2.5%, 5.0%, 7.5% and 10% were combined with fishpond water or distilled water for watering. They were incubated for one month. The experiment was set up in Completely Randomized Design with three replicates. The results showed that fishpond sediment treatments decreased P bonding energies of P sorption and after P desorption also the rate constant of P sorption. The best treatment in this experiment was the application of 10% of fishpond sediment watered by fishpond water for those determined parameters. The results suggested that application of fishpond sediment and water increased the efficiency of P fertilization in land integrating agriculture and fishery.

1. Introduction

Water flowing from rivers in the upper reaches of the Gunung Salak is widely used for agricultural activities in villages around Bogor. Utilization of water from Mount Salak in addition to agriculture is as a source of water to irrigate fishponds. This is typical situation in those villages integrating agriculture and fishery. However the farmers discard the fishpond water into the canals. This water flows into the rivers that pass through Jakarta and these rivers lead to the Jakarta Bay.

The report that the Jakarta Bay was enriched by phosphorus (P) attracts the researchers to investigate the ways to lower the concentration of P in the Jakarta Bay. It is reported that the concentration of P in the form of phosphate has increased [1]. It was also said that 0.1 µM phosphate caused an increase in the algae population [2]. Many dead fish in Jakarta Bay are thought to be due to increased growth of algae. The growth of algae resulted in reduced oxygen levels in the Jakarta Bay for fishes living in Jakarta Bay.

Research related to the evaluation of the nutrient of fishpond sediment and fishpond water has not been done much. P in the fish feed applied to the fishpond mostly is sedimented as fishpond sediment [3]. It was reported that one year old fishpond and fishpond water in several fishponds in the Petir village had relatively high P content [4-5].
The mechanism of P availability in soil added with fishpond sediment and water has not been widely studied. Therefore this study aimed to evaluate the mechanism of P availability through P sorption, P desorption and P sorption kinetics. The results of the study of P sorption, P desorption and P sorption kinetics will answer whether the application of fishpond sediment and fishpond water increase the efficiency of P fertilization in locations integrating agriculture and fishery.

2. Materials and Methods

2.1. Materials

The study used soil samples, fishpond sediment and fishpond water from the Petir village Petir, Darmaga, Bogor. The position of Petir village [5] is presented in Figure 1.

![Figure 1. The position of Petir village](image)

Soil samples were collected in farm of farmer in Petir village with a depth of 0-30 cm. While fishpond sediment and fishpond water were collected from fishponds of farmer near farms where the fishpond has reached one year. The one year old fishpond was selected because it had a relatively high P and organic C content based on survey research in 2012 [4].

2.2. Methods

The incubation experiment was carried out to determine the effect of fishpond sediment and fishpond water. Soil samples and fishpond sediment were air dried and then crushed to pass the 2 mm filter. Then 300g of oven-dry weight soil were weighted and put it in an incubation bottle. Then the bottle with the soil sample in it was treated with fishpond sediment in percent weight with a rate of 0% (L1), 2.5% (L2), 5% (L3), 7.5% (L4) and 10% (L5). One set of treatments was added distilled water (AQ) and a set of treatments were added fishpond water (AK) to reach 80% of field capacity. The experimental design carried out was a completely randomized design with three replications. Each treatment was repeated three times so that the number of experimental units was 30 experimental units. Bottles that already contain treated soils were incubated for one month. After completion of the incubation period, an experiment was carried out to analyze P sorption, P desorption and P sorption kinetics.
Fox and Kamprath method was used to the P sorption experiment [6]. Concentration of P ranging from 0 to 250 mg P L\(^{-1}\) were added to the 3.00g of air-dried soil and 0.01 mol L\(^{-1}\) CaCl\(_2\) was used as background electrolyte. Soil suspension was shaken at a speed of 180 rpm using a shaker for six days for 30 minutes every morning and evening to reach equilibrium. The soil suspension was centrifuged for 15 minutes at a speed of 2500 rpm after equilibrium. The soil suspension was filtered using filter paper and the supernatant was put in to a bottle for P content measurement. Murphy and Riley method [7] was used to determine the P content in the soil solution. UV-VIS spectrophotometer (UV-1280, UV-VIS Spectrophotometer, Shimadzu Corporation, Japan) was used to determine the absorbance at 660 nm. The Difference between the amount of P added and the amount P in the solution was considered as the amount of P sorbed by the soil.

The Langmuir equation was used to fit data of P sorption. The Langmuir equation was written as follows:

\[ \frac{1c}{q} = \frac{c}{b} + \frac{1}{Kb} \]

Where, \(c\) = P concentration in the soil solution in the equilibrium condition (mg P L\(^{-1}\)), \(q\) = the quantity of P sorbed per unit mass of soil (mg P kg\(^{-1}\)), \(b\) = P sorption maximum of the soil (mg P kg\(^{-1}\)), \(K\) = a constant related to the bonding energy of P sorbed by the soil (L mg\(^{-1}\)).

P desorption was conducted using the soil from sorption after the supernatant solution was decanted off. It was added 28 mL of 0.01 mol L\(^{-1}\) CaCl\(_2\) [6]. Samples were further shaken daily twice for 30 minutes to reach equilibrium for 6 days. After that soil suspension was centrifuged at a speed of 2500 rpm [8]. The determination of P in the supernatant were same as in the P sorption experiment. The amount of P sorbed by the soil after desorption was the amount of P sorbed of P sorption experiment minus P in soil solution [8]. The K values after P desorption was designated as \(K'\) to differentiate the P bonding energy symbol of P sorption.

The P sorption kinetics was conducted following the method described by Hartono [9]. 3.00g of air-dried soil after one month incubation was added 250 mg P L\(^{-1}\) made from KH\(_2\)PO\(_4\). 0.01 mol L\(^{-1}\)CaCl\(_2\) was used as background electrolyte. The soil suspensions were shaken for 1 minute, 5 minutes, 10 minutes, 15 minutes, 20 minutes, 30 minutes, 60 minutes, 180 minutes, 360 minutes, 720 minutes, 1440 minutes, 2880 minutes [9]. The soil suspension were centrifuged at 2500 rpm for 15 minutes after the shaking period. The protocol of P determination in the supernatant were same as in P sorption experiment. The amount of P sorbed by the soil after desorption was the amount of P sorbed of P sorption experiment minus P in soil solution [8]. Data were simulated by the following first order kinetic equation to obtain the rate constant of P sorption and maximum P sorbed in the P sorption kinetics experiment as follows:

\[ P\ \text{sorbed (mg kg}^{-1}\) = a \left(1-e^{-kt}\right) \]

where:

- \(a\) = maximum P sorbed (mg kg\(^{-1}\))
- \(k\) = rate constant of P sorption (minute\(^{-1}\))
- \(t\) = time of shaking (minute)

Analyses of variance followed by a Duncan’s test were applied to evaluate the effect of treatments to Langmuir parameters of P sorption, desorption and parameters of the first order equation in P sorption kinetics.

3. Results & Discussion

Table 1 showed that the fishpond sediment did not significantly decreased the P sorption maxima but significantly decreased the P bonding energies. The treatment of fishpond sediment watered with fishpond water at the rate of 5%, 7.5% and 10% decreased significantly the P bonding energies. Of all these treatments, the rate of 10% watered by fishpond water had the lowest K value compared to the other treatments. The low value of K in the treatment of 10% of fishpond sediment watered by fishpond water
was due to the increase in pH, cation exchange capacity, available P and organic C [5] and also anions from organic compounds in the fishpond sediment and fishpond water. Anions blocked the P sorption sites of soil colloids so that the P added was bound on the weak sites. Some researches related to the application of soil ameliorant such as the application of organic matter found that organic matter decreased soil P sorption maxima and their P bonding energies by blocking P sorption sites of the soil by the anions released [10-11].

Table 1. P sorption maxima (b) and bonding energies (K) of the treated soils

| Treatment | P sorption maxima (b) (mg P kg⁻¹) | Bonding energies (K) (L mg⁻¹) |
|-----------|----------------------------------|-----------------------------|
| L1 AQ     | 1889b                            | 1.00ab                      |
| L2 AQ     | 2000bc                           | 0.94abc                     |
| L3 AQ     | 2167bc                           | 0.78abcde                   |
| L4 AQ     | 2000bc                           | 0.70bcde                    |
| L5 AQ     | 2500ac                           | 0.57de                      |
| L1 AK     | 2167bc                           | 1.03a                       |
| L2 AK     | 2000bc                           | 0.83abcd                    |
| L3 AK     | 2333bc                           | 0.65de                      |
| L4 AK     | 2000bc                           | 0.68cde                     |
| L5 AK     | 1619bc                           | 0.55e                       |

Means followed by the same letter within a column are not significantly different (Duncan’s test, P < 0.05)
L1= 0% fishpond sediment, L2= 2.5% fishpond sediment, L3= 5% fishpond sediment, L4= 7.5% fishpond sediment, L5=10% fishpond sediment, AQ= distilled water, AK= fishpond water.

P sorption curves are presented in Figure 2. From those curves it is shown that the application of 10% fishpond sediment watered by fishpond water decreased the P sorbed by the soil in each P concentration in soil solution.

![Figure 2](image_url)  
**Figure 2.** P sorption curves of 10% fishpond sediment watered by fishpond water (L5 AK) compared to other treatments

P desorption study (Table 2) showed that P bonding energies after P desorption (K’) reaction in soils treated by fishpond sediment watered by distilled water and fishpond water were significantly lower than that of soils without any addition of fishpond sediment (L1 AQ and L1 AK). It means that after some P desorbed the remaining in P sorption sites were sorbed with lower bonding energies than those in soils without addition of fishpond sediment. Compared to K values in P sorption experiment, the K’ values increased in soils without addition of fishpond sediment watered by distilled water or fishpond water.
However in soils treated by fishpond sediment the K’ values relatively did not change compared to their K values of P sorption. Soil treated by 10% of fishpond sediment and fishpond water had the lowest of K’ values. This treatment was supposed to contribute higher organic C, higher CEC, higher P and also higher anions than those of other treatments. Those contributions affected in lowering the capacity of the P sorption sites.

Table 2. Bonding energies after desorption reaction (K’)

| Treatment | Bonding energies (K’) (L mg⁻¹) |
|-----------|-------------------------------|
| L1 AQ     | 2.17a                         |
| L2 AQ     | 1.11bce                       |
| L3 AQ     | 0.70be                        |
| L4 AQ     | 0.60bef                       |
| L5 AQ     | 0.67bef                       |
| L1 AK     | 1.55cd                        |
| L2 AK     | 2.00ad                        |
| L3 AK     | 0.80ef                        |
| L4 AK     | 0.60ef                        |
| L5 AK     | 0.53f                         |

Means followed by the same letter within a column are not significantly different (Duncan’s test, P < 0.05) L1= 0% fishpond sediment, L2= 2.5% fishpond sediment, L3= 5% fishpond sediment, L4= 7.5% fishpond sediment, L5=10% fishpond sediment, AQ= distilled water, AK= fishpond water

P sorption kinetic study is presented in Figure 3, Figure 4 and Table 3. Figure 3 and Figure 4 shows the curves of P sorbed of treated soils with different time of shaking. Those figures showed that the fishpond sediment treatment decreased the P sorbed by the soil in each time of shaking. Table 3 showed that the treatment of 10% of fishpond sediment watered by fishpond water decreased the percentage of P sorbed in each time of shaking higher than that of the other treatments.

Figure 3. P sorption kinetic of soils treated by fishpond sediment and distilled water L1= 0% fishpond sediment, L2= 2.5% fishpond sediment, L3= 5% fishpond sediment, L4= 7.5% fishpond sediment, L5=10% fishpond sediment, AQ= distilled water
Figure 4. P sorption kinetic of soils treated by fishpond sediment and fishpond water. 
L1= 0% fishpond sediment, L2= 2.5% fishpond sediment, L3= 5% fishpond sediment, L4= 7.5% fishpond sediment, L5=10% fishpond sediment, AK= fishpond water.

Table 3. Percentage of P sorbed in kinetic experiment

| Treatment | Time of shaking (minute) | P sorbed (%) |
|-----------|--------------------------|--------------|
| L1 AQ     | 1           | 26.6         |
|           | 5           | 33.0         |
|           | 10          | 35.8         |
|           | 15          | 32.1         |
|           | 20          | 40.2         |
|           | 30          | 37.4         |
|           | 60          | 42.3         |
|           | 180         | 54.8         |
|           | 360         | 59.0         |
|           | 720         | 64.0         |
|           | 1440        | 73.4         |
|           | 2880        | 77.1         |
| L2 AQ     | 1           | 24.7         |
|           | 5           | 31.7         |
|           | 10          | 34.1         |
|           | 15          | 31.0         |
|           | 20          | 39.8         |
|           | 30          | 36.9         |
|           | 60          | 41.1         |
|           | 180         | 54.5         |
|           | 360         | 58.2         |
|           | 720         | 64.8         |
|           | 1440        | 73.1         |
|           | 2880        | 77.9         |
| L3 AQ     | 1           | 24.6         |
|           | 5           | 31.5         |
|           | 10          | 33.9         |
|           | 15          | 30.4         |
|           | 20          | 37.9         |
|           | 30          | 35.9         |
|           | 60          | 40.7         |
|           | 180         | 54.3         |
|           | 360         | 58.6         |
|           | 720         | 64.4         |
|           | 1440        | 73.4         |
|           | 2880        | 78.0         |
| L4 AQ     | 1           | 24.4         |
|           | 5           | 31.9         |
|           | 10          | 34.8         |
|           | 15          | 30.8         |
|           | 20          | 38.7         |
|           | 30          | 36.6         |
|           | 60          | 41.9         |
|           | 180         | 54.6         |
|           | 360         | 59.4         |
|           | 720         | 64.6         |
|           | 1440        | 74.2         |
|           | 2880        | 78.8         |
| L5 AQ     | 1           | 22.9         |
|           | 5           | 31.4         |
|           | 10          | 30.9         |
|           | 15          | 29.4         |
|           | 20          | 38.1         |
|           | 30          | 35.2         |
|           | 60          | 40.6         |
|           | 180         | 53.8         |
|           | 360         | 58.2         |
|           | 720         | 63.6         |
|           | 1440        | 73.1         |
|           | 2880        | 77.5         |

L1= 0% fishpond sediment, L2= 2.5% fishpond sediment, L3= 5% fishpond sediment, L4= 7.5% fishpond sediment, L5=10% fishpond sediment, AQ= distilled water, AK= fishpond water.

The rate constant ($k$) and P sorption maxima ($a$) in this study is showed in Table 4. The $k$ values of P sorption decreased significantly with the application of fishpond sediment watered by distilled water or fishpond water. It means that the rate of P sorbed by the P sorption sites was slowed down by the application of fishpond sediment. As for the $a$ values showing the P sorption maxima were not significantly different among the treatments. Soil treated by 10% of fishpond sediment and fishpond water had the lowest of $k$ and $a$ values.
Table 4. first order kinetics parameter of $P$ sorption

| Treatment | Rate constant ($k$) (minute$^{-1} \times 10^{-2}$) | P sorption maxima ($a$) (mg P kg$^{-1}$) |
|-----------|---------------------------------|---------------------------------|
| L1 AQ     | 5.84a                           | 1920a                           |
| L2 AQ     | 5.30ab                          | 1898a                           |
| L3 AQ     | 4.87bcd                         | 1902a                           |
| L4 AQ     | 4.94bc                          | 1891a                           |
| L5 AQ     | 4.59cd                          | 1894a                           |
| L1 AK     | 4.56cd                          | 1924a                           |
| L2 AK     | 4.63bcd                         | 1876a                           |
| L3 AK     | 4.51cd                          | 1893a                           |
| L4 AK     | 4.26cd                          | 1913a                           |
| L5 AK     | 4.19d                           | 1893a                           |

L1 = 0% fishpond sediment, L2 = 2.5% fishpond sediment, L3 = 5% fishpond sediment, L4 = 7.5% fishpond sediment, L5 = 10% fishpond sediment, AQ = distilled water, AK = fishpond water

4. Conclusions
The fishpond sediment treatments decreased P bonding energies of P sorption and after desorption and also decreased the rate constant of P sorbed compared to soils without addition fishpond sediment. The best treatment among the treatments was 10% of fishpond sediment watered by fishpond water. The results suggested that application of fishpond sediment and fishpond water increased the efficiency of P fertilization in land integrating agriculture and fishery.

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