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# Study on Pond Bottom Soil Physico-Chemical Properties inTraditional-Intensive Aquaculture System of BLUPPB Karawang, Indonesia

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## Abstract

*Pond sediment quality is one of the important factors in the success of aquaculture activities. This study aimsat assessing ponds bottom soil physico-chemical properties of traditional and intensive aquaculture systems. Each pond with an area of 4000 $m^2$was used as sample consisting of five earthen ponds of L. vannamei intensive shrimp farming (VNE), fiveL. vanamei intensive shrimp ponds lined plastic mulch (VNP), five traditional polyculture ponds (Poly), and 5 traditional milkfish nursery ponds (MN). Core tube was used to take 5-10 cm depth of pond bottom soil from the edge to center of each pond. Soil data were statistically analysed using ANOVA and post hoc HSD Tukey. The result showed that ponds clay content, total phosphorus, iron, calcium, potassium and magnesium includedin very high criteria and parameters while sand, c-organic C: N ratio included in very low criteria. Soil pH, CEC, redox potential, and bulk density were in intensive systems while total nitrogen and total sulfur were still in optimum criteria for aquaculture. Aquaculture systems significantly ($p<5\%$) affected pondssoil quality parameters of bulk density, c-organic, total N, C:N ratio, total S, and total P. Efforts are needed to improve soil quality conditions based on the status of physico-chemical parameters.*

**Keywords:** Pond, Aquaculture, Phisyco-Chemical, Soil, Traditional-Intensive.

## Introduction

Today, aquaculture is an important component for fisheries in Indonesia. Aquaculture production value in 2013 increased by 46.94 %, compared to the year 2012 or reaching IDR 111.5 billions from IDR 75.9 billions[1]. All human activities, including aquaculture, will affect or be affected by the environmental system[2]. Environmental impact of aquaculture activities can backfire for aquaculture itself. The impact of aquaculture activities has resulted in environmental degradation[3]. The impact of environmental degradation is the decline of land productivity. Mass mortality due to vibriosis and viral diseases on shrimp farming can be caused by secondary effects of environmental degradation in aquaculture area.

Three decades ago, when technology was less intensive, aquaculture was considered as an environmentally friendly activity. A major change in this perception has happened lately along with the adoption of intensive production techniques and the development of aquaculture areas to the coastal and offshore areas. Feed loss, feces and excretion metabolite dissolved in intensive aquaculture will lead to increased nutrient input in the pond, decreased oxygen and increased sedimentation. Since aquaculture activities using fertilizers in growing of life feed and aqua feed contains high protein but low in feed utilization, the aquaculture activities always generate waste consisting of organic material and nutrients[3,4].

In aquaculture activities over the years, the water quality much more attention than the pond soil quality[5]. In fact, Physical and chemical characteristics of pond water are strongly influenced by the basic properties of the pond sediment[6]. Pond sediment quality is one of the important factors in the success of aquaculture activities[7]. Shrimp and fish farmers are widely believed that the high accumulation of organic material on the pond bottom causes a decrease in sediment quality and also has a negative impact on water quality[8]. Soil quality is an important factor that determines the ponds productivity due to its function in controlling the basic stability of the pond bottom, water pH and nutrients concentration in water which are necessary for the growth of phytoplankton[7].

Knowledge of the physico-chemical properties of the pond bottom soil has becomes very important to be studied. Information on pond bottom soil physico-chemical composition can be use as the basis for providing input to the preparatory process of pond.BLUPPB Karawang is an aquaculture area, which is located in West Java, Indonesia. This region has been in operation since the 1980s. Therefore, this study aims at assessing ponds bottom soil physico-chemical properties of traditional and intensive aquaculture systems of BLUPPB Karawang aquaculture area. The information obtained can be used as a basis in the management for sustainable aquaculture.

## Material and Methods

**Studi area and selection of ponds:** This research was conducted in the aquaculture area of BLUPPB Karawang, as seen in **Figure-1**, Pusakajaya Utara Village, District of Cilebar, Karawang, West Java Indonesia (107.43$^0$E and 6.10$^0$S) in April-May 2015. Twenty ponds with an area of each 4000 m$^2$ were used as sample, consisting of 5 earthen ponds of vannamei intensive shrimp farming (VNE), 5 vannamei intensive shrimp ponds lined plastic mulch (VNP), 5 traditional polyculture ponds (Poly), and 5 traditional milkfish nursery ponds (MN). Ponds sample were former intensive tiger shrimp farms from the 1980s to the 2000s. In the traditional ponds given chemical fertilizer inputs, fast drying without sediment removal was done between crops. While in intensive ponds artificial feed, fertilizer and liming were given as inputs during culture. Drying, sediment removal, and liming were conducted between crops.

**Collection of soil samples:** Pond bottom soil samples were taken at 10 points at the same distance along a transect from the tip to the middle of the pond. Soil sampling followed the pattern S[6]. Samples were taken using a core tube made of PVC pipe with a diameter of 5 cm and a length of 35 cm at a depth of 5-10 cm. Each pond was represented by 10 sample points then combined to obtain a sample for each plot or area[5,9]. A total of 1 Kg soil samples was taken for each pond which is the result of merging the soil of 10 sample points of each pond. Furthermore, soil samples were inserted to black plastic bags and sent to the laboratory.

**Analysis of collected samples:** The analysis of soil pH and potential red ok performed in situused ORP meter. Bulk density analysis carried out by the procedure was described by Boyd[6]. Total nitrogen was analyzed using dry combustion[10]. Soil texture was analyzed using pipette method. Organic material was analyzed using Walkey and Black for carbon organic. CEC was measuredby saturation with 1 M $NH_4OAc$ at pH 7.0. Total phosphorus, total sulfur, calcium, magnesium and iron extracted using $HNO_3$[11].

**Statistical Analysis:** ANOVA continued withpost hoc test using HSD Tukey was conducted to analyze the effect of aquaculture systems on the ponds bottom soil physico-chemical quality parameters. Pearson correlation analysis was conducted to examine the relationship among soil physico-chemical parameters. Statistical tests were performed with the help of Xlstat Pro software.

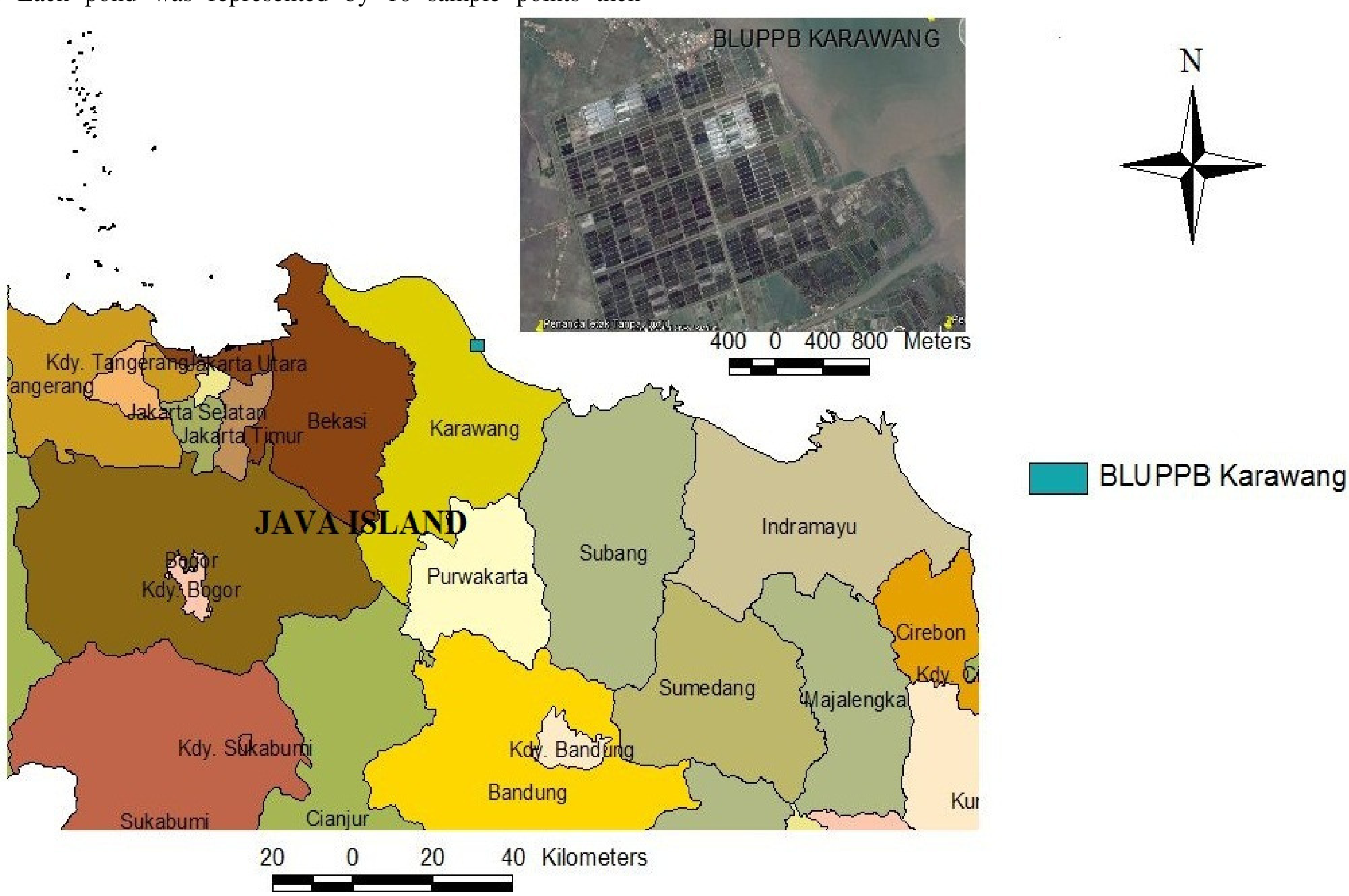


**Figure-1**
**Map of BLUPPB Karawang as research sites**

## Results and Discussion

**Soil texture:** Soil texture of studied ponds has ranged 1-9% of sand content, silt content ranging from 20-42% and clay content ranged from 57-79% as seen in Table-1. Based on the results of the soil triangle identification, soil texture in studied area was a type of clay. Results of the analysis of variance on different aquaculture systems during the study showed no significant differences (p>5%) for the clay content. Good pond bottom soil containing at least 20% clay and the optimal range of 30% -40% to avoid excessive water[6]. Sufficient clay content will benefit from tilling (clays and clay loams) than ponds with a low clay content (sands, sandy loams, and loams)[8]. However, the pond bottom soil with too high clay content will be difficult to be tilled, dried, sticky and easier to erosion[12]. Sandy clay loam to sandy loam is more suitable for intensive aquaculture systems[5]. Therefore it can be said that texture of the soil at the study site in general is still viable for aquaculture activities despite having too low sand content and too high for clay content.

**Bulk density:** The average of bulk density values for milkfish nursery ponds (MN), polyculture (Poly), vanamei intensive plastic lined ponds (VnP) and vanamei intensive earthen pond(VNE) are respectively 0.67±0.09, 0.55±0.12, 0.82±0.22and 0.83±0.16 g/cc as can be seen in Figure-2. Statistical analysis showed that aquaculture systems affected significantly (p <5%) to the value of ponds bulk density. In general, the soil bulk density ranged from 0.17 to 1.55 g/ cc with an average of 0.92 g/cc[13]. Sediment with bulk density values of 0.5 or 0.6 is said to be too soft and in a bad condition compared with greater soil bulk density value. The range of the value of the mineral soil bulk density is 1-2 g/cc. Organic soil will be lighter than mineral soils, for example peat with a bulk density of 0.2 to 0.4 g/cc[6]. Thus, it can be said that the traditional ponds system has too low bulk density values for aquaculture activities. In the intensive pond bulk density value is more ideal for aquaculture activities. There are differences in bulk density values of ponds with sediment removal and without sediment removal[14]. Ponds with sediment removal have higher bulk density values. This is likely to be a factor of higher bulk density values in intensive aquaculture systems compared to traditional systems during the study, considering the intensive system that carried better pond preparation including sediment removal.

**Soil pH:** The range of pH values are 6.72 to 7.05 as can be seen in Table-2. In the intensive systems pH values were slightly lower than in traditional systems, especially on the polyculture ponds although the results of statistical analysis showed no significant differences (p>5%). Ponds bottom soil had pH values less than 4 to 9, but the best pH values for ponds aquaculture is near neutral (Boyd, 1995). Therefore it can be said that soil pH in the ponds sample were still in the optimal range for aquaculture activities. Soil pH in the traditional ponds and semi-intensive ponds system did not show any big difference[15]. Soil pH values dropped significantly in the drying ponds before culturel[16]. The relatively low pH of the soil in intensive ponds occurred probably as a result of better tillage so that the ponds bottom was not too anaerobic compared to traditional ponds.

**Organic carbon:** The range of soil organic carbon obtained during the study ranged from 0.32% to 0.90% with average organic carbon content was 0.56 ± 0.037%. Results of analysis of variance showed a significant difference (p<5%) in the values of c-organic in the different aquaculture systems. Recommended organic carbon is in the range of 1-3%[6]. Based on the recommendation, it can be said that soil c-organic values in the study were not in the optimal conditions for aquaculture activities. The amount of organic carbon in estuary reported ranged from 1.122% to 8.994%[17]. There was a report of a low concentration of c-organic (0.07 ± 0.64%) in the area of ponds aquaculture which was former mangrove forest[18]. Ponds sediment organic matter decomposes very easily due to the low proportion (5-15%) of carbon and nitrogen[19]. Therefore it can be expected that the low values of c-organic during research occurred as a result of exploitation of soil resources for aquaculture activities for many years. The low proportion of ponds carbon and nitrogen ratio occurred as a result of input fertilizers and aqua feed containing high nitrogen. Organic material in the traditional system (2.62 ± 0.4%) was higher than the organic material in the intensive shrimp culture (1.90 ± 0.6%)[15]. The optimum drying in intensive shrimp ponds resulted in most organic material that accumulated decomposition better[6]. Therefore, the lower c-organic in the intensive ponds than traditional ponds was suspected to be caused by better drying during pond preparation, and input feed containing high nitrogen content resulted in faster decomposition process in pond soil.

**Total nitrogen**: Average Pond soil total nitrogen was 0.40±0.01% with a range 0.31-0.49% as can be seen in Table-2. The study was also able to show that intensive aquaculture systems have total nitrogen content lower than traditional ponds (p<5%). Concentrations of total nitrogen in pond sediment were 0.3-0.5%[19]. Total nitrogen values of brackish water ponds in Takalar Indonesia ranges from 0.00 to 0.75% with an average 0.21 ± 0.19%[20]. Total nitrogen content of the pond bottom soil reported 5.42%-5.26%, including high and good enough for aquaculture production[21]. The average total nitrogen in brackish water ponds was0.30%[6]. Based on the data and some previous studies, ponds bottom soil on the location of this research have high average nitrogen content, but still in the optimal range for aquaculture activities. The high content of nitrogen in the ponds bottom soil in studied area was possibly caused by the old age of ponds and the accumulation of inputs of nitrogen fertilizers and aqua feed containing nitrogen[19,22]. There are differences in the concentration of total nitrogen in pond bottom soil through sediment removal and without sediment removal[14]. The process of better ponds preparation on intensive farms is possibly able to keep the concentration of total nitrogen of pond bottom soil lower than the traditional systems which are actually with minimal inputs. Application of nitrogen fertilizers in traditional systems may also be a causative factor for high content of total nitrogen in traditional ponds.

**C:N ratio:** The range of carbon: nitrogen (C:N) ratio values in ponds soil samples were only about 0.87-1.91 with the average 1.37±0.06. Values of C:N ratio of the soil in some aquaculture systems only differed significantly (p<5%) between polyculture traditional system (Poly) and intensive vannamei earthen ponds aquaculture system (VNE). The highest average value of C:N ratio was in the traditional polyculture system and the lowest was intensive vanamei earthen pond system. C:N ratio in the soil of brackish water ponds was 6:1. Only a few samples that had a C:N ratios above 10, and aquaculture production in the range of pond soil C:N ratio 10-15 had the best productivity[6]. Therefore pond bottom soil samples had a very low value of C:N ratio and less optimal for aquaculture activities. Lower C:N ratios have been reported in ponds with intensive production. High inputs of organic material containing nitrogen in the ponds soil becomes the factor of lower C:N ratios than soil on terrestrial ecosystems[6]. Therefore, the lower value of C:N ratio in intensive pond soil samples compared to the traditional systems is possibly due to higher nitrogen inputs from aqua feed and fertilizer create more carbon lost through decomposition ($CO_2$ and $CH_4$) than the proportion of ammonia released in the end of decomposition process.

**Table-1**
**Texture of pond soil samples of the different aquaculture systems**

| Aquaculture system | Commodity | Sand | Silt | Clay | Texture type |
|---|---|---|---|---|---|
| | | % | % | % | |
| Traditional | MN | 1.80±0.84 | 29.20±7.40 | 69.00±6.96 | clay |
| Traditional | Poly | 2.00±0.71 | 25.20±1.79 | 72.80±2.28 | clay |
| Intensive | VnP | 2.40±1.95 | 24.20±3.35 | 73.40±5.13 | clay |
| Intensive | VnE | 3.00±3.46 | 25.00±4.30 | 72.00±6.67 | clay |

MN= Milkfish Nursery; Poly= Polyculture; VnP = Vannamei plastic mulchlinedpond; VnE =Vanamei earthen pond

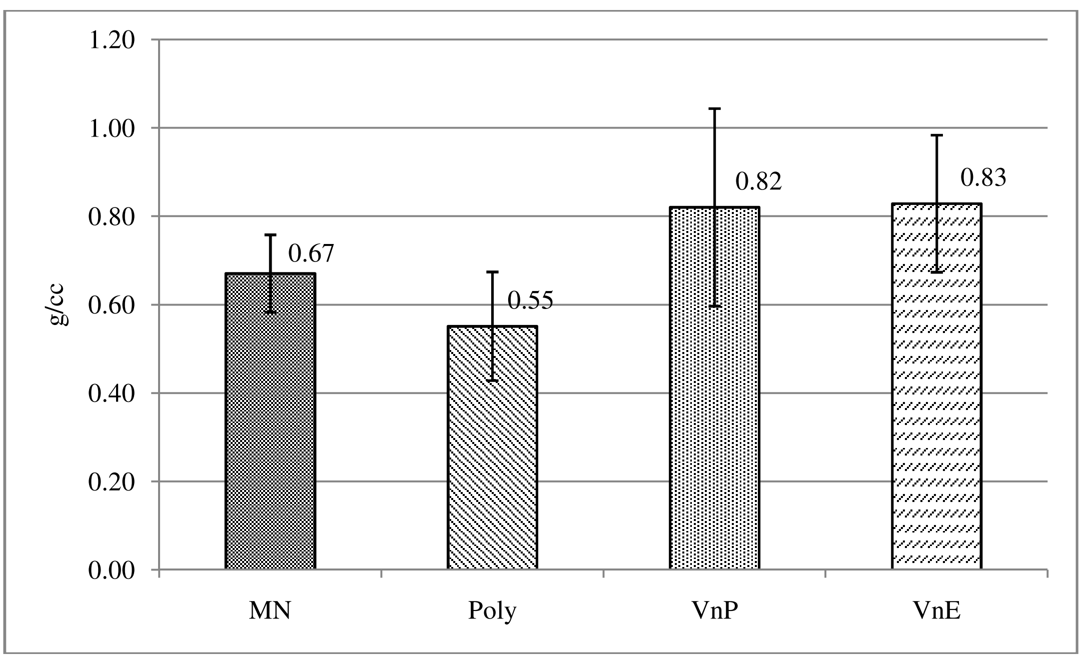


**Figure-2**
**Ponds soil bulk density of some aquaculture systems**

**Total sulfur:** The concentration of sulfur ranged from 0.01% until 1.09%, with an average 0.39±0.083%. Results of ANOVA also showed that aquaculture systems significantly (p<5%) affected the total sulfur concentration. Traditional polyculture ponds soil had the highest value of total sulfur while shrimp vanamei intensive earthen ponds had the lowest total sulfur content. Total sulfur value was reported in the range 0.433±0.612% on intensive shrimp pond with 4 years pond age[23]. Total sulfur content of 0.1-0.5% in the ponds soil included in the medium criteria[6]. Therefore it can be said that pond soil samples had a medium total of sulfur content. Total sulfur concentration increased linearly to the age of the ponds[22,24]. The original pond soil was low in sulfur content[25]. In the traditional pond in which sediment removal was never done was likely to be similar to the old ponds, so its sulfur concentration was higher than intensive ponds in which sediment removal was done regularly (the same as the original ponds soil) therefore it was able to keep the concentrations of total sulfur lower.

**Cation exchange capacity (CEC):** CEC value during this study ranged from 15.46 to 20.56 mEq /100g with an average 17.79±0.25 mEq/100g. Cation exchange capacity values from all ponds soil samples in different aquaculture systems showed no significant differences (p>5%), in both traditional and intensive systems. Pond soil in South Sulawesi Indonesia reported having CEC value ranging from 9.34 to 75.65 CEC mEq/100g with an average of 30.54 ± 15.09 mEq /100g[20].CEC values 12-25 mEq/100g included in medium criteria[26]. It can be saidthat CEC value on the pond soil samples included in the medium criteria. Soil cation exchange properties occuredas the result of clay content and soil organic matter[19]. CEC value based on the data obtained was more influenced by the high clay content than the factor of soil organic matter, given the low value of organic materials (c-organic) in soil samples (less than 1%). No differences in the value of the CEC between traditional and intensive farms systems may also be affected by soil pH value whichwas also not different between traditional and intensive systems

**Table-2**
**Ponds soil chemical properties in different aquaculture systems**

| Parameters | Aquaculture systems | | | |
|---|---|---|---|---|
| | Traditional | | Intensive | |
| | MN | Poly | VnP | VnE |
| pH | $6.91\pm0.46^{a}$ | $7.048\pm0.36^{a}$ | $5.74\pm0.07^{a}$ | $6.72\pm0.27^{a}$ |
| C-org (%) | $0.526\pm0.08^{a}$ | $0.746\pm0.06^{a}$ | $0.45\pm0.21^{ab}$ | $0.41\pm0.06^{b}$ |
| Total N (%) | $0.42\pm0.04^{ab}$ | $0.451\pm0.02^{a}$ | $0.30\pm0.06^{b}$ | $0.37\pm0.02^{b}$ |
| C:N ratio | $1.28\pm0.25^{ab}$ | $1.66\pm0.14^{a}$ | $1.21\pm0.33^{ab}$ | $1.11\pm0.15^{b}$ |
| S (%) | $0.44\pm0.32^{ab}$ | $0.82\pm0.18^{a}$ | $0.20\pm0.33^{b}$ | $0.08\pm0.16^{b}$ |
| CEC (mEq/100g) | $17.95\pm1.51^{a}$ | $18.16\pm0.96^{a}$ | $14.30\pm1.11^{a}$ | $17.88\pm0.88^{a}$ |
| Redox (mV) | $0.40\pm27.07^{a}$ | $-7.28\pm21.12^{a}$ | $1.35\pm3.71^{a}$ | $6.6\pm8.47^{a}$ |
| P (ppm) | $3,640\pm477^{b}$ | $2,680\pm487^{b}$ | $10,280\pm6,069^{a}$ | $9,000\pm3,977^{ab}$ |
| Fe (ppm) | $50,400\pm 6,177^{a}$ | $50,520\pm3,474^{a}$ | $50,060\pm4,714^{a}$ | $50,220\pm2,340^{a}$ |
| Ca (ppm) | $6,920\pm4,103^{a}$ | $9,020\pm3,401^{a}$ | $16,640\pm9,721^{a}$ | $17,760\pm8,336^{a}$ |
| K (ppm) | $9,660\pm1,532^{a}$ | $8,300\pm894^{a}$ | $7,800\pm1,350^{a}$ | $9,600\pm447^{a}$ |
| Mg (ppm) | $11,140\pm2,669^{a}$ | $9,780\pm1,045^{a}$ | $7,600\pm901^{a}$ | $8,800\pm418^{a}$ |

[a,b]The same letters in different column showed no significant differences ( p > 5 % ) in different aquaculture systems; MN: milkfish nursery pond, Poly: polyculture pond, VnP: vannamei plastic lined pond, VnE: vannamei earthen pond

**Redox potential (Eh):** The average value of the redox potential (Eh) were 0.335±3.823 mV with a minimum value -34.2 mV and a maximum 27.6 mV as seen in Table-2. Results statistical ANOVA, the redox potential values showed no significant differences (p>5%), although visually potential redok value on intensive farms was relatively higher than on traditional farms. Recommend redok potential values should be not less than -200 mV. According to the data, it may be said that the redox potential values of ponds soil samples in different aquaculture systems during the research is still in the optimal value. A negative value of soil redox potential indicates high electron activity and the level of anaerobic soil conditions[27]. The redox potential values in intensive aquaculture system of brackish water shrimp farming activities were relatively better, while the value of the redox potential on traditional farms were relatively low[20]. As of this research, the results can be explained by the well performance of intensive systems, drying process and ponds soil management, while both processes are not performed optimally on traditional farms. Consequently, traditional farms are always submerged by water. At the ponds soil is always submerged, the soil pores are also always filled with water, resulting in the deficiency of oxygen, and the soil tends to be in a reduced state.

**Total phosphorus:** The concentration of total phosphorus in the ponds soil samples ranged 2,100-20,500 ppm with the average 6,400±1,062 ppm. Results of ANOVA showed the concentration of total phosphorus were significantly different (p<5%) between intensive aquaculture system and traditional system as can be seen in Table-2. In the intensive system total phosphorus was higher than in traditional. Total phosphorus concentrations > 400 ppm is qualified as very high[6]. The increasing concentration of total phosphorus was linear to the increasing of ponds age[24,25]. Phosphors that did not go wasted at harvest, mostly in a state bound in the soil in the form of unavailable to plants[6]. Pond bottom soil accumulated a 67.8% total phosphorus that entered the pond[28]. Boyd; In the old ponds, the highest total content of phosphorus is at a depth of 5-10cm of soil layer and not on the soil surface[25]. Based on the data, it can be said that the concentration of phosphorus in ponds of research, includes in very high criteria. The high concentration of phosphorus is probably influenced by the old age of ponds. Higher concentration of phosphorus in intensive farms was caused by higher aqua feed input during culture and phosphorus settles and bounded not in the soil surface, soits difficult to remove during ponds sediment removal.

**Iron, calcium, potassium and magnesium:** Iron concentrations in pond soil samples ranged from 43,300 to 60,700 ppm with an average of 50,300 ± 906 ppm. The concentration of calcium in the ponds soil samples ranged 3,200-33,400 ppm with an average concentration 12,585±1,784 ppm. Potassium concentration obtained in this study 7,100-12,200 ppm with an average concentration 9,230 ± 265 ppm. Pond soil magnesium concentrations ranged from 8,100 to 15,700 ppm with an average 9,710±373 ppm. Results of statistical analysis for all nutrient above showed no significant differences (p>5%) among different aquaculture systems. It can be said that the concentration of all nutrients above is very high according to criteria for brackish water ponds soil[6]. Concentrations of iron, calcium, magnesium and potassium was higher in older ponds and there were no differences of iron concentrations in sediments in the different depths[22]. Large increase in the Fe content after the production cycle and asymptotically in the older ponds[24]. There are no differences of iron concentrations in the ponds with and without sediment removal (p>5%)[14]. Magnesium concentration in the sediment increased after the production[29]. Lime application resulted in the accumulation of calcium carbonate on the pond bottom soil[30]. The high concentration of magnesium, potassium and calcium in the soil of brackish water ponds resulted from the absorption of these nutrients from the brackish water and settle in soil sediment during the drying process[24]. Usually high concentration of magnesium in the soil is considered beneficial to pond aquaculture systems[3]. Furthermore, there is no limit for the maximum and minimum concentration of potassium recommended for aquaculture.

Based on the explanation above, the high concentration of these nutrients in the ponds soil samples possibly is caused by natural soil conditions at the study site and the old age of the ponds. Absorption of nutrients available in brackish water pond by bottom soil also becomes a factor causing the high content of these nutrients in the soil. Application of calcium during culture in intensive systems also leads to the concentration of calcium in intensive farms higher than on traditional farms although statistically there is no significantly different. The high concentration of potassium, magnesium and calcium is presumed not to be a problem for the aquaculture activities, keeping in none of maximum and minimum limits for these concentrations in pond soil, even considered to be favorable for aquaculture activities.

**Correlation between soil quality parameters:** Bulk density parameters was very significantly (p<1%) and negatively correlated to the c-organic (r= -0.8), total nitrogen (r= -0.85), C:N ratio (r=-0.6) and total sulfur (r= -0.73). Clay content was very significantly and negatively correlation to the concentration of magnesium (r = -0.6). The pH value was very significantly and negatively correlated to the value of the potential redox (r= -0.97) and positively correlated to the iron content (r=0.63) and magnesium (r= 0.63). Organic carbon was very significantly and negatively correlated to the value of the bulk density (r= -0.8) and positively correlated to total nitrogen (r= 0.72), C:N ratio (r = 0.92) and total sulfur (r= 0.87). Total nitrogen was very significantly and negatively correlated to the value of the bulk density (r= -0.85) and positively correlated to the concentration of c-organic (r= 0.72) and total sulfur (r= 0.61). C:N ratio was very significantly and negatively correlated to the bulk density (r=-0.6), and positively correlated to the c-organic (r= 0.92) and total sulfur (r= 0.82). Total sulfur was very significantly and negatively correlated to the bulk density (r=-0.73), positively correlated to the c-organic (r= 0.87), total nitrogen (r = 0.61) and the C: N ratio (r = 0.82). CEC values did not correlate significantly to all soil quality parameters l. Redox potential was negatively correlated to the soil pH (r= -0.97), iron (r= -0.66) and magnesium (r= -0.65). Total phosphorus was very significantly andpositively correlatedto calcium (r= 0.59). Iron was very significantly and positively correlated to soil pH (r= 0.63) and magnesium (r= 0.66), negatively correlated to the value of redox potential (r= -0.66). Calcium content was very significantly andpositively correlated only to total phosphorus (r= 0.59). Potassium did not correlate significantly to any of soil parameters. Magnesium was very significantly and negatively correlated to parameters of clay content (r= -0.60) and redox potential (r= -0.65), positively correlated to pH (r= 0.63), and iron (r= 0.66)

## Conclusion

Clay content, total phosphorus, iron, calcium, potassium and magnesium belong tovery high criteria and parameters of sand while c-organic C:N ratio belong to very low criteria. Soil pH, CEC, redox potential, bulk density in intensive systems, total nitrogen, and total sulfur are still in optimum criteria for aquaculture. Aquaculture systems significantly affect some ponds soil quality parameters. Efforts areneeded to improve soil quality conditions based on the status of physico-chemical parameters.

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