INTERACTION BETWEEN POND-BOTTOM SOIL AND WATER QUALITIES

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ABSTRACT
Considerable monthly variations were observed in soil properties and water qualities of two ponds during a six-month period. The textural class of soil of Pond 1 was silt loam and that of Pond 2, in general, silty clay loam. The inwash of silt, etc., with the large volume of surface run-off of rain water from the surrounding agriculture farm, and the suspension of the dead self-vegetation of the pond, resulted in the lowest value of transparency in Pond 1 being recorded during July; whereas, the relatively abundant growth of phyto-plankton in Pond 2 was responsible for reduced transparency there in May and again in August, as compared with the same in the remaining four months of the study period. The pH of bottom soil and of water indicated that Pond 2 is more suitable for fish culture. In both Pond 1 and Pond 2, pH values showed a more or less direct relationship with dissolved oxygen content and an inverse relationship with free carbon dioxide. The organic carbon content of Pond 1 and that of Pond 2 have been classified as supporting average production. No direct relationship between exchangeable potassium of soil and potassium of water in the two ponds could be established. In Pond 1 chlorium value of water maintained an inverse relationship with that of soil, while in Pond 2, again, this relationship was not clear. The total nitrogen and organic carbon contents of soil exhibited a direct relationship in both Pond 1 and Pond 2. The concentration of ammonia-nitrogen was higher in Pond 1 than in Pond 2, while the reverse was true for nitrate-nitrogen. The nitrate-nitrogen value of soil in Pond 1 showed no distinct relationship with that of water, while a more or less inverse relationship between the two was observed in Pond 2. Available soil-phosphorus of Pond 1 showed an inverse relationship with that of water, while the same did not show any clear relationship in case of Pond 2. The iron-content of soil as well as of water of both the ponds was found to be in the relatively higher range for fish ponds. In both Pond 1 and 2 the iron-content of the water showed an inverse correlation with that of soil.

INTRODUCTION
It is well-known that the growth and palatability of fishes of different water-bodies, even if they lie side by side, are different. Again fishes of the same pond vary in too many aspects from season to season. It is not unreasonable to assume that this so happens due to the variation in the inherent qualities of
water as well as of soil, the two interacting with, and influencing, each other. In this connection Banerjea (1967) pointed out that in agricultural practices it was generally found that adjoining plots produced the same crop yield, but in fish culture practices it was sometimes found that two ponds lying close to each other, and with the same management practices showed a marked difference in their fish-crop.

The water of the pond, the habitat of fishes and other aquatic organisms, is in close contact with the bottom mud. In normal ponds, not influenced by external factors, the physical and chemical properties of pond water are more or less a reflection of the properties of the bottom-soil; and the nutrient status of both water and soil play the most important role in governing the production of planktonic organisms in fish ponds, and that must be understood to concern both quality and quantity (Banerjea 1967). An understanding of the inherent fertility status of the soil, and its influence on the productive quality of the water of the pond, is expected to better explain the differences in the growth and taste of fishes than would a study of the water qualities alone.

The object of the present study, therefore, has been to have a basic knowledge of the soil conditions and water qualities of ponds and, secondly—which is considered more important—to find out the nature of interaction between the physico-chemical qualities of soil and water.

**Materials and Methods**

Two artificial perennial ponds in Bangladesh Agricultural University Campus, Mymensingh, were selected for the study. The ponds were arbitrarily numbered as Pond 1 and Pond 2 for the sake of recording the data and reporting the results.

Pond 1 is believed to have been constructed about 150 years back primarily as a source of domestic water supply. This is more or less rectangular in shape with an area of 0.60 acre at the highest water-level. There are four narrow inlets to carry water from the adjoining Agriculture Farm land to the pond. The pond was covered with a thick growth of water hyacinth (*Eichhornia crassipes*) right from the beginning of the study (23 April 1976). Pond 2 is a newly-constructed pond, dug in 1973. It is moderately large and 'L' shaped with a water area of 7.60 acres. The water is fairly clear and free from vegetation except some rooted ones in the shallow shore area. It is a rain-fed pond having no inlets or outlets.

The investigation continued for a period of six months, from 23 April to 23 September 1976. Three stations in each pond were selected arbitrarily and marked by bamboo poles. Water and soil samples were collected from the same places throughout the period of the investigation. Samples were collected
between 0900 hours and 1200 hours. Recording of on-the-spot data and sampling for water and soil were made at monthly intervals on the 23rd of each month using a small steel boat. Collection of samples on each sampling day was started at Station I of Pond 1 terminating at Station III of Pond 2.

Monthly sample of pond-bottom soils were collected from the soil-water interface with the help of an Ekman Dredge (15 cm x 15 cm in cross section) which was designed to trap normally a column of soil of 3-4 cm deep. Soil samples collected from different stations were put into separate wide-mouthed, clean, glass bottles of 1-litre capacity, and were carried to the laboratory. Collections were restricted within the radius of one square meter of the fixed poles. The samples were air-dried, ground, sieved through a 10-mesh sieve, and bottled for laboratory analyses, and then the percentage of moisture in the air-dried samples determined by drying the soil overnight in an oven at 105°C. Analyses were made from air-dried samples but results were expressed on oven-dry basis, corrections having been made for the percentage of moisture.

Three water samples—one each from the bottom, 120 cm above the bottom, and surface—were collected from each fixed point at monthly intervals on the 23rd of each month using a Kemmerer-type water-sampler. Water samples for each station as collected by the sampler were put into three separate clean glass-stopped bottles of 500ml capacity. For the determination of the dissolved oxygen duplicate samples were taken in 250ml blackened bottles. Free carbon-dioxide was measured on the spot immediately after collection of the sample. All the bottles containing water were kept in a black wooden box for protection from light, and carried to the laboratory for analysis. Determinations of pH, hardness and dissolved oxygen were made immediately after reaching the laboratory, and the remaining portions of the samples were stored by adding 1 to 2 drops of toluene after filtration through Whatman-1 filter paper to estimate the chemical constituents.

Colour of both wet and dry soil samples were determined by eye-estimation. Texture of the soil was determined by mechanical analysis by Hydrometer Method. The temperature of the air and of the water collected from different depths were recorded. The transparency of water was determined with a standard Secchi disc. The data for rainfall, sunshine hours, and relative humidity were collected from the nearby Weather Yard of the Bangladesh Agricultural University, Mymensingh.

Soil-pH was determined by Fisher Laboratory pH meter and organic carbon by Wet Oxidation Method of Walkley and Black (1935). Nitrate-nitrogen was determined on evaporated soil extract with phenol disulphonic acid by developing nitrophenol-disulphonic yellow colour measured with colorimeter while ammonia-nitrogen and phosphate-phosphorus were determined after Jackson (1962). Total nitrogen was determined by Semimicro Kjeldahl Method (Black 1965). Exchangeable potassium, calcium and magnesium were determined on the ammonium acetate extract by Eppendorf Flame Photometer, and iron after Piper
For most of the chemical analyses of water, standard method of American Public Health Association (1971) were followed with slight modifications wherever necessary. However, phosphate-phosphorus was determined after Jackson (1962) and potassium, calcium and magnesium by Eppendorf Flam Photometer. Iron content of water was estimated volumetrically after Piper (1950) and Vogel (1961).

**RESULTS AND DISCUSSION**

Data obtained on monthly variations of rainfall, hours of sunshine, relative humidity; and air and water temperature, and water level are presented in Fig. 1. Data on the average values for pH, organic carbon, total nitrogen, nitrate-nitrogen, ammonium-nitrogen, phosphorus (P₂O₅), exchangeable potassium, exchangeable calcium, exchangeable magnesium, and iron of soil and those for water level, transparency, temperature, pH, total hardness, dissolved oxygen, free carbon dioxide, nitrate-nitrogen, phosphate-phosphorus, potassium, calcium, magnesium, and iron of water have been presented in Table 1 and Table 2 and Figs. 2-4.

![Graph](image-url)

**Fig. 1.** Monthly variations of rainfall, sunshine hours and relative humidity together with air and water temperatures and water level at Pond 1 and Pond 2.
TABLE 1. Average (average of three stations) monthly variations of organic carbon, total nitrogen and ammonia nitrogen of soil in Pond 1 and Pond 2 during 23 April to 23 September 1976.

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<tr>
<th></th>
<th>POND 1</th>
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<tr>
<td>Organic carbon (%)</td>
<td>1.00</td>
<td>0.95</td>
<td>0.99</td>
<td>0.98</td>
<td>1.01</td>
<td>1.04</td>
<td>0.89</td>
<td>0.82</td>
<td>0.95</td>
<td>0.92</td>
<td>0.95</td>
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<tr>
<td>Total nitrogen (%)</td>
<td>0.137</td>
<td>0.097</td>
<td>0.127</td>
<td>0.125</td>
<td>0.128</td>
<td>0.139</td>
<td>0.114</td>
<td>0.104</td>
<td>0.118</td>
<td>0.115</td>
<td>0.117</td>
</tr>
<tr>
<td>Ammonia nitrogen (me/100 g)</td>
<td>5.04</td>
<td>5.26</td>
<td>5.00</td>
<td>5.23</td>
<td>4.96</td>
<td>4.90</td>
<td>3.57</td>
<td>3.08</td>
<td>3.65</td>
<td>3.56</td>
<td>3.89</td>
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TABLE 2. Average (average of 3 readings - one for each station) monthly variations of transparency and average (average of nine readings - 3 for each station) monthly variations of total hardness, dissolved oxygen, and free carbondioxide of water in Pond 1 and Pond 2 during 23 April to 23 September 1976.

<table>
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<tr>
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<th>POND 1</th>
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<td>AUG</td>
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<tr>
<td>Transparency (in cm)</td>
<td>—</td>
<td>99.00</td>
<td>91.50</td>
<td>76.00</td>
<td>96.50</td>
<td>96.00</td>
<td>112.00</td>
<td>106.50</td>
<td>127.00</td>
<td>122.00</td>
<td>108.00</td>
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<tr>
<td>Total hardness as CaCO₃ (ppm)</td>
<td>87.00</td>
<td>84.22</td>
<td>71.00</td>
<td>71.56</td>
<td>73.11</td>
<td>77.78</td>
<td>82.89</td>
<td>74.55</td>
<td>64.37</td>
<td>68.89</td>
<td>68.11</td>
</tr>
<tr>
<td>Dissolved oxygen (ppm)</td>
<td>2.57</td>
<td>2.01</td>
<td>1.83</td>
<td>1.39</td>
<td>1.47</td>
<td>1.19</td>
<td>7.17</td>
<td>7.74</td>
<td>7.21</td>
<td>6.57</td>
<td>7.34</td>
</tr>
<tr>
<td>Free carbondioxide (ppm)</td>
<td>14.79</td>
<td>14.64</td>
<td>22.11</td>
<td>26.98</td>
<td>28.43</td>
<td>29.49</td>
<td>1.04</td>
<td>1.93</td>
<td>2.58</td>
<td>2.53</td>
<td>2.24</td>
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</table>
Throughout the present study, the colour of soil of both Pond 1 and Pond 2 remained, in general, dark before drying and gray after drying. But the very upper surface of the mud showed a brownish red tinge before drying. As per textural classification the bottom-soil of Pond 1 was found to be silt loam and that of Pond 2 in general silty clay loam throughout the investigation. However, to start with, the soil at Station III of Pond 2 was found to be silt loam in April and May, subsequently changing to silt clay loam as for the other two stations. The general gray colour of soil is thought to be due to the presence of organic matter, while the brownish red tinge provided an indication of deposition of ferric oxide.

The soil texture of Pond 1, which was silt loam throughout the investigation, might be an indication of homogeneity of the constituents due to the age of the pond. On the other hand, Pond 2, being a newly dug one, showed a trend of changing from silt loam to silty clay loam. As pointed out by Nees (1946), an ideal pond-soil should not be too sandy to allow too much leaching of the nutrients, nor should it be too clayey to keep all the nutrients adsorbed in it. On the basis of soil-texture, then, both the ponds may be taken to be ideal or near-ideal for fish cultural purposes.

The gradual acidic trend of the soil of Pond 1 (Fig. 2A) might be due to the short supply of oxygen to the soil-water interface as a result of which the decomposition of organic matter slowed down giving rise to reduced or partially oxidized compounds like H₂S, CH₄ and short-chain fatty acids which are, according to Banerjea (1967), the causative agents to make the soil strongly acidic, unless it is naturally buffered. Schaperclaus (1933) reported that slightly alkaline pH was favourable for both soil and water of a fish pond. Banerjea (op.cit.) maintained that an almost neutral soil reaction (pH 6.5-7.5) of ponds was optimal for fish culture, while moderately acid (pH 5.5-6.5) and moderately alkaline reactions (pH 7.5-8.5) were likely to produce average yields of fish.

On all occasions the water of Pond 1 was found in the acidic range showing a gradually decreasing trend as the experiment progressed, while that of Pond 2 fluctuated through alkaline and acidic ranges (Fig. 2A). In case of both Pond 1 and Pond 2, a more or less direct relationship between the pH value and the dissolved oxygen content was observed. A similar phenomenon was also reported by Sitaramiah (1966). Again, a more or less inverse correlation between pH value and free carbon dioxide was noticed in both Pond 1 and Pond 2. Michael (1969) also observed similar relationship between these two factors. Royce (1972) reported that values of water-pH outside the range of about 4.5-10.0 were detrimental to fish, but that is rarely occurred. Banerjea (1967) reported that water with an almost neutral reaction was best suited for a fish pond and the ponds having the water-pH outside the range of 6.5-8.5 were all found to be unproductive.
The gradual decrease in the pH values of soil and water as the experiment progressed in Pond 1 might be due to its remaining covered with water hyacinth, resulting in an increase of carbondioxide through respiration and decomposition, and decrease in photosynthetic activities in the water. In contrast, the sharp decline of pH values of water as well as of soils of Pond 2 (Fig. 2A) in June, that was followed by a gradual, but slow, decreasing trend up to August.

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**Fig. 2.** Monthly variations of (A) pH and (B) exchangeable potassium of soil and water in the two ponds.
might be correlated with relatively heavier rainfall in June (Fig. 1). This would confirm the findings of Khalaf and MacDonald (1975) that rainfall produced an immediate decrease in the pH of the ponds.

Fig 2A will indicate that the pH values of waters in both Pond 1 and Pond 2 always maintained a more or less direct correlation with the values of those of bottom-soils. It is also interesting to note that specially in case of Pond 1 the amplitude of difference between water and soil pH values was found to be very narrow except in month of April. This might be accounted for by the greater decomposition and lower photosynthetic activities in Pond 1. The productivity of Pond 1 was found to be less than that of Pond 2, which has been thought to be due to the acidic nature of the former pond (Mollah and Aminul Haque 1978). This would confirm the observations of Alikunhi (1957) that in India, water on acid soil was generally less productive of fish than that on alkaline soil.

An inverse correlation was established between pH value and iron content of water in both the ponds. Uspenski (1927) showed that acidic waters were capable of holding more iron than alkaline ones because, they explained, a decrease in the pH of water brought in more soluble iron from the substratum. Brambel and Cowles (1941), on the otherhand, showed that very minute quantities of soluble iron existed in water at pH value of 8.5 to 9.8.

Banerjea (1967) considered a concentration of less than 0.5% for organic carbon to be too low and a concentration of more than 2.5% for the same to be too high for fish ponds. He maintained that an average production could be obtained from ponds having 0.5-1.5% organic carbon in their soils, whereas, according to him, ponds with 1.5-2.5% organic carbon-content appeared to give optimum production.

The least concentration of organic carbon-content (Table 1) of soil of Pond 1 as obtained in May (0.95%) might be correlated with precipitation and the resultant higher water-level (198 cm) on the one hand, and relatively higher decomposition of the organic matter due to the addition of new water on the other. And the gradual increase from July to September could be attributed to the death of the water hyacinth. The same explanation would hold good when Pond 2 was considered for the months of April and May. But the increased concentration in the months of June, July and August might be correlated with the organic deposition and minimum decomposition because of non-availability of the required amount of oxygen.

According to Banerjea (1967) ponds having soil with available nitrogen (NO₃-N+NH₄-N) below 25 mg/100 g of soil was poor in production, and those with available nitrogen in the range of 25-75 mg/100 g gave "high, average or low" production, while ponds having available nitrogen more than 75 mg/100 g of soil showed no difference in production from the latter range. On the
basis of this the bottom-soils of both Pond 1 (95.06-101.07 mg/100 g) and Pond 2 (62.76-78.84 mg/100 g) could be classified as high, average or low in production.

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**Fig. 3.** Monthly variations of (A) exchangeable calcium and (B) exchangeable magnesium of soil and water in the two ponds.
It is logical to put that during the entire study period the ammonia-nitrogen value of Pond 1 was always greater than that of Pond 2 while the reverse was true for the nitrate-nitrogen except only in the month of June. The reason for this lone exception was not clearly understood. But the overall low value for nitrate-nitrogen and high value for that of ammonia-nitrogen in Pond 1 was thought to be due to the oxygen deficiency in that pond to convert ammonia-nitrogen into nitrate-nitrogen.

An abrupt and unusual rise of nitrate-nitrogen value of water in May from its minimum in April in Pond 1 (Fig. 4A) might well be correlated with the addition of a large volume of rainwater washed out from the surrounding agriculture farm. David et al (1969) stated that during the rainy months the nitrates were supplied through flood washing, while in summer low levels, the supply was ensured by bottom-sediments. The gradual decrease of this nutrient starting from June till September in both the ponds could be attributed to the subsequent fall of dissolved oxygen-content which is in conformity with the findings of Zafar (1964) and Venkateswara (1969). No well-marked relationship between the nitrate-nitrogen of water and that of soil in Pond 1 was observed, while in case of Pond 2 an ill-defined negative correlation was noticed (Fig. 4A).

In his study Banerjea (1967) observed that in the range of 3-6 available phosphorus (expressed as mg P₂O₅/100 g of soil) 26 out of 27 ponds were productive and one was unproductive; in the range of 6-12, out of 18 ponds 14 were productive, 3 average and only one was unproductive; while ponds with available phosphorus above 12 were all productive. The range of available phosphorus as recorded for Pond 1 (4.89-8.70 mg/100 g) provided, therefore, an indication of the moderate productivity of the bottom-soil, while the bottom-soil of Pond 2 (10.53-16.93 mg/100 g) indicated its high productiveness in respect of phosphorus. In the present study the reasons for the abrupt fall in the available phosphorus value in May (4.89 mg/100 g) in Pond 1 could not be ascertained. The monthly increasing value of the item in the soil of Pond 2 (Fig. 4B) could be an indication of gradual deposition of the same in the bottom of the newly dug pond.

In case of Pond 1 the highest phosphate-phosphorus concentration of water as recorded in May (Fig. 4B) could be attributed to the addition and accumulation of inorganic phosphate from the surrounding agriculture farm through runoff. Michael (1969) maintained that phosphorus might get entry into the pond water through the inflow. Saha et al. (1971) also suggested that the rain washings were the main causative factors for the steep rises of nitrate and phosphate in pond waters. According to the phosphorus fertility scale given by Moyle (1946) both Pond 1 and Pond 2 fall in the good and very food categories.
Fig. 4. Monthly variations of (A) nitrate-nitrogen and (B) phosphate-phosphorus and (C) iron of soil and water in the two ponds.
Available phosphorus of water and that of soil of Pond 1 showed a more or less inverse relationship while in Pond 2 the similar correlation was ill-defined (Fig. 4B).

The values for potassium of water and of soil in Pond 1 did not show any apparent relationship. On the other hand they showed more or less direct relationship in Pond 2 except in July when the potassium recorded its highest value in soil, the reasons for the same remaining obscure.

The highest value for potassium of water as obtained in April in Pond 1 might be correlated with low water level and high pH value. And the increasing trend from August onward would be accounted for by the release of potassium directly from the plant tissue after decomposition.

According to the classification proposed in 1934 by the German limnologist W. Ohle (Reid 1961) both Pond 1 and Pond 2 were unproductive (poor) in respect of calcium content. In Pond 1 calcium value of water exhibited an inverse relationship with that of soil (Fig. 3A), while in Pond 2 the correlation was not clear.

The values for magnesium in the water of Pond 1 maintained a direct relationship with that of the soil except in the month of June. Similar relationship was observed for Pond 2 in all the months except in April and May (Fig. 3B). The reasons for this peculiar behaviour was not clearly understood.

It is evident from the researches of Uspenski (1927) that iron forms a limiting factor in the development of plankton, and this is of great importance in determining the vegetation in the aquatic habitats.

The high iron-content of soils of Pond 1 and Pond 2 (3.55-5.24%) had some conformity with the findings of Banerjea and Ghosh (1970) who found iron to fluctuate between 4.92% and 7.17% in case of some Indian ponds.

Schaperclaus (1933) described how the water used in the fishponds of Lusatia in the Eastern Zone of Germany, was bright red with iron oxide and with pH values of 3 to 5, yet very good fish crops were obtained from these ponds. This bright red colour of water could indicate that the iron content of the water in those ponds was much higher than 2 ppm. The results of the present investigation also showed high iron-content (11.79-19.86 ppm.) of water. The higher values of iron was correlated with lower values of pH as well as of dissolved oxygen, since oxygen can convert ferrous iron to ferric state causing their subsequent precipitation in the bottom-mud, and this is considered to be the reason for the inverse relationship between the iron-content of water and of soil as observed in both Pond 1 and Pond 2 (Fig. 4C).
References


Banerjia, S. M. 1967. Water quality and soil condition of fish ponds in some states of India in relation to fish production. *Indian J. Fish.*, 14: 115-144.


