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Comparative study of physico-chemical properties of soil according to the age of aquaculture pond of Bangladesh

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Abstract - Soil quality is an important factor in fish pond productivity as it controls pond bottom stability, pH of overlying water and concentrations of plant nutrients required for the growth of phytoplankton. A satisfactory site for constructing fishponds is that where the soil is very deep with neutral pH, weather infiltration is very low; mineralization of organic matter takes place rapidly. The present study was carried out to assess different soil parameters in different aged ponds and to find out the relationship between different aged ponds with different bottom soil parameters. Three groups of ponds (1-5 years, 6-10 years and above 10 years) were analyzed. There was no significant change of soil pH among different aged ponds. Significant variations were observed in textural compositions of different aged group pond's soil. Mean percentages of clay and silt were found to be increasing with the increase of pond's age. Amount of organic matter and organic carbon also increased sharply with the increasing of pond's age. No significant variation were found from different aged group ponds for soil pH but the amount of organic matter, organic carbon, silt and clay were significantly increased with the increasing of pond age that may deteriorate the quality of pond's bottom soil.

Keywords: Soil quality, pond age, soil texture, pH, organic matter and organic carbon.

Introduction

Bangladesh is a land of rivers with a long coast line (713 km) from Khulna to Cox's Bazar. In different region of coastal belt aquaculture has been practiced for a long time. At present day aquaculture is a profitable business and is going to be more popular in these days. In Bangladesh perspective, aquaculture may be a good process to minimize the poverty and to meet the demand of animal protein.

Water quality management has been considered one of the most important aspects of pond aquaculture for many years, but less attention has been given to the management of pond bottom soil quality. The condition of pond's bottoms and the exchange of substances between soil and water can be strongly influenced water quality (Boyd, 1995). More attention is being devoted to the study of pond soils, and practical aquaculturists are beginning to seek information on pond bottom management. In order to have a clear understanding of the various physico-chemical and biological processes and to make decisions on the suitability of sites for aquaculture as well as effective managements of the soils for increased productivity of the ponds, one needs to have good knowledge on the nature and properties of the soil (Ahmed, 2004). The science of aquaculture has many similarities with that of agriculture though it is a recent development compared to the latter. Many of the ideas in aquaculture are derived from the experiences in agriculture. Agriculture deals with soil-plant-animal relationships where as aquaculture deals with the interaction of relationships of soil, water and biota.

Pond soil plays an important role in the balance of an aquaculture system and consequently on the growth and survival at aquatic organisms (Ahmed, 2004). The pond soil can function as a buffer to the aquatic ecosystem. It provides all the important nutrients with water and serves as a biological filter through the adsorption of the organic residues of feed, fish excretions and algal metabolites (Townsend, 1982). Feed applied to increase fish and shrimp growth is settled to the pond bottom. An excessive application of formulated feed results in the loss of the capacity of soil to keep uniformity in constituents. In semi-intensive and intensive fish ponds, significant quantities of organic material can be accumulated in bottom sediments. Inorganic nutrients released to the water from microbial decomposition of residual feed can stimulate heavy phytoplankton bloom (Avnimelech, 1984). In the shallow water bodies, there is an intense interchange of organic or mineral compounds between the soil and water and higher water exchange may results in large amount of sediment input (Wrobel, 1983).

Bottom soil quality is one of the key factors in the success of aquaculture, especially in semi-intensive and intensive culture systems. Although pond soils are involved in many processes that affect water quality, the most soil related problem facing shrimp and fish farmers are organic soils or potential acid-sulphate soils, sedimentation, organic matter accumulation and attendant anaerobic conditions on pond bottoms. It has been suggested that organic matter increases in bottom soil with increasing of ponds age until equilibrium organic matter concentration is attained (Avnimelech, 1984; Boyd, 1995). Studies have shown that new ponds have lower concentrations of organic matter than older ponds, but information on the rate of increase in organic matter over time is lacking (Munsiri *et al.*, 1995, 1996).

Soil respiration rate measured as carbon dioxide evolution increases with increasing organic matter concentration (Sonnenholzner and Boyd, 1982; Boyd *et al.*, 1994). However, no studies have considered if the rate of carbon dioxide evolution per unit of organic matter decreases as ponds become older and more stable organic matter accumulates in pond soils (Boyd *et al.,* 1994). Knowledge of the rate of soil organic matter accumulation and any changes in the reactivity of organic matter with ponds age will be valuable in determining how often ponds should be drained and their bottoms dried in order to enhance organic matter decomposition. The present study was carried out to investigate bottom soil parameters in different aged ponds and lastly find out the relationship between different aged ponds with different bottom soil parameters.

Materials and Methods

Study area and selection of ponds

Total nine fish ponds have been selected from Gumanmordon village near Halda watershed, Chittagong. This study area was chosen for this study as aquaculture has been developed extensively in this area for the last 2 decades due to suitable environmental parameters and availability of natural fry from the Halda River (a unique natural spawning ground). Figure (1) is illustrated the study location. The areas of the selected ponds were ranged between 2,000 to 5,000 m^2 with average depths of about 1 to 1.5 m and had been used for poly-culture. An attempt was taken to select ponds that are similar with respect to stocking densities, fertilization and feeding regimes and other management inputs. Only ponds that have been in continuous production for a known number of years were selected. For this experiment, selected culture ponds have been divided into 3 groups (1-5 years aged, 6-10 years aged and above 10 years aged). Information's of selected ponds were collected from the pond owners or managers.

Collection of Soil samples

Bottom soils were collected from the selected ponds with 5 cm diameter core tube at a depth of 0-10 cm of the pond bottom. Approximately 1 kg samples were collected from each pond at a 10 m distance for every replication. Then soil samples were put in tight plastic bags and transported to the laboratory. In the laboratory the samples were air dried at 60°C, broken into smaller size particles with mortar and pestle and sieved through a 2mm sieve.

Analysis of collected samples

Hydrogen ion concentration was obtained by a soil pH meter. Soil texture was detected following the procedure described by Boyd (1995). Soil organic matter was detected following the Boyd (1995b) method. In the laboratory soil Organic Carbon was determined according to the method of Walkley-Black method which was modified by Jackson (1958). Total alkalinity of the taken sample was determined by following the titrimetric method according to APHA (1976).

Statistical Analysis

The nature of this study does not allow for replication of pond ages as treatments. A logarithmic transformation was done on the data to improve normality. Analysis of variance (ANOVA) was performed to assess whether physico-chemical properties of soil varied significantly according to the age of the cultured pond; possibilities less than 0.01 ($p < 0.01$) were considered statistically significant. Statistical software SPSS 19.0 has been used to perform the data analysis of this study.

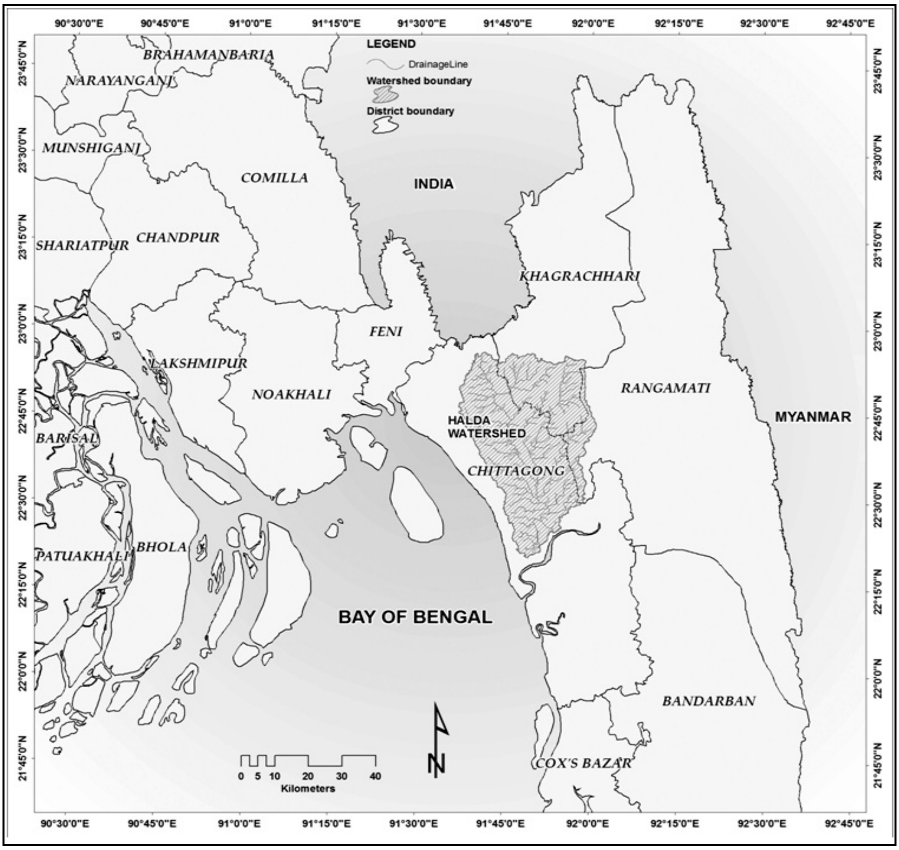

Figure 1. Geographical location of the study area (Shed colored).

Results and Discussion

Physico-chemical parameters of soil from selected culture ponds were analyzed periodically. Physico-chemical properties of soil included soil texture, soil pH, soil alkalinity, organic carbon and organic matter. The results are described below.

Soil texture

The term texture refers to the particle size distribution in soil. A soil texture name can be assigned with a soil triangle using data on percentages of sand, silt, and clay. In the present study, (1-5) year aged ponds contain 54-56 % of sand, 29-31 % of silt and 11-15 % clay which may be considered as sandy loam soil. (6-10) years aged ponds contains 48-50 % sand, 22-25 % silt and 27-28 % clay which may be considered as sandy clay loam soil. Above 10 years aged ponds contain 33-37 % sand, 31-48 % silt and 15-32 % clay which may be considered as clay loam soil (see Table 1).

Table 1. Percentage of compositions and texture class of soil collected from different aged ponds.

Selected Ponds	Pond's group	Pond's area	Sand %	Silt %	Clay %	Texture type
Pond 1	1-5	2500 m^2	56	29	15	Sandy loam
Pond 2	Years	3100 m^2	54	35	11	Sandy loam
Pond 3	aged	4200 m^2	56	31	13	Sandy loam
Pond 4	6-10	3700 m^2	49	24	27	Sandy clay loam
Pond 5	Years	2800 m^2	50	22	28	Sandy clay loam
Pond 6	aged	5000 m^2	48	25	27	Sandy clay loam
Pond 7	<10	4800 m^2	37	48	15	Silt loam
Pond 8	Years	3600 m^2	33	39	28	Clay Loam
Pond 9	aged	2900 m^2	37	31	32	Clay loam

Significant variations were observed in textural compositions of different aged group pond's soil. Mean percentages of clay and silt were found to be increasing with the increase of pond's age, where the mean percentages of sand particles were seen to be decreasing with increasing of pond's age (see Figure 2). According to Pudadera (1984) sandy clay loam type of soil is the preferable kinds of soil type for Aquaculture. He also stated that sandy clay loam to sandy loam was preferred for the semi-intensive and intensive culture where artificial food was used as the main source of food. Ahmed (2004) reported that sandy clay loam to sandy loam type of soil is suitable for coastal aquaculture in Bangladesh. So, it can be lucidly remarked that the bottom soil of all the studied ponds were suitable for aquaculture.

Soil pH

The soil pH of the selected ponds were recorded ranged between 6.2-6.3 from (1-5) years aged ponds, 6.0-6.2 from nearly (6-10) years aged ponds and 6.1-6.2 were found from above 10 years aged ponds (see Table 2). Maximum soil pH (6.3) was recorded from (1-5) years aged ponds. No significant variations in soil pH were found in the present investigation. The reason is that farmers continuously use lime to maintain the water quality of these ponds. Banerjee (1978) stated that soil pH could be depended on various factors. When the mud layers are not well aerated and the supply of oxygen falls short then the decomposition rates of the products are reduced or partially oxidized. However, the production of H_2S, CH_4 and short chain fatty acids are undesirable in as much as they make the soil strongly acidic and reduced the rate of bacterial action, ultimately leading to less productivity.

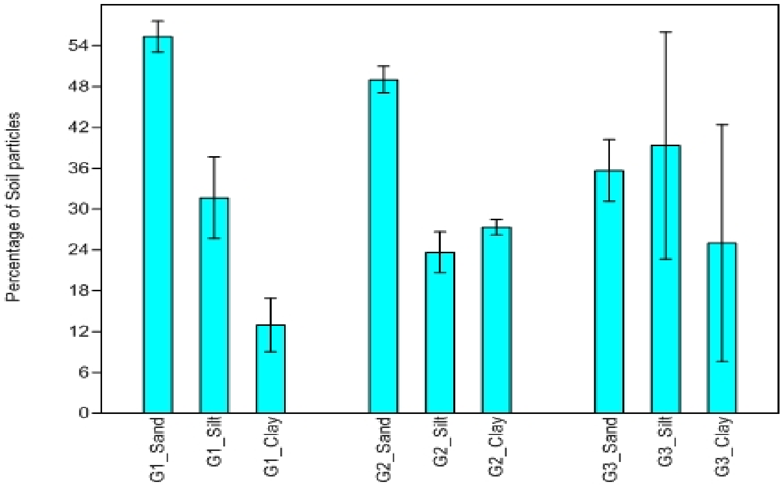

Figure 2. Comparison of the soil texture among different pond's group (G1 = 1-5 years aged ponds, G2 = 6-10 years aged ponds and G3 = above 10 years aged ponds)

Soil alkalinity

The amount of total alkalinity were found 28-31 ppm from (1-5) years aged ponds, 23-26 ppm from (6-10) years aged ponds and 9-13 from above 10 years aged ponds (see Table 2). In the present study, it is observed that the amount of total alkalinity has been slightly reduced with the increase of pond's age. Soil alkalinity varied from pond to pond. Ahmed (2004) reported that alkalinity range 20-28 ppm is the suitable range for coastal aquaculture in Bangladesh. The amount of alkalinity obtained from the selected ponds (1-10 years aged ponds) are almost similar to the optimum level (20-35 ppm) reported by (Boyd, 1976; Boyd *et al.*, 1994). Previous study is suggested that the higher amount of alkalinity is harmful for the proper growth of shrimp and other cultivable species (Townsend, 1982).

Organic matter

In the present study, 7.6-8.4 % of organic matter were found from (1-5) years aged ponds and 10.6-11.3 % and 12.9-13.4 % organic matter were found from (6-10) years and above 10 years aged ponds respectively (see Table 2). It is apparent from the study that comparatively high amount of organic matter was determined from above 10 years aged ponds. The cause of increasing organic carbon of soil might be attributed to using of artificial or supplementary feeds in these culture ponds.

Ahmed (2004) argued that organic carbon was rich in post monsoon and in monsoon period and it decrease with the depth of pond. Organic matter is higher in the coastal area. The benthic communities varied significantly with seasonal difference but failed to show any dependence on organic carbon. Mostly they interact with salinity and particle size.

It is difficult to assess organic matter concentrations in soil because there are different kinds of organic matter. Organic soils have high concentrations of recognizable plant remains that are quite resistant to decomposition by bacteria and other microorganisms. Organic soils have 15 to 20 % organic carbon (about 30 to 40 % organic matter). Such soils are not good for pond aquaculture and should be avoided. In the present study highest amount of organic matter was recorded 13.4 from above 10 years aged ponds which percentage were almost similar to optimum level.

Organic carbon

The amount of organic carbon were found 4.42-4.53 %, 5.58-5.74 % and 7.53-8.58 from (1-5) years, (6-10) years and above 10 years aged ponds respectively (see Table 2). Boyd *et al.* (2002) recommended that range of organic carbon 1.0-3.0 % is the best range for coastal aquaculture. Boyd (1994) also reported that organic carbon value 0.60-1.50 % is highly suitable for aquaculture. Ahmed (2004) reported that organic carbon range 0.95 to 1.50 % is the suitable range for aquaculture of Bangladesh. The concentration of organic carbon in the present study due to using supplementary feeds in the ponds which remain unused and deposited on the soil bottom.

It is apparent from the present study that comparatively high amount of organic carbon was determined from bottom soil of old ponds. The increased organic carbon of the soil might be attributed to unused supplemented feeds were used and stocking density was precisely low. It showed noted that the quantity of supplemented feed was increased day by day which may be reason of comparatively higher value of organic carbon of soil.

There was no significant change of soil pH in the pond bottom soil among different aged ponds (see Table 2). Soil texture is changed with the increasing of clay and silt particles in (6-10) years and above 10 years aged group ponds. Amount of organic matter and organic carbon are also increased sharply with the increasing of pond's age (see Table 2).

Table 2. Amount of soil pH, alkalinity, organic matter and organic carbon obtained from the selected ponds (Mean ± Standard deviation).

Name of the ponds	pH	Alkalinity (ppm)	Organic matter (%)	Organic carbon (%)
Pond 1	6.2±0.6	30±3.2	8.4±1.8	4.42±0.9
Pond 2	6.2±0.2	28±1.8	7.6±0.8	4.47±0.4
Pond 3	6.3±0.8	31±2.0	8.1±2.0	4.53±1.1
Pond 4	6.2±0.3	24±4.6	10.9±1.3	5.74±0.7
Pond 5	6.0±1.1	23±2.8	11.3±2.5	5.58±13
Pond 6	6.1±0.7	26±1.7	10.6±0.9	5.58±0.5
Pond 7	6.2±1.2	13±0.4	13.4±3.2	8.31±1.7
Pond 8	6.1±0.9	11±1.9	12.9±1.2	7.53±0.6
Pond 9	6.2±0.4	9±3.6	13.2±0.8	8.58±0.4

Too heavier textured soils such as pure clay may not be satisfactory as they have very high absorptive property and thereby act as a sink for nutrients like phosphorus which may not be easily released to overlying water. These soils may also give problems of developments of deep cracks when dry (on draining the pond) thereby allowing seepage losses of water.

Table 3 is representing the correlations among the soil parameters for three different aged group ponds. In the correlation matrix, significant relationship was found between clay and organic matter ($r=0.99$, $p<0.05$ in 1-5 years aged group ponds), sand and organic matter ($r=0.99$, $p<0.05$ in 6-10 years aged ponds). In above 10 years aged group ponds, significant relationship were observed between pH and sand particles ($r=1.0$, $p<0.01$) and silt and alkalinity ($r=0.99$, $p<0.05$), respectively. However, negative relationship also found between silt and organic matter ($r=0.999$, $p<0.05$ for 1-5 years aged ponds and $r=0.994$, $p<0.05$ for 6-10 years aged ponds).

Table 3. Correlations among the soil parameters for three different aged group ponds.

		1	**2**	**3**	**4**	**5**	**6**	**7**
(1-5) years	pH	-						
	Alkalinity	.756	-					
	Organic Matter	.143	.756	-				
	Organic Carbon	.891	.376	-.322	-			
	Sand	.500	.945	.929	.052	-		
	Silt	-.189	-.786	-.999*	.277	-.945	-	
	Clay	.000	.655	.990*	-.454	.866	-.982	-
(6-10) years	pH	-						
	Alkalinity	.327	-					
	Organic Matter	-.569	-.963	-				
	Organic Carbon	.866	-.189	-.082	-			
	Sand	-.500	-.982	.997*	.000	-		
	Silt	.655	.929	-.994*	.189	-.982	-	
	Clay	-.866	-.756	.904	-.500	.866	-.945	-
Above 10 years	pH	-						
	Alkalinity	.000	-					
	Organic Matter	.918	.397	-				
	Organic Carbon	.969	-.248	.791	-			
	Sand	1.000**	.000	.918	.969	-		
	Silt	.034	.999*	.428	-.215	.034	-	
	Clay	-.292	-.956	-.648	-.046	-.292	-.966	-

Note[1] **: Correlation is significant at the 0.01 level (1-tailed).*. Correlation is significant at the 0.05 level (1-tailed).

Conclusion

Sustainable aquaculture development can bring real and lasting benefits for aqua farmers and dependent communities. But the environmental consequences of inappropriate or excessive development will adversely impact on the wider communities and the farers themselves through poor farm performance or failure. There is therefore an increasing need for good planning and management of aquaculture in our countries. Environmental capacity is being used in some progressive developed countries to inform the management of aquaculture as it provides a more objective basis on which to plan and regulate aquaculture conditions, recognizing the cumulative impacts of resource users and the assimilative capacity of the environment.

In the above discussion it has shown that all parameters of soil such as texture, pH, alkalinity, organic carbon and organic matter more or less similar to the standard level for aquaculture activity in Bangladesh. Public opinion is also more or less similar to the investigation. Considering results of soil analysis it may be suggested that soil characteristics in the Halda watershed area seems to be suitable for development of aquaculture. 1-10 years aged ponds are found to be more suitable than that of above 10 years older ponds. From above discussion it may be concluded that if proper management strategies can be developed then the aquaculture will be successfully developed in that area.

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References

Ahmed, H. 2004. Soil Quality Analysis and Considerations in the selection of sites for sustainable Aquaculture in the South East Coast of Chittagong Specially Halishahar Area. M.Sc. Thesis (unpublished), Institute of Marine Sciences and Fisheries, University of Chittagong, Chittagong, Bangladesh, 80 pp.

APHA. 1976. Standard methods for the Examination of Water and Waste Water, 14th Edition, N.Y., American Public Health Association, 1193 pp.

Avnimelech, Y. 1984. Reactions in fish pond sediments as inferred from sediment cores data. Publication No. 341, Technion Israel Institute of Technology, Soils and Fertilizers Research Center, Haifa, Israel, pp: 1-46.

Banerjee, R.K. 1978. Water quality and soil condition of fish ponds in some states of India in relation to fish production. Indian Journal of Fisheries, 14: 113-114.

Boyd, C.E. 1976. Lime requirement and application in fish ponds. FAO Aquaculture Conference. FIR: AD/Conf. 196E/ 13, 3 pp.

Boyd, C.E. 1995a. Bottom Soils, Sediment, and Pond Aquaculture. Chapman and Hall, New York, New York.

Boyd, C.E., 1995b. Bottom Soils, Sediment and Pond Aquaculture. Chapman and Hall, New York, New York.

Boyd, C.E. 2002. Water quality management for pond fish culture. Elsevier Sci. Public Co., Amsterdam, 319pp.

Boyd, C.E., Tanner, M., Madkour, M. and Masuda, K. 1994.Chemical characteristics of bottom soils from freshwater and brackish water aquaculture ponds. Journal of the World Aquaculture Society, 25: 517-534.

Jackson, M.L. 1958. Soil Chemical Analysis. Prentice-Hall, Englewood Cliffs, New Jersey.

Munsiri, P., Boyd, C.E. and Hajek, B.F. 1995. Physical and chemical characteristics of bottom soil profiles in ponds at Auburn, Alabama, and a proposed method for describing pond soil horizons. Journal of the World Aquaculture Society, 26: 346-377.

Munsiri, P., Boyd, C.E., Teichert-Coddington, D. and Hajek, B.F. 1996. Texture and chemical composition of soils from shrimp ponds near Choluteca, Honduras. Aquaculture International, 4: 157-168.

Pudadera, B. 1984. Pond culture: Liming and fertilization. Aqua-train /NACA/84-64, 13pp.

Sonnenholzner, S. and Boyd, C.E. 1982. Vertical gradients of organic matter concentration and respiration rate in pond bottom soils. Journal of the World Aquaculture Society, 31: 376-380.

Townsend, W.N. 1982. An Introduction to the Scientific Study of the Soil. Edward Amold (Publishers) Ltd. U.K, 209pp.

Wrobel, 1983. Instrumental Methods for Analysis of Soil and Plant Tissues. (Ed. By L.M. Walsh). American Soil Institute, 120pp.

دراسة مقارنة للصفات الفيزيائية والكيميائية للتربة حسب عمر احواض الاستزراع المائي في بنغلاديش

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المستخلص – تعتبر نوعية التربة عاملاً مؤثراً في إنتاجية أحواض الأسماك لأنها تؤثر في إستقرار التربة والأس الهيدروجيني للماء وتراكيز المغذيات اللازمة لنمو العوالق النباتية. تهدف الدراسة الحالية إلى تقدير خواص التربة في أحواض سمكية مختلفة الأعمار. إختيرت ثلاثة مجموعات من أحواض الأسماك حسب العمر (1 - 5، 6 - 10 وأكثر من عشرة سنوات). لم يلاحظ إختلاف بالأس الهيدروجيني. برزت الإختلافات بتركيبة التربة فالأحواض الأقدم إزدادت بها نسبة الطين إلى الغرين وكذلك نسبة الكربون العضوي. هذه الخصائص من شأنها التقليل من صلاحية التربة في أحواض الأسماك.