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The Problem of Water Seepage in Aquaculture: A Preliminary Study of the Soils of Arac Fish Farm, Omuihuechi-Aluu, Rivers State, Nigeria

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Abstract: Preliminary study on the problem of water seepage in some ponds was carried out at the experimental fish farm of Nigerian Institute for Oceanography and Marine Research (NIOMR) /African Regional Aquaculture Centre (ARAC), Aluu, Rivers State of Nigeria. Soil profile holes of 4.50 cm diameter were drilled in the bottom of two ponds (6 and 9) to a depth of 2 m. Undisturbed soil samples were collected and subjected to visual inspection and particle size analysis. Visual inspection of top soil samples of pond bottoms across the fish farm was also carried out. Results of study so far carried out revealed that ARAC fish farm at Aluu, is sitting on a thin bed of a mixture of clay and lateritic soils. Immediately underlying this is a bed of sandstone of unknown thickness. The top cohesive bed for pond 6 analyzed 50.25% (clay); 43.87% (laterite); 3.84% (silt) and 2.01% (sand) while pond 9 analyzed 85.15% (sand); 13.73% (silt) and 1.10% (clay). The conclusions from the results are that the contamination of the clay soils by laterite soils conferred a condition of non-uniformity, increased effective porosity and permeability to the clay soil; and that the problem of inadequate water supply for the pond merely exacerbates the situation. The solution lies in sealing the pond bottoms by either importation of clay soils with appropriate compaction or bentonite treatment or both. Deepening the ponds will worsen the problem.

Key words: Fishponds, suggestions, solutions, water seepage problems

INTRODUCTION

Inland aquaculture is presently responsible for a relatively major component of the total fish landing in Nigeria. Okpanefe *et al.* (1986) conducted a survey on fish production from aquaculture in Nigeria, which revealed that of the 5641.61 ha of land under fish culture, 5411.33 ha is used for inland aquaculture. This represents 95.92% of the total surface area used for aquaculture. However, the actual production of fish from the total area put under cultivation ranged from a mere 20,000-24,000 tons annually (Tobor, 1991). Anyanwu (2006) put the figures at 0.40-0.50 metric tons annually. This is grossly insignificant when compared with Nigeria's proven potential of 0.65-1.50 million tons annually (Anyanwu, 2006). Further, at only 50% capacity utilization, 5411.33 ha of land under inland aquaculture cultivation should produce at least 200,000 metric tons of fish annually. That this is not so indicates gross under-utilization which is attributed largely to problems associated with water seepage (Uzukwu, 2008) and acid sulphate soils (Dublin-Green,1988) in fish ponds. Quite many ponds in fish farms across Nigeria are affected by problems of water seepage. Some have been closed down as a result. Examples of note include the moribund Aviara fish farm in Isoko district of Delta State and Nonwa fish farm in Ogoni district of Rivers State. The task of developing inland aquaculture to its maximum potential in Nigeria can only be realized through proper soil explorations of sites prior to site selection for aquaculture (Uzukwu, 2010a). In this regard Uzukwu (2010b) stated that emphasis should be placed on the quality of soil substrate to control the nature of overlying water in fish ponds through soil-water interaction.

This study reviews some of the literature on problems and solutions of water seepage in aquaculture and also presents the results of preliminary investigation of the problems of water seepage of some fish ponds in NIOMR/ARAC fish farm Omuihuechi - Aluu, Rivers State.

What is seepage? Seepage is the slow movement of water through pond bottoms and dykes into the subsoil (dela Cruz, 1983). This is a major to soils engineers in aquaculture. In order to reduce seepage problem in ponds to the barest minimum, soil explorations to determine

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surface and subsurface soil conditions at the site should be made prior to procurement (Kovari, 1984). The problems of water seepage can be solved by applying Darcy's law (dela Cruz, 1983).

Role of soil in a fish pond: The most important function of the pond soil is that it holds water, it is the pond substrate and dyke building material. Loganathan (1984) stated that a satisfactory pond bottom soil is that in which infiltration of water is low, mineralization of organic water takes place rapidly, nutrients are adsorbed and released slowly over a long period of time. In general moderately heavy textured soils, having neutral pH, abundant organic matter content and low salinity levels are desirable (dela Cruz, 1983). The indication is that not all soils are good for pond construction.

Soil classification: In aquaculture, soils are classified into three major types (Sivalingam, 1974):

- Pervious soils
- Impervious soils
- peaty soils

Pervious soils are very sandy soil or mixed gravel and sand, and have very little water retaining properties. Such soils (sites) should be avoided (Kovari, 1984).

Impervious soils are usually of silt or clay or a mixture of one or both with a small percentage of sand and/or gravel. They have good water retaining properties, and therefore sites with impervious soils are suitable for pond construction.

Peaty soils have a high percentage of partly decomposed vegetation and are spongy in texture. Sites with peaty soils are often subject to dyke settlement problems since the vegetation eventually decomposes completely and creates void (Dublin-Green, 1990). Kovari (1984) stated that areas with organic soil over 0.6m in thickness are not suitable for pond construction due to potential high seepage. Most times the soil condition may be a mixture of pervious and impervious soils. The selection would then depend on the permeability. Kovari (1984) recommended that soils with coefficient of permeability less than $5x10^{-6}$ m/sec are suitable for pond construction.

Soil smapling and textural analysis: Soil sampling points for soil profile are usually selected to ensure adequate representation of the site soils. Kovari (1984) stated that samples should be taken from dug pits measuring 0.80x1.50 m with a depth of 1.50 to 2.00 m. Samples should be collected from all parts of area to be covered for pond construction. A minimum of 6 samples per hectare at well spaced intervals should be taken using soil auger or pothole digger (Uzukwu, 2010a). Samples are usually taken with a black polythene bag to maintain them in their wet state and prevent oxidation of the soil materials during transportation (Dublin-Green 1988).

Texture refers to the relative proportions of sand, silt and clay in a soil. It is a very important soil parameter because it determines the suitability of a site for aquaculture. Soil texture can be determined in the laboratory by particle size analysis using any of three methods namely.

- Mechanical analysis
- Pipette analysis
- Hydrometer method (Mckeague, 1981; Loganathan, 1984). Results of particle size analysis provide percentages for the three size classes. The results are also used to assign a particular textural class to each sample using the textural triangular diagram (Fig. 1) or prepare a particle size frequency curve (Fig. 2) from which one could draw conclusion on the suitability of the soil for pond construction as follows:
  - a site will be suitable for construction of fish ponds if soils below the proposed pond bottom can be plotted to the left side of grain size curve A (Fig. 2)
  - From the standpoint of water retaining properties, clay, sandy clay, silty clay and clay loam are naturally suitable for pond construction (Table 1). But sandy clay, clay loam, silty clay loam, sandy clay loam are best in terms of productivity. The laboratory analysis for texture requires skilled personnel, takes time to complete, besides requiring special equipment/apparatus. When these equipment are not readily available, field methods (profile hole, feel, and ball) can be used of which Dureza (1982) and Uzukwu(2010a) described as simple and fairly accurate.

A case study: Niomr/arac fish farm, omuihuechi-aluu background to the study: The NIOMR/ARAC fish farm Aluu was constructed between 1981 and 1983 under the auspices of the Food and Agriculture Organization (FAO). It was established as an experimental freshwater fish farm for research into freshwater fish production.

The 81 ha fish farm (Ajayi, 1991) is located near Omuihuechi village in Aluu Clan of Rivers State. It is situated 350 m from the New Calabar River which is located on the eastern flank of the Niger Delta river system. At Aluu where ARAC fish farm is located, the river is fresh and tidal. The Niger Delta, of which the study area is part, is a sedimentary basin whose origins date back to the Eocene period about 40 million years ago. It has its remote origins South of Onitsha and extends towards the Equator up to the outer edge of the continental shelf in the Gulf of Guinea (Ibeh, 1988).

Ecologically the study area belongs to the freshwater swamp forest zone of the Niger Delta. The climate is

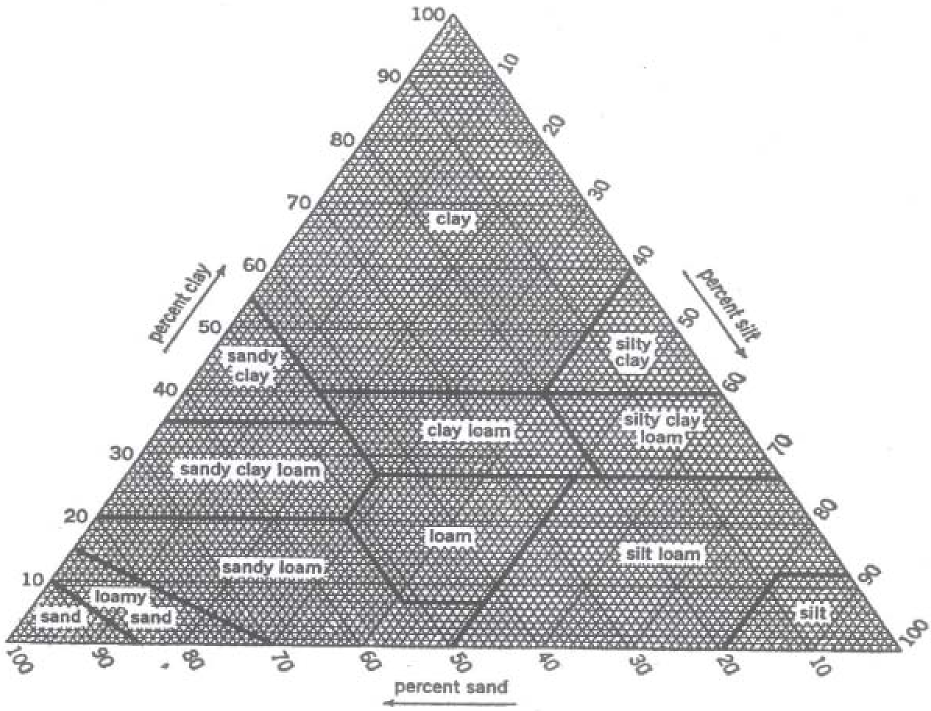

Fig. 1: Textural triangular diagram

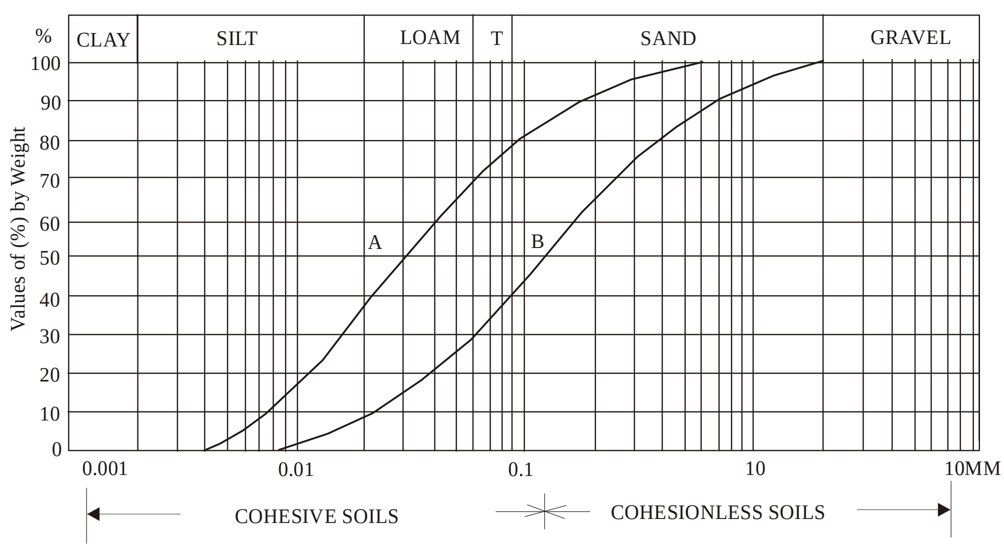

Fig. 2: Semilogarithmic grain-size curves of soils

characterized by a dry season during November to March and wet season during April to October with monthly average rainfall of 254 mm (Erondu and Chindah, 1991). Some ponds in the farm have been having acute seepage problems. This is despite its proximity to the New Calabar river. During the rainy season (April to October) when the water table is high, the ponds have no problem in holding water. But during the dry season (November to March) the ponds experience rapid loss of water through seepage.

The ponds soils, as a result, have been subjected to repeated cycle of dry and wet conditions with shrinkage cracks over the years. This study is aimed at identifying

Table 1: Soil Textural Class and Suitability for pond Construction

Texture class	Group	Remark	Slope of dike
Clay; Sandy Clay; Silty Clay; Clay Loam	1	Suitable	1:1 or 1:2
Silty Clay Loam; Sandy Clay loam Loam	2	Suitable, but requires more compaction with heavy machinery	1:2
The rest	3	Not suitable	

Uzukwu (2008)

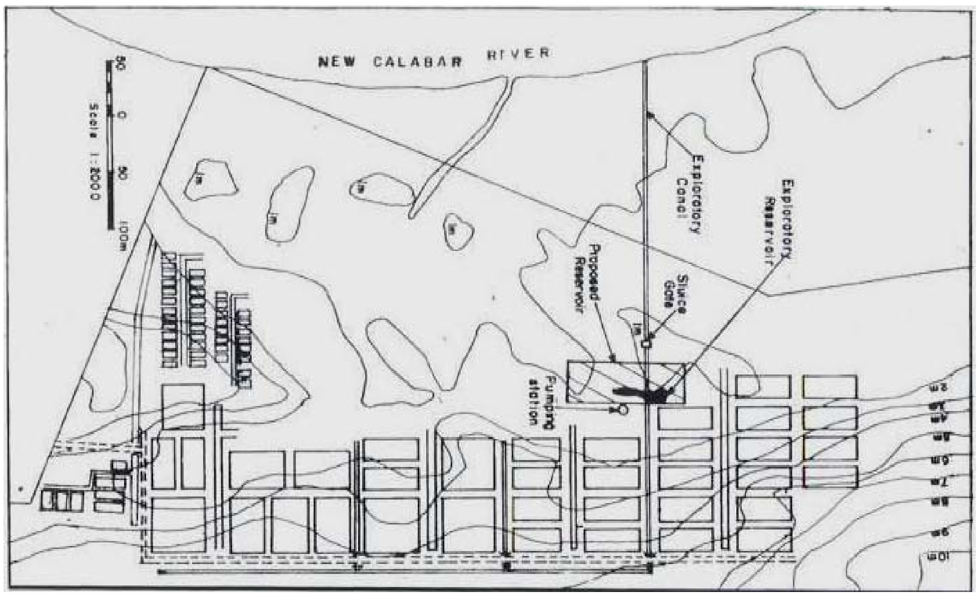

Fig.3: Topographic map of ARAC Fish Farm, Aluu (modified after Apapa, 1995)

the cause(s) of the seepage problems in some ARAC fish ponds at Aluu with a view to proffering suggestion for solutions.

MATERIALS AND METHODS

ARAC Fish Farm at Aluu is made up of 33 big ponds and 40 small ponds. This study was carried out in ponds 6 and 9, which were dry with shrinkage cracks at the time of study (March). Soil profile holes of 4.50 cm diameter were drilled in ponds 6 and 9 using a soil auger. The depth of the profile holes was 2.00 m. Undisturbed soil samples were collected in black polythene bags, labeled and transferred to the laboratory for visual inspection and particle size analysis.

Particle size analysis of the soil samples was carried out. 100 g of air-dried soil sample was dispersed using 5% calgon (sodium hexametaphosphate). The percentages of the soil separates (sand, silt, and clay) were determined using pipette method as described by loganathan (1984), Dublin-Green (1988) and Uzukwu (2010a). The textural classes of the soil samples were determined using the textural triangular diagram (dela Cruz, 1983).

Visual inspection of the soil samples from the profile holes as well as pond bottom samples from 10 cm depth across the fish farm was also carried out.

RESULTS

Results of visual inspection of the pond bottom soils at 10cm depth revealed that the last ten (10) ponds situated on the extreme right of the farm are predominantly sandy (Fig. 3). The bottom soils of the remaininig big ponds are predominantly a mixture of clay and lateritic soil while the bottom soils of the 40 small experimental ponds are mainly lateritic soils. The pond - sub bottom profile hole samples showed that for pond 6 at a depth of 0.8 m from the pond bottom, the soil consisted of a mixture of clay and laterite (ferrugenised) soil formation, while from 0.8 m downwards the soil consisted almost entirely of sand (Fig. 4). For pond 9 at a depth of 0.35 m from the pond bottom the profile hole soil samples consisted of a mixture of clay and laterite while from 0.35 m downwards the soil consisted almost entirely of sand.

The results of particle size analysis of the profile hole samples for ponds 6 and 9 are presented in

Table 2: Particle size analysis of cohesive bed for ponds 6 and 9.

Pond	Clay (%)	Laterite (%)	Silt (%)	Sand (%)
6	50.25	43.81	3.84	2.01
9	58.41	33.96	4.57	3.05

Table 3: Particle size analysis of non-cohesive bed for pond 6 and 9

Pond	Clay (%)	Laterite (%)	Silt (%)	Sand (%)
6	2.20	-	19.50	80.20
9	1.10	-	13.73	85.15

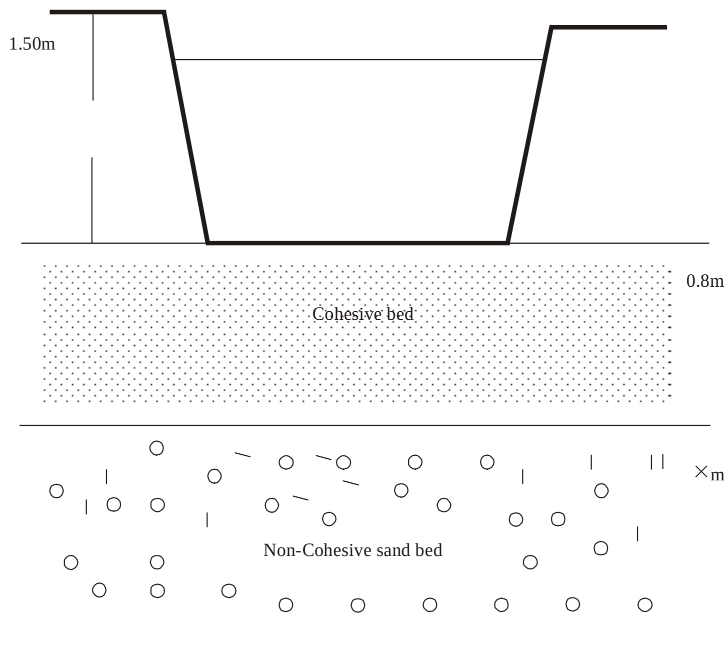

Fig. 4: Scheme showing the sub - pond bottom formations and their bed thickness for pond 6

Table 2 and 3. For pond 6 the top (cohesive) bed analysed 50.25% (clay); 43.81% (lateriate); 3.84% (silt) and 2.01% (sand) while for pond 9 the top (cohesive) bed analysed 58.41% (clay); 43.81% (lateriate); 3.84% (silt) and 3.05% (sand). For pond 6 the non-cohesive bed analysed 80.20% (sand; 19. 50% (silt) and 2.20% (clay) while pond 9 analysed 85.15% (sand); 13.73% (silt) and 1.10% (clay). Texturally, the top (cohesive) beds ranged from clay to sandy clay while the non-cohesive beds were predominantly sandy. This agreed with a range of clay to loamy sand obtained by Uzukwu (2000) along the centre line of an exploratory canal in the farm.

DISCUSSION

Preliminary study so far carried out has revealed that ARAC fish farm which is situated at Omuihuechi - Aluu is sitting on a thin bed of mixture of clay and lateritic soil formations. Immediately underlying this is a bed of sandstone whose thickness was not determined in this study (Fig. 3). According to Iloeje (1980) lateritic soils are deeply corroded and grey or reddish in colour, generally sticky and impervious to water, hence are good for pond construction. Clay soils are naturally cohesive soils which are recommended for pond construction (dela Cruz, 1983; Kovari, 1984). Coche and Muir (1992) stated that soils of clay content of 20% and above with good compaction are adequate for fish pond construction. The clay contents of ponds 6 and 9 were 50.25 and 58.41%, respectively, figures which are quite above the recommended 20% minimum. It is therefore reasonable to deduce that the contamination of clay soil by lateritic soil, as revealed in this study, is the cause of the seepage problem in ARAC fish ponds.

The effect of contamination of the clay soil by lateritic soil is to create a condition of non-uniformity and hence interconnected interstices (pores) in the clay soil thereby increasing its effective porosity and permeability much beyond its natural background levels. From the foregoing, it is therefore expected that during the rainy season, when water table is high the pores in the clay/lateritic soil mixture are effectively plugged by capillary moisture and the ponds can retain water. But during the dry season, the capillary moisture and water table sink down, the pores are unplugged and the ponds cannot hold water.

Results of this study suggests a careful management of the soils of ARAC fish farm, Aluu. Prior to this preliminary investigation, the measure adopted to solve the seepage problems had teen to continue to deepen the ponds by excavating out the pond bottom soils. This was intended to meet a more impervious substrate. Today the pond bottom of most of the ponds are now below the water drainage pipes of the monks. This in turn has created another problem, that is, the ponds can no longer be drained completely on their own without pumps. Yet the seepage problem is not resolved. This study has shown that the thickness of the clay soil in ARAC fish farm is rather small and decreases towards the river.

The indication is that depletion of the clay soil thickness by deepening the ponds would rather exacerbate the seepage problem than solving it. The optimal solution of the problem would be to import clay soils of adequate plasticity such that when spread on the pond bottom and compacted to a predetermined permeability (void ratio) and shear strength would eliminate or reduce seepage to the barest minimum. Alternatively the ponds bottom may be treated with bentonite as described by Szilvssy (1984). However, this may not be effective without first solving the problem of inadequate water supply of the farm. Kovari (l984) and Szilvssy (1984) have stated that when cohesive soils are exposed to repeated cycle of wetting and drying, shrinkage cracks are liable to develop, which facilitate the entrance of water into subsurface layer to initiate physical and chemical weathering and hence destruction of the soil structure. With inadequate supply of water there is no guarantee that the ponds would be maintained in wet state always especially in dry season.

The problem of inadequate water upply systems (pump sump, canal, reservoir, pump designs) for the farm has been addressed by Uzukwu (2000). The sandstone formation underlying the clay and laterite (ironstone) bed in the farm is a feature of a typical deltaic model sequence comprising three distinctive sets of sediments namely the prodelta (clays), delta slopes (siltstone) and topset (sandstone). The findings in this study will be further elaborated at the conclusion of the detailed soil investigation of the entire ponds in the farm.

CONCLUSION

From the results of this preliminary investigation the following conclusion can be drawn:

- The problem of water seepage in ARAC fish ponds at Omuibuechi Aluu during the dry season is caused by pervious thin bed of clay soils which is contaminated by lateritic soils thus conferring a condition of non-uniformity, increased effective porosity and permeability to the clay soil.
- The problem was aggravated by the problem of inadequate water supply for the ponds over the years leading to repeated cycle of drying and wetting of the ponds which in turn leads to shrinkage cracks, chemical and physical weathering of subsoil and hence the destruction of subsoil structure.
- The solution of the problem lies in sealing the pond bottoms by either importation of clay soils or bentonite treatment, and also ensuring that the ponds are not left dry f‘or prolonged periods by ensuring adequate water supply during dry season. Further studies will be focused on the distribution of thickness of clay/lateritic soil in the entire farm and the index properties of the cohesive and non-cohesive soils.

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