RAPID RECLAMATION OF BRACKISH WATER FISHPONDS IN ACID SULFATE SOILS

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1 Summary

The reclamation of acid sulfate soils for agriculture is generally considered to be a slow process. The productivity of brackish water fishponds in these soils also remains poor for 5 to 15 years after construction or deepening. This is due to the very slow growth or inactivity of the algae on which the fish feed, and to the intermittent fish kills by extremely acid water which leaches from the dikes during rains after dry periods. However, the water management possibilities inherent in the operation of brackish water fishponds in tidal areas with a dry season enable the operators to reclaim both the pond bottoms and the surrounding dikes in one dry season, without a need for expensive chemical amendments.

The procedure involves thorough drying and dry cultivation of the pond bottom until it cracks to a depth of about 10 cm, followed by repeated inundation with saline or brackish water. The water is renewed every few days until its pH remains above 5. This cycle of thorough drying and repeated flushing is restarted one to several times, until the pH of the first inundation water after drying remains above about 5. Most of the acid is thus removed by diffusion into the standing water rather than by leaching to the subsoil.

The surrounding dikes are reclaimed at the same time. First, low paddy bunds are built along the edges of the flat crests of the dikes or a small ditch is dug along the center. Cross bunds are constructed wherever the elevation of the dike changes. Saline or brackish water is then

pumped into the enclosed shallow basins or ditches on top of the dikes in the same periods in which the pond bottoms are flushed. The dikes are allowed to dry out again at the same time as the pond bottoms.
With this procedure, brackish water fishponds in acid sulfate soils were made productive within one dry season after construction or deepening. Milkfish (Chanos chanos) harvests were about 0.4 to 0.5 t/ha every 4 months, the same as from well managed brackish water fishponds in non-acid marine clays, and there were no fish kills after rain in the treated ponds.

2 Introduction

The extent of acid sulfate soils in the Philippines is variously reported, but appears to be less than about half a million ha. Until about a decade ago, much of this area was mangrove forest. Smaller areas were used for one poor crop of paddy rice per year and for fishponds. In recent years, the area of fishponds has increased rapidly at the expense of the mangroves and the former paddy fields. Fishponds now appear to be the most important kind of land use in the coastal acid sulfate areas of the Philippines (Figure 1).

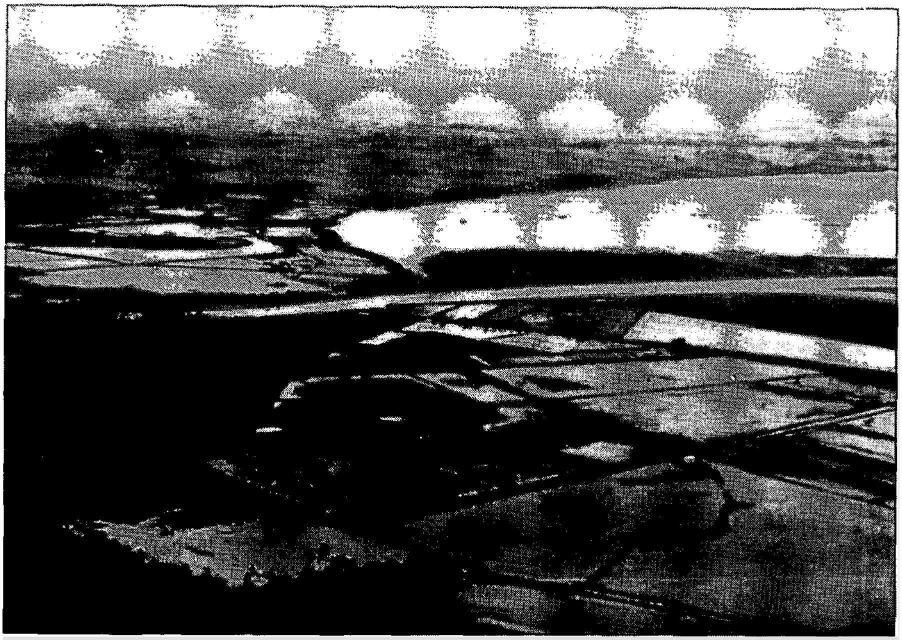

Figure 1. Aerial view of a brackish water fishpond area NE of Iloilo, Panay Island, Philippines

Brackish water fishponds are of two main kinds. Shallow ponds, with about 0.3 m water depth, produce milkfish (*Chanos chanos*, Pilipino: bangus), mainly for local consumption. Deep ponds, about 1 m, produce prawns (*Microbrachium* or *Penaeus monodon*) which is mainly exported to Japan.

Particularly in the first 5 to 10 years after construction or deeper excavation of fishponds in acid sulfate soils there are major problems precluding economic operation or even production. Growth of algae is inhibited or restricted by the low pH and the very low phosphate concentration of the pond water. The growth rate and the condition of the fish are impaired by the low pH and the unfavourable ionic composition of the pond water, the periodic presence of finely dispersed ferric hydroxide and the poor supply of algal feed. Moreover, there are sudden fish kills during rains after extended dry periods, owing to extremely acid water seeping into the ponds from the surrounding dikes. After about a decade, these problems gradually recede but fish production remains low, of the order of 0.6 t/ha per year. This should be compared with an average 1.5 or, with recommended management and fertilizer levels, up to 2.5 t/ha

per year in areas with non-acid coastal clays.
The much more profitable prawns die in the first years and fail to grow satisfactorily even after many years in the acid sulfate areas, since they require a higher pH than milkfish.
Traditional, small fish farmers dig very shallow ponds to minimize the problems and limit capital costs. They survive and learn to live with the problems, but do not rise above poverty within a decade, and slowly even after that period. Larger farmers whose holdings are mainly financed externally, as well as companies developing extensive areas for fishponds, tend to abandon their efforts on this land and sell out after a few years of failure, whereupon a next victim repeats the process.
A rapid and low-cost reclamation method of fishponds in acid sulfate soils should be of great economic importance for the Philippines and other countries with extensive acid sulfate areas near the coast.
The next sections summarize normal fishpond operations, processes taking place in the fishpond soil and the resulting problems faced by the fish farmers, earlier reclamation efforts and requirements for permanent reclamation. The last five sections of the paper describe a general work plan and a sequence of activities that has been successful in reclaiming previously improductive acid sulfate fishponds within one dry season.
Figure 2 illustrates the different growth rates of fish in acid sulfate fishponds without and with reclamation.

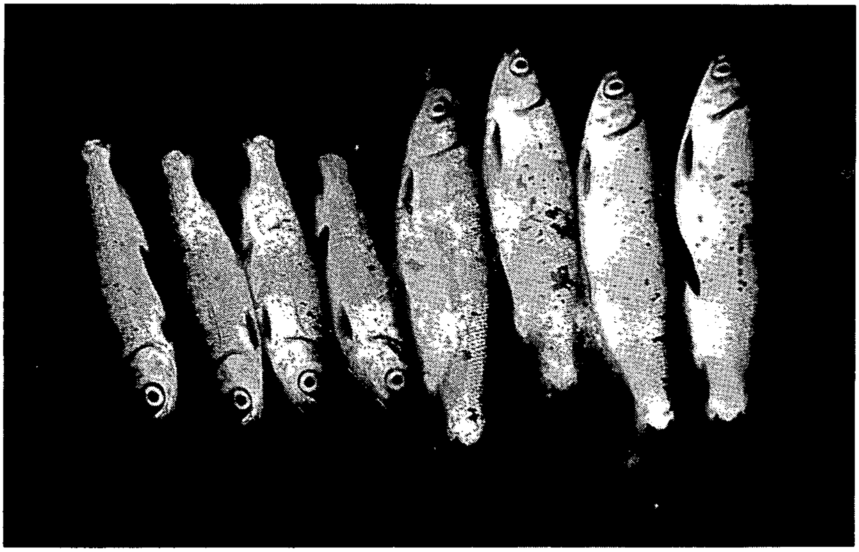

Figure 2. Milkfish from unreclaimed and reclaimed acid sulfate fishponds, 90 days after stocking (120 days old)

3 Construction and normal use of brackish water fishponds

Ponds are constructed by excavating a layer of soil from the area of the proposed pond, generally about a hectare in size, and building a surrounding dike with the excavated material. A sluice gate is built, using brick or concrete and wood, to connect the pond with an adjacent saline or brackish tidal river or canal. The pond bottom slopes down very slightly toward a shallow central channel ending at the sluice. The tidal fluctuation of the water level in the canal or river allows filling or draining of the pond twice a day. If there is fish in the pond, the water can be changed after insertion of a screen in the sluice opening. Before the start of each fish crop, the surface of the pond bottom is dried to a depth of several centimeters in order to destroy predators, disease carriers and parasites of the fish, such as certain snails. Then, 2 or more tons of chicken manure per ha are spread on the bottom to provide nitrogen and phosphate for the growth of green (and some blue-green) algae. After the pond is filled, an initial amount of 16-20-0 fertilizer is broadcast at a rate of 50 kg/ha. The seawater and the soil of the pond bottom supply sufficient potassium and minor elements. Algae start to grow, generally without inoculation, and soon form a thick mat that sinks to the bottom. Fingerlings raised from brood in a separate small pond are then stocked to graze the algae. Every 2 weeks, fertilizer at a rate of 8 kg N and 10 kg P_2O_5 per ha is broadcast (or placed to dissolve on a semi-submerged platform) as a top-dressing for continued algal growth. After 3 to 5 months, depending on the feed supply and the growth rate of the fish, the pond is harvested by draining the water and collecting the fish near the sluice, or traditionally, but less efficiently, by dragnet.

Prawns are produced in similar but deeper ponds. These are fed a protein diet mainly derived from operation of the fishponds: undersize fish, culled predator fish and filleting waste, supplemented by agricultural by-products (e.g., leaves of legumes), and by slaughtering waste if available.

4 Processes taking place in the pond soil during drying and after filling the ponds

The pond soil, initially reduced, contains the usual marine salts and considerable amounts of exchangeable ferrous iron. Upon oxidation, ferric hydroxide is formed and the soil may become partly aluminum-saturated. The pH drops from near-neutral to lower values. In acid sulfate soils, pyrite oxidation produces jarosite and iron hydroxide as well as sulfuric acid which attacks the clay minerals. The pH drops to very low values. The soil becomes largely aluminum-saturated; some free acid remains; aluminum salts are formed.

After inundation, the pond soil becomes reduced again. Acid is consumed by reduction of ferric hydroxide to ferrous ions. Part of the free acid and the aluminum salts and, somewhat later, large amounts of ferrous salts diffuse from the soil into the pond water. This process appears to be speeded up by the salts in the saline or brackish water.

Rain falling on previously dry dikes leaches further quantities of acid and aluminum salts as well as ferrous salts into the pond water, both from the surface and from the interior of the dikes. In the course of a few days, the ferrous iron is oxidized, producing more acid and finely

distributed ferric hydroxide which remains suspended in the pond water for several days. If powdered lime is used to reduce the acidity of the water, ferric hydroxide is formed more rapidly.
Any phosphate that might have been present in the water is quickly trapped by the large amounts of aluminum salts or by free aluminum in the surface soil.

5 Problems faced by fishpond operators in acid sulfate areas

The main problems arising after construction or deeper excavation of fishponds in acid sulfate soils comprise the insufficient growth of algae, the poor condition and consequent slow growth of the fish, the hazard of sudden fish kills during rain after dry periods and, even if these are solved, the very low efficiency of phosphate fertilizers as normally applied.
The growth of the algae is inhibited or retarded by the low pH of the water, the high aluminum and the low phosphate concentrations. The low pH and the high aluminum concentrations may kill or, in less severe cases, weaken the fish so that they are an easy prey for diseases and parasites. The sudden influx of acid and aluminum salts from the dikes during rains after a dry period causes an ionic imbalance in the fish. That stress is commonly lethal to a large proportion of the population. Finely divided ferric hydroxide subsequently appears in the water and clogs the gills of the survivors, killing another contingent and weakening the remainder.
A lesser problem is the erosion of the dikes during heavy rains owing to the lack of a good vegetation cover on the acid, toxic soil for the first 5 to 10 years.

6 Earlier reclamation efforts

Farmers in one area on northwestern Panay Island, Philippines, have developed an effective, albeit very slow, reclamation method. Very large, wide, broad dikes are first constructed. Their level crest is ploughed repeatedly. Rains between ploughings remove some of the free acid that has developed in the oxidized, ploughed layer. Gradually, the surface material is brought back into the pond to form a 'safe' pond bottom with little or no free acid. The whole process takes 5 to 10 years and eventually creates moderately productive ponds.

Other reclamation methods that have been tried include:

- liming the pond bottom, which generally requires very large lime applications and does not eliminate the hazard of acid leaching from the dikes;
- heavily liming the crest and the sloping sides of the dikes, which seems to minimize the acid hazard from the first but not from subsequent rains;
- liming the junction of dike and pond bottom as well as facing the lower slope of the dike with limestone, both of which are apparently ineffective.

7 Requirements for permanent reclamation and use

Methods of permanent reclamation and use should prevent diffusion of acids, aluminum salts and large amounts of ferrous salts from the pond bottom into the pond water, prevent leaching of the same compounds from the dikes and minimize the rate of phosphate fixation by aluminum compounds in the pond soil.

The upper 5-10 cm of the pond bottom is regularly oxidized between successive production seasons. Therefore, the pyrite from this layer and a few centimeters below needs to be oxidized and the acids formed by the oxidation should be removed or neutralized. Deeper horizons remain continuously reduced in this land use, and need not be reclaimed.

In contrast to the pond bottom, a large part of the dike body dries out between production seasons and the upper part remains oxidized even during fish or prawn production, at least in dry periods. Therefore, the acid from as much as possible of the dike material should be removed before regular use of the ponds.

Neutralization of the first 10 cm pond bottom and of the whole dike body would generally require prohibitive amounts of lime. Moreover, it would

be impractical to incorporate the lime throughout the dike. Removal of the acids is therefore indicated.
Methods to minimize phosphate fixation should be part of the regular management, since regardless of the reclamation method, much active aluminum remains in the pond soil.

8 General work plan; materials and equipment required

The procedure involves a precisely planned sequence of filling, draining and drying the ponds, cultivation by tooth harrow and finally broadcasting a small amount of lime without incorporating this in the pond soil. In the same period, the top of the surrounding dikes should be made into a series of long, narrow paddies by small levees along their edges, and seawater pumped (or carried) into these.
A pH meter or a roll or strips of pH indicator paper should be available. A tooth harrow and a draft animal are needed for cultivating the pond bottom. A small diesel-powered pump, mounted in a small boat or on a raft of bamboo or oil drums makes it possible to rapidly inundate the tops of the dikes. About one ton of powdered agricultural lime per hectare is also required.
The whole work plan can be completed in about 2½ to 3 months. All the work should be done in the dry season. Treatment of the pond bottom and of the dikes should proceed at the same time, as described below. During the first heavy rains after the pond is again in operation, some further work should be done, as described in the last section.

9 Treatment of the pond bottom

In the early part of the dry season, the pond has to be prepared for removal of the acid. This is done by drying the pond thoroughly. Small drains should be dug to let all remaining patches of standing water run dry. After one week's drying, the pond bottom should be tilled by tooth harrow in two directions. It should again be harrowed after thorough drying (when cracks in the soil are about 10 cm deep), so that the surface layer is broken into small pieces, but not into a powder. If there is no rain, the total drying period will probably take 2 to 3 weeks. Now, the acid in the dry layer is ready to be removed. Brackish or salt water is brought in to fill the pond. The pH of the water is measured immediately after filling and every few hours thereafter. The pH is expected to drop rapidly from that of seawater (7-9) to lower than 4, often about 3.

At the first opportunity after the pH has become constant, the pond should be drained and the drainage water should go to the sea, not into any other pond. This treatment removes part of the acid.

The pond is refilled and the pH checked again. The water should be drained as soon as possible after it has a constant pH. The refilling and draining process should be continued as long as the constant pH remains below about 5. This may take from less than a week (4-6 refills) to about two weeks. When the water remains at a higher pH, the pond bottom is drained and thoroughly dried again as described above.

After thorough drying, the pond bottom is cultivated and again refilled as described above. This time, the pH probably will not drop as low as in the first series of filling and draining.

When the pH remains above 5 in the seawater brought into the dry pond (after 1-3 drying cycles), the pond is drained and 500 kg agricultural lime per ha (not calcium oxide or hydroxide) is broadcast, well-distributed over the bottom. The lime should not be incorporated into the soil. The pond is then ready for the start of normal operations, if the dikes have also been treated.

10 Treatment of the dikes

At the same time when the acids are removed from the pond bottom, the acids in and on the dikes should also be removed. Because the dikes are normally dry, the acid can be washed out without first drying as is needed for the pond bottom.

Small levees, similar to the levees between wetland rice fields, should be constructed on the top of the dikes along both sides, and the surface between them should be levelled carefully. At the same time, any holes in the top surface should be filled and compacted. If the dike material is very loose and erodible, for example owing to high organic matter contents, a small ditch can be constructed along the centre of the level dike crest. This would have somewhat broader levees.

To avoid excessive amounts of earth movement, this bunding and levelling, or ditching, can be done separately for each section of dike, depending on its elevation, with cross bunds between sections. This work should be completed by the time the pond bottom has dried out and is ready for first filling.

Specifications for dikes to be newly constructed in acid sulfate areas should include levelling of the dike tops and construction of levees or ditching to avoid delay in reclamation.

At that time, seawater or brackish water (not acid drainage water) should be pumped or brought up into the levelled paddies on top of the dikes, enough to keep them flooded to more than 10 cm depth. At first it will be necessary to check the whole top surface and the length of the small levees and stop any visible leaks. Acid water will soon seep out toward the pond or the canal. Pumping of seawater from the intake canal (not acid drainage water) should be continued as necessary to keep all the tops of the dikes flooded.

When the pond bottom is ready to be dried thoroughly again, the top of the dikes should be allowed to dry out. If there is still some water standing after 2 days, this should be drained to the canal if possible, otherwise through the pond. When the pond bottom has thoroughly dried and has been cultivated, the top of the dikes should be flooded again during the next series of filling and draining the pond. When the pH of the water in the pond remains 5 or above, the standing water on the top of the dike should be removed.

The next work should be done while the tops of the dikes are moist. On dikes between two ponds, both levees are removed and the soil material brought towards the centre. The top of the dikes should be smooth and slightly sloping from the centre to both sides, without loose soil material. On dikes along a canal, only the levee along the side of the canal should be removed and the material brought toward the other levee. The top of these dikes should be smooth and slightly sloping towards the canal.

Then, 1 kg agricultural lime per 10 meters is broadcast on the slope of the dike along each pond, and 1 kg per 20 meters on the dike tops.

Weeds will start to cover the dikes, protecting them against erosion by rain, or grass can be planted to speed up the revegetation. Alternatively, pineapples can be planted on the dikes to provide more cash income. This was successfully practised in one location (Figure 3).

Figure 3. Pineapples growing on a long established dike of a brackish water fishpond in an acid sulfate area

11 Management measures

To decrease the rate of phosphate fixation during the growing season, silica-rich materials that bind some of the aluminum in the pond soil may be broadcast over the pond bottom. Readily available, cheap silica sources include partly decomposed rice hulls. Then, the usual amount of chicken manure is distributed over the pond bottom and the pond is filled. A few days later, initial amounts of N and P_2O_5 fertilizer are broadcast in the pond water. In normal, non-acid fishponds, the recommended amounts of phosphate are broadcast once every 2 or 3 weeks. In acid sulfate fishponds, however, the phosphate should be divided into portions broadcast every 2 days, or weekly portions should be placed in jute bags just submerged on floating platforms, 2 per ha, to dissolve slowly. By either one of these methods the phosphate concentration in the pond water can be kept high enough for good growth of algae, without excessive losses by fixation on the material of the pond bottom.

After sufficient growth of algae, the pond can be stocked. The regular, recommended fertilizer dosage should be continued but the phosphate should be applied as described above.

12 Prevention of fish kills during rains

Although much acid has been removed from the dikes, there may still be a danger of acid water seeping from the dikes into the ponds during heavy rains. As soon as heavy rain starts, the pH of the pond water along the dikes should be checked. Checking should be continued for several hours. If the pH drops below 5, agricultural lime should be broadcast immediately into the pond water along the dikes. About 1 kg of powdered agricultural lime should be used per ten meters in each pond along each dike. This is about 1 bag (50 kg) of lime for the four sides of a one-hectare pond.

When this is done, the pH should be measured again after a day. If it is still lower than about 5, the lime application should be repeated.

Because the pH meter should be used outside during heavy rain, a large, strong, clean see-through plastic bag should be kept with the meter. Before going out, the meter should be placed in the bag. The meter can then be read and operated through the plastic from outside. The cable of the meter should come out downward from the bag. This way, the meter can be kept dry.

It is advisable to practise the pH measurement and broadcasting the right amounts of lime along a short section of dike well before the first heavy rains to get acquainted with this procedure.

Once acid comes out of the dikes during rain, it is too late to start practising and also too late to go and buy a stock of agricultural lime. Therefore, a stock of at least 200 kg (4 bags) agricultural lime should be kept for each hectare of fishpond that has shown problems before.