THE USE OF POLLUTANTS FOR AQUACULTURE - CONDITIONING OF WASTES FOR AQUACULTURE

by

GEORGE L. CHAN
University of Papua, New Guinea

CONTENTS

Abstract

The role of human and animal wastes in improving the fertility of fish ponds has long been recognized in many countries. However, because of the lack of understanding of the process involved, particularly as regards public health, this practice has been viewed as insanitary and non-aesthetic and is generally frowned upon. This paper describes work done to condition these wastes in a sanitary and scientific manner to make their subsequent use in aquaculture not only non-objectionable, but also very profitable. These benefits result from the useful by-products generated, such as fuel in the form of methane gas, animal feed in the form of algae, and fertilizer. More important still, the effluent leaving the system is completely purified and can be disposed of without creating any pollution problem.

1 INTRODUCTION

In all the South Pacific islands and in the coastal villages of Papua, New Guinea, fresh fish and shellfish have always been the staple protein food of the people. This protein source, together with breadfruit, cassava, sweet potato, taro and yam, and the local fruits, provided a natural balanced diet for the people. Pigs and chickens were also available.

The introduction of the copra industry was the start of a series of cash crops that upset the *status quo*. The people began to aggregate in large plantations and urban centres to work for cash. Unfortunately these plantations - copra, coffee, cocoa, vanilla, groundnut, rubber - have been constant failures and urban areas are now faced with serious problems of unemployment, overcrowding and unsanitary living conditions. Nevertheless, the present trend remains in favour of increased industrialization and production of export crops, despite the increasing consumption of imported foods.

Industrialization and urbanization will give rise to excessive production of waste products, harmful effluents and domestic sewage. All of these pose a threat to the aquatic resources. Certainly, the resources of this region should be developed, but not at any price, and only on a scale appropriate to the local resources.

At the moment, the region has to cope with the problem of human and animal waste disposal only, as nature's ability to recycle this output has been exceeded in certain areas. It is possible, however, to work within the context of biological laws and condition these wastes to produce food, particularly fish and shellfish.

2 ORGANIC MATTER

Domestic and animal wastes are the products of food and drink that have undergone chemical changes inside the body, and consist of:

(a) water and minerals originally found in the food and water;
(b) non-pathogenic bacteria from the digestive tract;
(c) cellulose; and
(d) organic matter, being the biodegradable remains of food subject to oxidation.

The organic materials (proteins, fats, sugars and starches) are the source of the problems associated with wastes, and are decomposed by oxidation, or by natural intestinal bacteria or saprophytic bacteria present in soil and water - in all cases consuming oxygen. The cycles of decay and life of organic matter are shown in Fig.1.

In a healthy river or lake, the living organisms - bacteria, plankton (algae and protozoa), plants and fishes - constitute a well balanced community responsible for the continuous self-purification of water, through:

(a) digestion and oxidation of organic matter by bacteria, producing carbon dioxide and nutrient salts;
(b) photosynthesis using carbon dioxide and nutrients from the decayed organic matter and providing oxygen;
(c) seafood production with natural protozoa living on algae and fishes living on both algae and protozoa.

Organic matter can be oxidized by bacterial action or chemical oxidation. In both cases, sunlight and warmth are advantageous.

The discharge of too much organic matter into the water will, directly or indirectly, deplete the oxygen content and overtax the processes of self-purification.

As a result of excessive sewage discharges, sewage fungi will appear on the sides and bed of the river or the edges of the lake, lagoon or sea. In turn the fungi will die and decay, consuming oxygen and will be carried away, thus extending the deoxygenation process. The more delicate plankton, plants and fishes will die, decompose and consume more oxygen, making the water incapable of supporting the higher forms of plant and animal life. These disastrous consequences on fish life can represent a serious economic loss.

In southeast Asia, the people have realized the usefulness of wastes in improving the fertility of fish ponds and have been using them for many years without knowing why the system works. Experience has taught them not to overload the ponds with wastes since this causes fish kills. So they either built very large ponds or a series of them to increase the dilution.

This practice can be unsanitary because of the handling of wastes and recycling of parasites, and it is frowned upon by people with different social backgrounds. But there is no doubt that the valuable nutrients in the wastes can be very important assets in aquaculture. With our present knowledge it is possible to condition such wastes in a sanitary and economical manner for subsequent utilization in aquaculture.

However, we cannot deal so easily with chemical pollutants (acids, alkalis, toxic salts, mineral wastes, wash waters from industry, oil spills and run-off of powerful pesticides and artificial fertilizers), which are more stable than organic matter.

These chemical pollutants cannot be treated by biological means and require very expensive mechanical and/or chemical processes. Any such effluent discharged into the receiving water will either kill all plants and animals, or have serious effects on them.

The objective is to use only organic wastes for aquaculture, but it is worth pointing out that along with aquaculture, we can also develop agriculture and small industries in the South Pacific along similar lines, without the creation of any chemical, thermal or air pollution.

3 CONDITIONING OF ORGANIC WASTES

This paper attempts to show how simple and profitable it is to condition organic wastes and prevent the above mentioned damages to rivers, lakes, lagoons and sea, and at the same time use them for aquaculture in ponds and tanks at village and semi-urban levels, thus providing local people with protein food at their own convenience.

The processes involved are sanitary and scientific, fully tested in practically every sewage treatment plant in the world, and also done in a very economical way. There are very useful by-products such as fuel in the form of methane gas that can be easily stored and piped to where it is wanted, feed in the form of algae and plants for the animals producing the wastes, and fertilizer for plants.

All the excreta produced by farm animals and the farm family will be isolated in a digester where organic matter will be digested by bacteria to produce methane gas that burns with a clean flame into carbon dioxide, which in turn can be used by plants during photo-synthesis. At the same time, the organic content of the wastes will be reduced by 60-70 percent, and the cellulose will settle at the bottom as stabilized sludge that can be used as humus.

Any parasite in the waste will be digested anaerobically, settled in a tank or pipe, and then filtered out before discharging the effluent into an algae basin and an algae pond, where photosynthesis will encourage algal growth and also produce oxygen for purification of the effluent.

The effluent from the algae pond entering a series of fish ponds will contain fine algae, minerals and oxygen - all essential nutrients for prolific growth of plankton and weeds for fish culture. Ducks can also be raised in the fish ponds without their competing for feed with the fish. The fish will control mosquito breeding and the ducks will control weeds.

To make sure that no algae will remain unused, the fish pond effluent will pass through a series of tanks and tubes for culture of oysters and shellfish that only require algae and oxygen to grow.

The final effluent will contain minerals only and to prevent them from causing prolific growth of weeds in rivers, lakes, lagoons or sea, it is distributed by subsoil perforated plastic pipes to irrigate and fertilize vegetable gardens, where legumes, leafy and root vegetables are rotated successively to provide feed for the animals and food for the family. The water leaving the system will be completely purified and can be disposed of in any way without creating any nuisance or pollution problems.

It should be pointed out that the utilization of sewage effluents in aquaculture is also practised in such highly industrialized countries as the U.S.A., Federal Republic of Germany, Japan, Israel and South Africa.

In Papua, New Guinea, gourami are bred in the first pond at Bomana Corrective Institutions, outside Port Moresby, where a 1 000 gal (4 550 l) digester has been built. However, there is not yet enough information to provide data on growth and rate of breeding. It is intended to use carp in ponds at Makana Vocational Centre, where a 450 gal (2 048 l) digester is being built, and also at the Cooperative Training College, where a 1 000 (4 550 l) digester has been planned. Both these places are on the outskirts of Port Moresby.

4 CONSTRUCTION OF AQUACULTURE UNIT (Fig. 2)

The design of the unit is a modified version of a 4-acre (1.6 ha) development for the Cooperative Training College at Laloki, Port Moresby.

4.1 Animal House

The animal house is octagonal in shape, with the concrete floor of each section sloping toward the centre where the digester and settling tank are installed. It has an area of 1 200 ft^2 (111 m^2) and is designed for an 8-sow operation for meat production; 2 cows or 12 goats for milk; and 60 chickens in batteries at 3 ft (91 cm) above the floor for eggs.

The chicken wastes fall on a fibreglass drain under the batteries and are washed into the digester without the pigs having access to them. The animal wastes on the concrete floor are washed with a hose into collector drains in the central part of the animal house and then into the digester.

4.2 Treatment Plant

4.2.1 Digester

The digester is circular, prefabricated in fibre-glass and of 1 000 gal (4 550 l) capacity. The inlet pipe has a T-piece with a cap that can be removed for desludging every three months. The gas cover has an effective storage capacity of 20 yd^3 (15.3 m^3) at atmospheric pressure (in fact, it is 10 yd^3 (7.7 m^3) at one atmosphere). The daily gas output is about 30 yd^3 (23 m^3), which is equivalent to 60 kilowatt/hours.

The gas is piped in a plastic pipe fitted with a water trap at the lowest point to drain the condensed water vapour in the gas. A flame trap made of brass wire gauze is also inserted in the pipe just before the gas appliance.

4.2.2 Settling tank

The settling tank is also circular, made in fibreglass, and has a capacity of 1 000 gal (4 550 l). It has a fibreglass lid fitted with an aeration pipe that can be removed for desludging twice a year. The sludge is left on a drying bed before using it as humus.

4.2.3 Filter

The filter is built in concrete blocks and consists of a scrubber fed from the bottom and a conventional slow sand filter of 200 ft^2 (18.6 m^2). It is only used when the animal house is washed two or three times a day, and is designed for a load of 500 gal (2 275 l) at a rate of 5 in (12.7 cm) vertical descent per hour.

4.2.4 Algae basin

The algae basin has a concrete floor and walls about 12 in (30.5 cm) high. The area is 1 200 ft^2 (111 m^2), divided into three compartments by two baffle walls to prevent shortcircuiting. This shallow pond ensures maximum penetration of sunlight into the liquid for maximum algal growth.

4.2.5 Algae ponds

There are two algae ponds in series, each 1 800 ft^2 (167 m^2) in area and 3 ft (0.9 m) deep, formed in earth into a V-shape (truncated), lined with puddle clay and then covered with 3-4 in (7.6-10.1 cm) of sand to avoid colloidal clay suspension that may interfere with sunlight penetration.

The algae is scooped every afternoon and is mixed with animal feed, or dried in the sun for future use. If more algae is required, the effluent from the filter can be pumped on top of the animal house, which will have a metal or asbestos cement roof in such a case, and the liquid flowing in a thin film in presence of sunlight will encourage more algal formation. It is interesting to note that the right kind of algae (*Chlorella*) has 50 percent protein and can also replace green feed for the animals very economically.

4.3 Fish Ponds and Tanks

There are 20 fish ponds, each measuring 200 ft (61 m) by 15 ft (4.6 m), with an average depth of 5 ft (1.5 m). They are built like the algae ponds, but without the sand cover. Gourami and various kinds of carp can be bred in the separate ponds to compare their rate of growth and breeding. It is estimated that these ponds will yield more than 10 t of fish per year.

The ponds are built long and narrow to facilitate the use of nets during harvesting. It will also improve the flow of water in the ponds, as it is intended to circulate the effluents by pumping through oyster tanks made in fibreglass and other shellfish tubes in plastic, where seed oysters and shellfish are placed for culture, and then discharge the water back into the inlets of the fish ponds. It is expected that the fish production will improve in the flowing water aquaculture.

4.4 Garden

The effluents from the fish pond flow through subsoil plastic pipes which are perforated to give as uniform a distribution as possible in the vegetable garden to irrigate and fertilize the plants at the roots. In this way it is possible to water four or five times the area that can be irrigated by overhead means. Through proper choice and rotation of tropical crops it is also possible to get about ten crops of legumes, leafy and root vegetables a year, all without using any kind of artificial fertilizer or watering the crops separately, except during transplanting of seedlings. Moreover, once the subsoil drains are laid, the soil only needs forking for an inch or two when transplanting the seedings, which can be done one week or so before harvesting the grown vegetables, between the rows, thus providing shade for the seedlings and allowing cultivation of the land on a continuous basis.

Rice, corn, sugar cane, beetroot, many green vegetables, and a wide variety of soya, snake and other beans, just grow in the favourable climate of the tropics, with pests controlling themselves biologically and using one or two of the crops to keep the survivors happy. The philosophy is not to get rid of all the pests, but to accept 10-20 percent in losses to them.

The absence of both artificial fertilizer and powerful pesticide in agriculture can be a blessing to aquaculture, when we think of fish kills and other pollution problems that the developed countries are having with their agricultural wastes.

4.5 Industry

With the production of methane gas as fuel, and minerals as fertilizer, at little cost, it is possible to have small industries based on the utilization of agricultural products and wastes as raw materials, which are always renewable, not like mineral resources that, once used, are not replaced or are replaced very slowly.

To start with, refrigeration facilities can be set up for conservation of seafood and fish processing (filleting, packaging, deep-freezing). The guts and residue can be made into fish meal for animal feed.

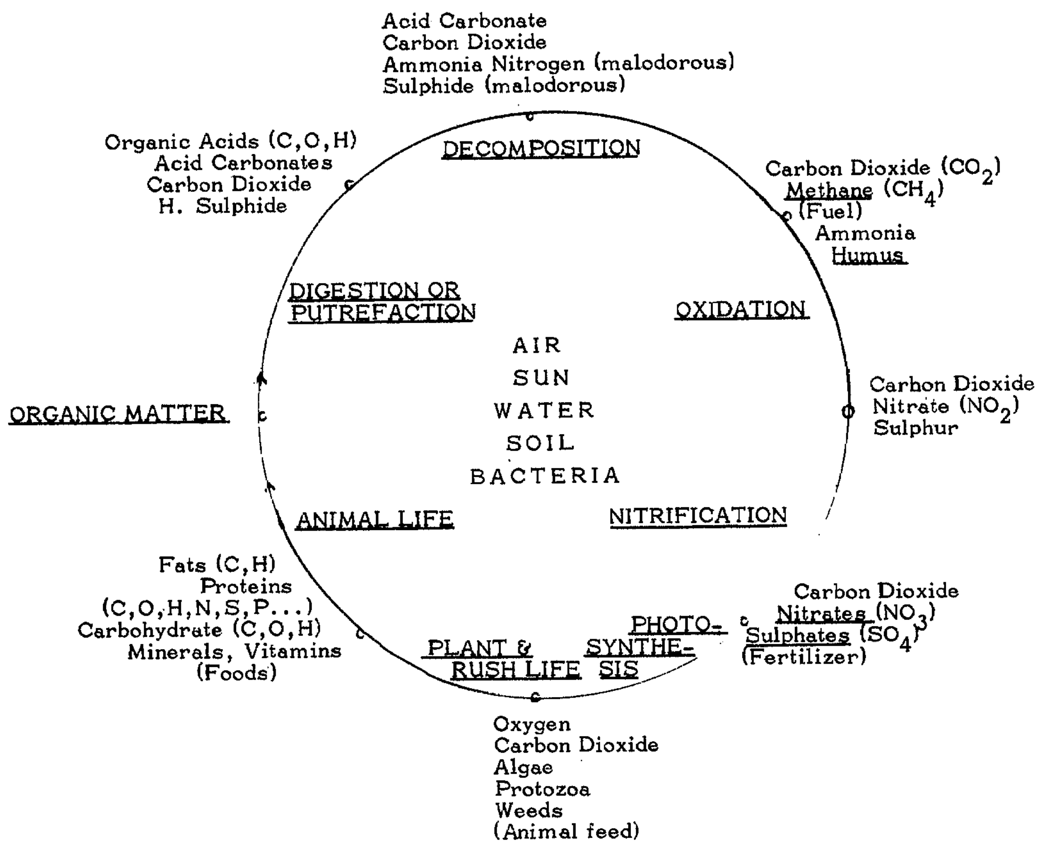
There can also be other industries such as dairy, abattoir, bakery, and small factories manufacturing cooking oil, margarine, sauces, flour, starch, soap, dyes, plastics, synthetic fibres, paints, glue, wax, paper, hardboard, fibreboard, rope, brush, cosmetics, drugs, rum, methylated spirits, disinfectants, charcoal, mat, carpet, insecticides (from plants), etc.

All these industries need fuel, which can be obtained in any amount by having more animals, and this also means more fish and shellfish. Since there is no worry about animal feed, which is produced in the system with the free fertilizer, there is no limit to this kind of development. What is more attractive is that the capital involved is relatively low and the return on this investment is much higher than any other kind of legitimate development, without creating new liabilities such as air, soil, water or thermal pollution.

5 CONCLUSION

The improvement in the quality of life through this kind of rural development and cottage industry will do away with poverty and unemployment at a price that developing countries can afford and the sharing of wealth more equitably among the local people will create an atmosphere that is conducive to peace and stability.

Fig. 1 Cycles of decay and life (organic matter)



ORGANIC MATTER:

CARBOHYDRATES	Cellulose	-	non-biodegradable
	Starches Sugars	-	biodegradable
PROTEINS	Amino acids	-	biodegradable
FATS	Fatty acids	-	slow biodegradation

Fig. 2 Aquaculture Unit