# NOTES ON, AND POSSIBILITIES OF, FERTILIZATION OF FISH PONDS IN INDONESIA.

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In Indonesia pond cultivation, as well as rice culture, is carried out by the small farmer on a small scale. The owner or tenant of a pond is usually a simple 'tani' with only limited financial means, although endowed with considerable technical skill. Usually he will be quite unable to expend large sums on fertilizers or manure for use in his ponds. For this reason artificial fertilizers are not used by the Indonesian fish-growers.

In recent years attempts have been made to intensify the fisheries industry by initiating co-operative movements, but as the level of education of the entire population has to be raised for this purpose and, in the first place, more settled conditions than the present are essential, hardly any results have so far been attained.

The above remarks are a necessary preliminary to our considerations on fertilization of ponds since they clearly demonstrate the great difference between the situation in Europe and America and that in Indonesia. For the same reason the use of fertilizers in ponds hardly ever formed the subject of investigation in this country.

Fish cultivation in Indonesia may be divided into the following classes.

1. Culture of the *bandeng* (*Chanos chanos* (*Forsk*)) in brackish-water ponds ('tambaks') situated along the shallow north coast of Java, along the coast of Madura and elsewhere.
2. Culture of common carp, other Cyprinidae and some Labyrinthici in fresh-water ponds, irrigation reservoirs and lakes in Java and elsewhere.
3. Culture of common carp in paddy fields, either simultaneously with, or after the rice.

An increase in the natural food production of the pond being the aim in all methods of fertilization, the principal question is the kind of natural food wanted in each individual case. Moreover, under what environmental circumstances is this food produced in the ponds and how is this food production influenced by cultural practice.

Schuster's monograph on tambaks gives the following data relevant to our purpose.

In brackish-water ponds the depth of the water does not exceed 40–60 cm. As the same applies in most fresh-water ponds we can state that the Indonesian pond is a shallow one. Tambaks are flooded with sea-water together with fresh-water. Consequently, the salt concentration in the water fluctuates between 0 and 260 per mille at various times of the year.

Values between 0 and 50 per mille are most frequent. Consequently, alkalinity is rather high (between 3 and 4·5 c.c. HCl/per litre) and there is no lack of calcium; *p*H values fluctuate between 7·1 and 7·9; the natural buffer capacity of the sea-water preventing greater fluctuations. The average amount of P is of the order of

4·3–6·2 mgr./m.$^3$, which is very minute. Potassium, on the other hand, is abundant. The fresh-water flowing in from the land side contains a fair amount of sediments rich in P and K, but poor in nitrogen (Schuster, 1950).

Fresh-water ponds dug in all kinds of soils and receiving all types of water show a great diversity in environmental factors.

Vaas (1947) gives some analyses.

## NITROGEN AND OXYGEN.

Rain-water contains ammonia and nitrates in amounts varying widely, depending on the amount of these gases present in the atmosphere. Nitrogen compounds in the air are generated by various activities of man (dungheaps, stables, factories). For this reason continuous rain will be less rich than intermittent showers. In Table I, two values both determined in Indonesia but differing rather widely, are given.

TABLE I.—*Nitrogen content of rain in Indonesia.*

| Location. | Year. | Rain in mm. per annum. | $N(NO_3)$-$N(NH_4)$ kg./ha./year. | $N(NO_3)$-$N(NH_4)$ mgr./l. | Author. |
|---|---|---|---|---|---|
| Deli | .. 1925-1940 | 2,000 | 30 | 1·5 | Roelofsen (1941) |
| Bogor | .. 1948-1949 | 5,000 | 13 | 0·26 | Baars (1950) |

However, as Baars (*l.c.*) pointed out, these large amounts of nitrogen cannot enrich the ponds without heavy losses.

Especially when showers are heavy, most of the water will leave the pond immediately *via* the outlet, and in that case when the pond water contains more nitrogen than the rain, all rain causes a dilution. When investigating nitrogen conditions in paddy fields, Baars found a considerable nitrogen fixation in the soil, firstly in the form of $NH_4$, which compound is converted into nitrate later on. However, heavy rains wash out a large portion of the nitrates previously formed.

The amount thus fixed and lost again proved to be much larger than the amount consumed by the rice plant during growth. For the rice plant in the paddy field, it is not so much a question of the quantity of nitrogen in the soil but rather of its availability.

It is deemed to be of primary importance to repeat Baars' paddy field investigations in fresh-water ponds, as many environmental factors are different in this case. Most paddy fields are dry during long periods and, even when flooded, conditions for aerobic nitrogen fixation seem to be realized.

Ponds are drained for short periods in between long cultivation periods. A heavy layer of mud containing remains of plants and animals is usually found on the bottom. Formation of $H_2S$ was frequently observed, especially in tambaks where it was found to kill young fry. Detailed observations are lacking, but in tambaks 10–30 per cent saturation of oxygen was found at the surface of the water in the morning, indicating that the amount of oxygen on the bottom must be small indeed. In the mud, however, anaerobic conditions must exist. According to Schuster (unpublished data), anaerobic nitrogen-fixing bacteria of the Clostridium-type occur in tambak mud. However, if we assume an anaerobic fixation by Closteria we cannot assume a nitrification in the same place.

According to Allinson *et al.*, De, and others, whose work was summarized by Fogg (1947), it is highly probable that the dense bottom vegetation of blue-green algae, consisting of such species as *Phormidium*, *Oscillatoria*, *Microcoleus* and *Lyngbia*, living on the mud in contact with both mud and water, is capable of aerobic nitrogen fixation. This was proved for many—unfortunately other—species in paddy fields in India. Thus this layer of bottom algae probably has a double function in Indonesian tambaks, its function as a food for the bandeng being well established. (Schuster *l.c.*)

The fundamental question as to whether the soil layer of our fresh-water ponds is devoid of oxygen or not still needs experimental elucidation. It is obvious that the answer to this question should be the basis for all fertilization projects. As the oxygen from the water on the bottom must be the principal source for the oxygen in the soil itself, we will describe briefly what is known about the availability of this gas in ponds here. Even in the morning, just before sunrise, when there has been no photosynthesis throughout the night and oxygen-consuming processess have been able to exert their maximal influence, in most cases there proved to be a certain amount of oxygen in the bottom layers of the water. The reason is found in the temperature fluctuations of the water. Fig. 1 (unpublished measurements made by M. Sachlan and I. Zahir) shows the fluctuations of the water temperature at the surface and on the bottom of a pond in Bogor in relation to the temperature of the air. It follows that only during the short period between 11 a.m. and 4 p.m. did the pond show a stratification with a very slight stability (difference in temperature 1° only), and that during the period between 5 p.m. and 9 a.m. the following morning the pond showed an inverse stratification owing to the steep drop in temperature of the air and the strong heat-retaining power of the mud on the bottom. It follows that during this second period the water must be in constant circulation even without any disturbing influence of the wind, as a heavy layer of cold water lies on top of a warmer layer with a lower density. This constant circulation brings about transportation of oxygen from the air to the bottom layers. Buschkiel (1939) investigated the same phenomenon in Javanese ponds with the aid of self-recording apparatus and arrived at similar conclusions.

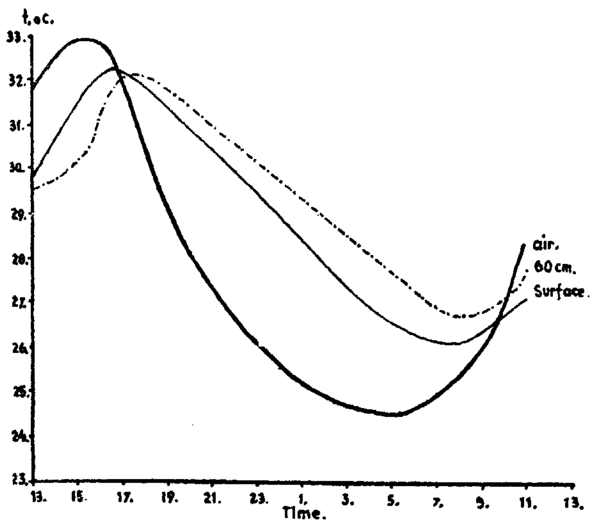


FIG. 1. Daily fluctuations in temperature in a shallow pond in Bogor.

Fig. 2 shows the result of an experiment carried out by the author and M. Sachlan in a pit at Bogor, measuring 2 metres by 1·20 m. in diameter. Compared with Fig. 1, where water having a depth of 60 cm. was measured, we find that the bottom layers do not warm up so much, resulting in a greater difference between surface and bottom temperature. On the bottom of the pit a fair quantity of decaying plant parts was accumulated and for this reason the amount of $CO_2$ on the bottom was fairly high, but even then the amount of oxygen did not drop below 3·8 mgr./l., which means a saturation of 48 per cent.

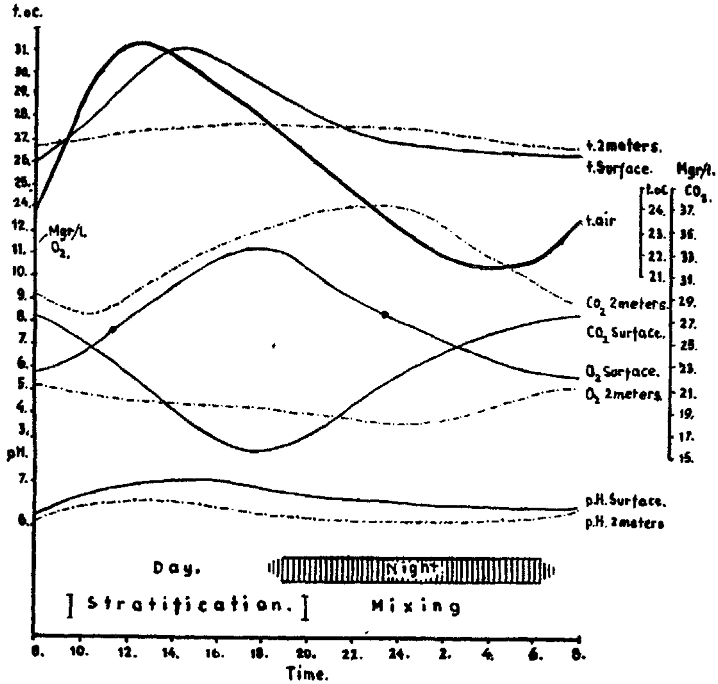


FIG. 2. Daily fluctuations in a 2 m. deep pit in Bogor (Java).

The outstanding importance of the stratification of the water for successful fertilization was recently emphasized again by Cooper and Steven (1948) in a critical review of the well-known experiments on fertilizations, carried out in Lock Craiglin in Scotland, where large amounts of phosphates were used to fertilize a small and shallow sea arm. According to these workers one of the principal reasons why the Scottish investigators did not succeed in making phosphate addition to sea arms an economic process, is to be found in the strong stratification of the water.

As winter conditions do not obtain in the tropics shallow ponds here do not show an annual change-over from a long stagnation period to a period of mixing, but are subject to a daily change instead, as was pointed out by Buschkiel (*l.c.*) and various others. He also mentions that in the upper soil layer of Indonesian ponds there is no pronounced acidification, as drained bottoms show a *p*H between 6·5 and 6·8, which value increases rapidly while the dry pond is exposed to the sun. On the other hand, the investigations of Van Raalte (1941) proved that the rice plants in our paddy fields have to rely on transport of oxygen from the air *via* leaves and stems to their roots. Recently the soils of paddy fields were investigated by Koenigs (1950) and De Gee (1950) at the Agricultural Research Station at Bogor.

The first author examined soil profiles in paddy fields and found that under the ploughpan at a depth of about 20 cm. a layer rich in iron hydroxides and manganese oxides occurred, which layer was formed when, in a reduced state, these metals sank through the topsoil with the water and were oxidized again in the subsoil.

De Gee was able to confirm this hypothesis by means of redox-potential measurements, finding strongly anaerobic conditions in the mud layer and a rise in the redox-potential value of the upper mud surface at a depth of 25–30 cm., precisely at the depth at which the manganese-oxide layer is found. Fig. 3 shows a simplified picture of the situation. The anaerobic situation is the direct result of the inundation, since in non-irrigated fields there is no drop in redox-potential (broken line in graph). Preliminary experiments in ponds indicated that the mud layer is strongly anaerobic, but in the hard soil under it the redox-potential rises again.

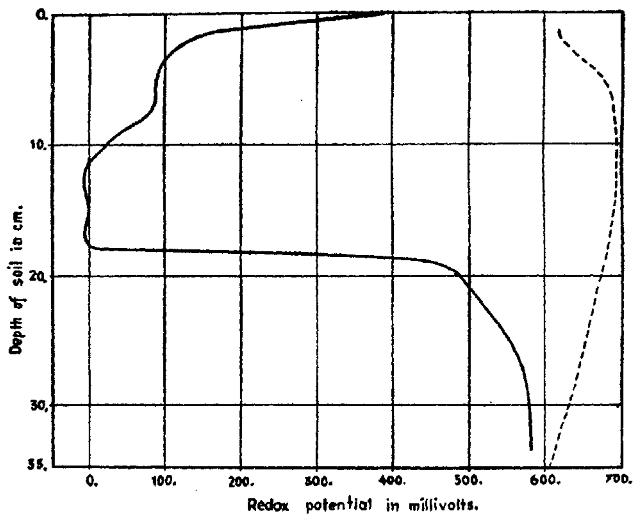


FIG. 3. Redox-Potential in soil of a wet paddy field (solid line), and on a non-irrigated field in the neighbourhood (broken line). After de Gee.

As a result of his elaborate studies on the exchange of minerals between mud and water in English lakes, Mortimer (1941) concluded that the anaerobic phase during stagnation was suitable for mineral exchange, especially of phosphorus, whereas the aerobic circumstances during the annual periods of mixing prevented such exchange because the oxydated iron compounds retained the phosphates.

Summarizing, we can state that we are far from being in a position to judge how organic fertilizers will be affected by environmental conditions in the water and the soil. We cannot yet decide whether the strong N-fixation observed by Baars in paddy fields will occur in ponds, nor are we certain about the leaching out of the nitrates. Thus, although agricultural practice in Indonesia led to the conclusion that nitrogen fertilization in paddy fields did not give good results, we are by no means certain that the same rule applies to ponds.

## CARBON DIOXIDE.

Swingle (1947) and many others hold the view that carbon dioxide, the basis of all photosynthesis, may often be a most important minimum factor for production in water. Burr (1941) and others proved that algae have their maximal photosynthesis at carbon-dioxide pressures far exceeding those usually found in natural waters.

This is an important reason why waters with a low calcium content are less fertile. Such waters are unable to hold a sufficient amount of bicarbonate in solution and for that reason the $CO_2$ pressure is bound to remain low.

Waters deficient in calcium have to rely on diffusion from the air in order to obtain the carbon dioxide necessary for photosynthesis. When such waters are not stirred by the action of the wind, the amount entering by means of diffusion only must remain very low because, as Burr pointed out, although diffusion of $CO_2$ occurs about 25 times as rapidly as diffusion of $O_2$ of the same pressure, the partial pressure of the latter gas in the air is about 700 times as high. Consequently, diffusion must be about 28 times as slow as oxygen diffusion.

When one notices the numerous examples in limnological literature of the slow rate of oxygen diffusion, one should not forget that carbon dioxide is much slower still. As stated above, the water in Indonesian fish ponds is in constant circulation for the greater part of the time. Furthermore, a constant supply of carbon dioxide is provided by the mud and often by the respiration of the zooplankton.

According to Höll (1932), free carbon dioxide would be the only suitable source of carbon for photosynthesis of Peridineae, although the author's observations in Java do not support this statement (Vaas, 1948). Ruttner (1947) found photosynthesis of water mosses (*Fontinales*) with bicarbonate weaker than that with $CO_2$. On the other hand, many other aquatic plants, such as *Elodea*, were found to consume the bicarbonate freely, thus increasing up to 11 the *p*H of solutions by the action of their photosynthesis.

In Indonesian ponds having a low calcium content, carbon dioxide production on the bottom is in many cases sufficient to maintain a fair concentration even when photosynthesis has reached its maximum. Markus (unpublished data) found the following figures when examining the carbon dioxide in ponds at Bogor, where calcium is low.

TABLE II.—*Carbon dioxide content of a pond in Bogor* (*after Markus*).

| Location. | $CO_2$ mgr./l. at 10 a.m. | $CO_2$ mgr./l. at 1 p.m. |
|---|---|---|
| Surface | 7·0 | 3·4 |
| 22 cm. | 7·2 | 4·1 |
| 42 cm. (bottom) | 8·1 | 6·2 |

Fig. 2 also shows an excess of carbon dioxide even during the day. Vaas (1947) examined a number of ponds in the morning in bright sunshine and found an excess of $CO_2$ in all cases but two, one being a sewage pond in Djogjakarta (*vide* p. 10) the other an eutrophic pond at Tjipanas, where *Osteochilus hasselti* was cultivated.

This pond was fed with warm spring water from young vulcanic soils and supported a dense, submerged growth of *Hydrilla verticellata*. The water was very clear, and photosynthesis was very active.

Only in those cases where the water is extremely rich in calcium and other minerals can $CO_2$ be a minimum factor in Indonesian ponds, and mobilization of the carbon dioxide supply, tied up in carbonates and bicarbonates, might be considered according to the principles laid down by Swingle (*l.c.*)

For such cases Swingle advocates the use of acid fertilizers or the addition of organic manures which yield acids on decomposition.

## PHOSPHORUS.

In contrast to N and $CO_2$, phosphorus cannot be supplied from the air, therefore conditions must be totally different in the case of this element.

The classical experiments in the German experimental ponds at Wielenbach and Sachsenhausen—valuable sources of information for every investigator in the field in question and comprehensively summarized by Neess (1946) for the benefit of modern American workers—proved that fish crops could be increased at the rate of an additional 2 kg. for every kg. of phosphorus added. According to the German workers we are concerned with the following food-chain. Phosphate → Nitrogen-fixing bacteria → N and P released from dead bacteria → Blue-green algae (*Anabaena*, later on *Aphanizomenon*) → *Chironomides* and *Tubificidae* on the bottom, burrowing in the soil, *Copepoda* in the water, subsisting on the living and dead blue-greens → Carp.

Following the above principles in recent experiments in America, Swingle (*l.c.*) found a close correlation between the amount of plankton in the water and the crop of *Leptomis macrochir* Raf. Plankton was markedly stimulated by the addition of fertilizers in which the ratios are N : P : K = 4 : 1 : 1. However, since colloidal clay and iron solutions are apt to withdraw a certain amount of phosphorus, a composition of 4 : 2 : 1 gave better results, increasing the production of fish by 200–300 per cent.

The plankton thus stimulated consisted mainly of *Scenedesmus*, *Ankistrodesmus*, *Pandorina* and other *Chlorophyceae* and, to a lesser extent, of *Mycrocystis* as a representative of blue-green algae.

Exactly the same species can be expected under similar circumstances in our ponds. However, it was clearly felt during the course of the above experiments that present knowledge on the physiology and ecology of algae is insufficient, as it is not yet possible to promote or suppress certain groups of algae at will. As Pringsheim (1950) pointed out in a recent article, the methods of pure culture developed by him may prove to be the ultimate solution to these and similar problems.

## LIGHT.

Of primary importance for cultivation in Indonesia is the antagonism elucidated by Swingle between the plankton on the one hand and the bottom vegetation—higher plants as well as algae—on the other hand. Although many submerged plants as well as certain algae are able to subsist floating in the water, they begin their life rooted in the soil, be it with the aid of true roots or with rhizoides. For this reason they must take their mineral food mainly from the soil, contrary to the plankton organisms, developing, living and feeding throughout the whole body of the water. The minerals necessary for growth are the same for both groups, in other words if one group manages to get a start, the other will soon be ousted. A dense growth of plankton can decrease the transmission of light to such an extent that the bottom does not receive sufficient light for the plants. For this reason easily soluble fertilizers will stimulate the plankton and damage the bottom vegetation. When the latter vegetation is undesirable, as is the case in various American ponds, fertilizers can be used even for its eradication. In Indonesian carp ponds (*Cyprinus carpio*) a well-developed bottom fauna, which does not depend directly on sunlight, is of much more importance than a bottom flora, and the *Crustaceae* living in the water are an important food for the common carp. It is, therefore, considered highly probable that the use of inorganic fertilizers will increase the yield of ponds where *Cyprinus carpio* or *Helostoma temmincki*, a typical plankton feeder, are the principal species cultivated. The common carp itself brings about a certain turbulence in the water owing to its habit of burrowing and digging in the soil. Thus the bottom vegetation is constantly damaged both directly and indirectly because sunlight is intercepted.

Buschkiel (*l.c.*) divided a glass tank into two equal sections by means of a glass plate. However, the two compartments were not quite watertight. When small carps were allowed to swim in one of the two sections, the water gradually became cloudy as the result of a dense growth of phytoplankton (*Scenedesmus* mainly), the other compartment remaining perfectly clear.

In ponds which must rely on their bottom vegetation for the production of food, conditions are quite different. *Osteochilus hasselti* is cultivated in clear water supporting a dense growth of *Hydrilla verticellata*, because the young leaves and notably their periphyton, are the principal food for that fish.

For *Chanos* the algal vegetation on the mud, composed of blue-greens and diatoms, is the most suitable food, while thread algae originating from the bottom form a danger when they float on the surface, as the malaria-mosquito lays its eggs among the floating masses (*vide* Schuster, *l.c.*). In both cases it is the soil that is to be fertilized and not the water. Swingle found that the bottom vegetation increased enormously when inorganic fertilizer was applied to ponds where the lower water layers were very cold and consequently hardly any mixing with top layers occurred. The same effect was found in the case of organic manures, such as cottonseed meal and ground flour, both heavy, insoluble substances, decaying slowly on the bottom of the pond and thus in the first place providing food for the bottom vegetation. In Indonesian ponds decomposition will be much more rapid and the frequent mixing of the water is also apt to counteract exclusive fertilization of the bottom.

A great disadvantage in the use of fertilizers in Indonesian ponds—even assuming that the owners had been able to find the necessary money—will certainly be the frequent changing of the water inherent to Indonesian practice. In many fresh-water ponds fry is reared up to the fingerling stage only, and fingerlings form the ultimate product sold for the purpose of rearing consumption fish. The growth periods in these ponds may be very brief. When water and soil are very fertile, they may be as short as one month.

Even when the periods are much longer than those just mentioned, water is constantly changed for various purposes, such as counting, landing, eradication of predators and, in the case of the brackish-water ponds, for the capture of prawns. This practice added to the inevitable leaching of the dykes, creates conditions differing entirely from those encountered in temperate climates.

In many Indonesian fresh-water ponds a steady flow of water is maintained, obviously much more than is absolutely necessary to compensate the combined losses of evaporation and leakage. Amounts of 5–10 litres/second/hectare are used. As the inlet and outlet of the pond are both situated in the top layers of the water, it is possible that the whole body of the water is not completely stirred, but what actually happens is that an upper layer of water straight from the inlet moves on towards the outlet without much mixing with the other water layers. On the other hand, we have seen that the fluctuations in daily temperature between the surface and the bottom indicate a high rate of mixing.

In Central Europe the water in carp ponds is not allowed to flow at all, only losses are compensated.

The author is not aware of any experiments carried out in Indonesia designed to compare a minimum water supply with the usual supply. It is understood that a rapid movement of the water is most unfavourable for the development of plankton, the scanty plankton of rivers as compared with lakes being a well-known illustration of this statement, known in limnology as 'Kofoids Law'. Whether a rapid flow through the pond will be a disadvantage from the point of view of the supply of minerals, depends on the relation between the respective mineral content of the water and the soil and on their powers to absorb minerals, or to liberate these substances. In many places in Indonesia the water admitted to the ponds contains much fertile silt.

As the above relations provide, so to speak, the material the fertilizer must use to build up its action, we should do well to defer our judgement until the results of numerous experiments and analyses are available.

### *The practical side of pond fertilization in Indonesia.*

#### (*1*) *Tambaks*

Fertilizers are not used in our tambaks; experiments on their use have not been conducted.

Stable manure is not used either, as hardly any cattle is raised in the tambak-area. As will be evident from a perusal of the aerial photographs in Schuster's tambak monograph, the tambak area in Java consists of closely serrated groups of ponds, with only a few dykes, canals and huts in between. There is hardly any space left for activities other than fish cultivation. In the case of fresh-water ponds conditions are quite different as these ponds usually lie more scattered between the houses and home gardens.

In brackish-water sewage reservoirs such as the 'Wester boezem' near Surabaja (*vide* Vaas, 1948), a great display of zooplankton in the water was observed. Green manuring of tambaks is a common practice in Indonesia, and experience has taught us that by adding about 2,000 kg. of grass or mangrove-leaves per hectare—piled up in the form of small heaps covered with earth—the formation of blue-green algae on the bottom is stimulated (Schuster, *l.c.*). These findings again are in accordance with Swingle's work. Along the coast vegetation on the dykes is rather poor owing to the salt content of the soil. However, in tambaks situated further inland, where less salt is found in the soil, a dense vegetation of grasses and *Cyperaceae* does occur. These plants may be used to great advantage as green manure, the usual practice again being to pile them up in small heaps showing above the water.

Shortly before the war experiments were started with fertilizers such as copra-slime.

Significant increases in the growth of the fish were noted when applications of 750–1,000 kg./ha. were used.

At the moment similar experiments are being carried out in Macassar, where inorganic fertilizers are also tested. Results are not yet available.

In brackish-water ponds in Formosa, Japanese culturists gained much experience in the application of various kinds of organic manures, such as waste products of fisheries, human faeces, rice polishings, press-residue of cocoanuts and groundnuts.

With applications of about 100 grams/m.$^2$, they were able to produce considerable masses of *Lyngbia* on the bottom of their ponds, on which alga good crops of bandeng subsisted.

The geographic and economic structure of the tambak industry in Java does not permit the use of such methods at the present time.

(2) *Fresh-water ponds*

In Indonesia the owner of practically every pond has built his 'convenience' above it, and a regular but small supply of human faeces is a common feature. For various fish and notably for the common carp, human faeces should not be regarded as a manure only, since it represents a direct food as well. The same applies for all sorts of household and kitchen waste, together with the waste products of home-rice polishing thrown into the pond—a common household practice.

Stable and green manure, such as leaves, should be regarded as a fertilizer only. This form of manuring is often used for the very young fry of various species and also for the rearing of *Helostoma temminckii*, as already stated, a typical plankton feeder. A good example is furnished by a Helotoma pond near Tasikmalaja studied by the author.

Five days after a successful spawning 375 kg. leaves, mixed with stable manure were applied to a pond having a surface of 65 m$^2$. After ten days a further 150 kg. of the same mixture was given and after 15 days another 75 kg. From the tenth day on, the mud on the bottom of the pond was churned up at frequent intervals by the fishermen with a hoe. The same operation has been carried out by Chinese fish-growers from time immemorial. The result of the fertilization is judged by the fish-grower himself according to the colour of the water. When the water is distinctly green the desired result has been attained and no more manure is added. The author noticed a well-developed plankton consisting of *Oscillatoria*, *Melosira*, *Diatoma*, *Navicula*, *Pediastrum*, *Oedogonium*, *Difflugia*, *Crustaceae* and *Rotifera*. Periphyton, too, showed fair development. This pond furnishes a good example of an unintentional application of Swingle's principles. If it is desired to stimulate the development of the plankton by means of additions of organic manure, frequent stirring of the bottom layers of the water and the mud provides a suitable means to ensure fertilization of the water. Although no experiments have been carried out in Indonesia, it is likely that in ponds deficient in lime, green manure mixed with lime will give much better results, as was frequently proved in other countries.

An example of the use of stable manure on a big scale is furnished by Lake Tjiburuj. Some years before the war this lake was under the management of the energetic owner of a dairy farm situated in the vicinity of the lake. With a clear insight into the possibilities of fresh-water fish culture this man secured the lease of the lake and started manuring it with his own stable manure and with as much as he could obtain from other sources. The waste products from some small-scale tapioca factories were also thrown into the lake. Fishing was prohibited throughout the year and only permitted on special days at fixed prices. Landings of 2,000 kg./ha. were attained within 7 months. Apart from a favourable economic situation as described above, hydro-biological features of the object in question must also be favourable to obtain similar results. Lake Tjiburuj is rich in lime, has a well-developed shore line and is favourably situated as regards mixing of the water by wind action. For these reasons no fish were ever killed in the course of manuring, as a result of anoxia.

Human faeces in the form of sewage is also used in Indonesia, with the double aim of purification of the sewage and fertilization of the pond. These forms of fish culture were described by the author elsewhere (Vaas, 1948). The situation was summarized in the following words.

'In Djokjakarta part of the effluent of a large septic tank, where the domestic sewage receives its first treatment, is further purified by technical means, the rest mixed with river-water at the rate of 1 : 3 fills a shallow pond of 840 m.$^3$ According to investigations by Schaeffer, the water discharged has lost all typhoid bacilli, the coli-titer is reduced to 1/100th of its original value, and the amount of organic matter and $NH_4$ is so much lower as to render the water quite safe to discharge. A mixed crop of fish is raised (*Cyprinus carpio*, *Puntius javanicus*, *Trichogaster pectoralis* and *Helostoma temminckii*), giving a yield of 500 kg. a year (about 4,000 kg./ha./year).'

'The microflora was found to consist of Diatoms near the inlet and Diatoms, *Protococcales* and Zooplankton near the outlet.'

In many places the domestic sewage of hospitals and similar large institutions is used to great advantage to fertilize fish-ponds.

In such institutions labour is cheap, sufficient space to dig ponds is usually available, waste products of human society are plentiful, there is much need of a cheap protein food, and the necessary capital is easily furnished by the institution. Reyntjes (1936) described the ponds near the lunatic asylum 'Sumberporrong' at Lawang, where the Fishery Officer J. Hofstee succeeded in raising a mixed crop of common carp and *Puntius javanicus* which yielded 3,000 kg./ha./year and more.

A small amount of disinfectants (creoline) in the sewage did not interfere with fish culture; this is decomposed in the open drains between the asylum and the ponds. Spawning, however, proved to be unsuccessful.

Fertilization of inland waters, such as lakes and large reservoirs, is regarded as a very difficult problem even in America and Europe. In a recent article Hasler and Einsele (1948) emphasized this point. They indicated the high costs, the danger of the occurrence of nuisance blooms of algae on the surface, the shortening of the

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1 This statement refers to the pre-war situation. At the moment the fish-pond is not used.

life-span of the water and the considerable gaps in our theoretical knowledge of the physiology of algae in their natural environment. In the above-mentioned article experiments and investigations are suggested to elucidate this difficult problem. The above-mentioned example of Lake Tjiburuj indicates that, under favourable conditions, good results can be attained in Indonesia.

Huntsman (1948) described a large-scale experiment in fertilization of a river with inorganic fertilizers. Results were not promising because the bottom absorbed too much and, moreover, the stretch affected was rather short. Nevertheless an increased production of algae and fish was observed.

Hitherto river fisheries in Indonesia received hardly any attention at all.

The author is well aware that in the foregoing more questions are put than answers given, more desiderata than data, yet he cherishes the hope that these notes on fertilization may be useful for those who are going to explore this interesting field.

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