Ecology of microalgae in a high rate pond for piggery effluent purification in Singapore

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Introduction

In Singapore a population of about 800,000 pigs in intensive pig farms generates some 14 million litres of waste water per day. Because of the limited area of the island, about two-thirds of which is required for rainwater catchment, this amount of waste cannot be distributed on the land as manure and constitutes a serious pollution problem. Under the auspices of the ‘Animal Waste Management and Utilisation Programme’ sponsored by the United Nations Development Programme (UNDP), the Food and Agricultural Organisation (FAO), the International Development Research Centre (IDRC) of Canada and the Primary Production Department (PPD) in Singapore, a comprehensive project to study the problem was initiated in 1976. It soon became apparent that achieving a reasonable standard of treatment by conventional means would be expensive and would reduce the competitiveness of locally-produced pork, but it appeared that, by growing algae on partially-treated liquid wastes, it might be possible to combine a more effective treatment process with the production of a saleable protein product to reduce costs.

The concept of growing algae as a nutrient source was derived from the NASA aerospace research programme in the early 1960s, and Oswald (1976) and Oswald & Benemann (1977) propounded the idea of cultivating these organisms in high-rate ponds. A high rate pond is a system for growing algae in open, shallow ponds containing liquid substrate rich in nitrogen, phosphates and carbon compounds. These nutrients, in the presence of adequate sunlight, stimulate rapid algal growth so that efficient removal of both the organic and mineral components in the liquid is achieved simply by removing the algal cells (Pirt et al. 1983). Shelef et al. (1980), in Israel, showed that such high rate ponds are useful and efficient in treating sewage.

Venkataraman et al. (1977) and Becker (1978), in an Indo-German project, reported the potential use of algae as a much needed protein source especially in developing countries. Intensive research on the cultivation of algal cells for protein

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has been carried out for more than 20 years in countries such as the U.S.A., Israel, Japan, Germany and India. For an equal acreage, algal protein production is 40 to 160 times as fast as that from soybeans. Algae have high contents of protein (about 40 to 70%) and of various vitamins. Nutritional studies with animals have shown that algal proteins can serve as an efficient supplement to soybean protein without adverse effects. Algae have been used for animal feed in the past, and in some countries are now cultivated on a large scale for this purpose.

The project in Singapore was conceived to investigate on a practical scale the possibility of treating pig-waste, recovering the algae produced and using them for animal feed. This paper is concerned with the growth and harvesting of the algae and their effects on the waste purification process.

**Materials and methods**

**Algal counts**

Quantitative data on algal populations were obtained using a light microscope and a haemocytometer slide. (Organisms larger than 100 μm could not enter the grid area between the cover slip and slide, so species such as the spined *Micratinia* and the large filamentous *Oscillatoria* spp. were difficult to count and, as is usually the case, were often underestimated or omitted completely.) The distribution of algal species in individual ponds was monitored by counting 100 cells under the microscope, keeping a separate total for each species ('differential counts').

**Biochemical Oxygen Demand (BOD<sub>5</sub>) and Chemical Oxygen Demand (COD)** were analysed in accordance with the Standard Methods listed by the American Public Health Association (Anon, 1980). The analyses were carried out three times a week and averaged weekly.

**Design and operation of treatment plant**

The algal plant was designed to treat the waste water generated from 1,500 pigs on an experimental farm in Singapore (Fig. 1). Waste from the pig barns is transported via open channels to intermediate sumps and then to homogenisation tanks. The waste is then pumped into primary clarifiers where the solid fractions settle and thicken before being fed to the anaerobic digester of 15m³ capacity. On average, the raw sludge contains 4000 mg of BOD<sub>5</sub>/l and the settled waste 2700 mg of BOD<sub>5</sub>/l.

The clarified overflow is allowed to flow by gravity into the open high-rate algal ponds, consisting of four small pilot ponds (A, B, C, D) each of 125m² area and two demonstration ponds each of 1200m², giving a total area of 2900m². The layout is shown in Fig 2. The ponds are constructed on a ‘race-course track’ design, orientated in an east-west direction to minimize shading, using pre-cut corrugated asbestos cement sections for the walls and a base of compacted clay with granite chips. The asbestos cement sections are held together by means of bolts and sealed with silicone sealant. This design is ideal for tropical conditions and has withstood rough operating conditions for over five years without any major problems.

The algal culture in the pond is kept in suspension by means of a specially-designed paddle mixer which acts as a positive displacement pump to support a linear velocity of not less than 12 cm/s. The algae must be maintained in suspension to provide equal exposure to sunlight and good access to nutrients. The waste organic compounds are