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DEVELOPMENTS IN AEROBIC STABILIZATION AND UTILIZATION OF ANIMAL WASTES IN NORTHEAST SCOTLAND: A REVIEW

PART I

BACKGROUND, EXPERIMENTAL FACILITIES AND BIOLOGICAL RESEARCH

Factors leading to the initiation of a multidiscipline project into aerobic stabilization of piggery wastes are outlined. The laboratory and field facilities developed and used to study various aspects of the stabilization process are described. The paper concentrates on the preliminary laboratory and field experiments which were designed to develop an understanding of the biology of stabilization and gain insight into the operational problems of the process. Conclusions are drawn from the results concerning modifications in design and operation which could lead to greater process efficiency.

1. INTRODUCTION

Legislation, climate and public attitudes are important factors in the disposal or utilisation of wastes and influence strongly the aims and objectives of a waste treatment research programme.

In many areas of North East Scotland permission to discharge a waste to a river or stream is given only if the discharge has a satisfactory quality. Approval to discharge is usually based on a standard of 20 mg/dm^3 O_2 for Biochemical Oxygen Demand (BOD) and 30 mg/dm^3 for Suspended Solids (SS). However, standards may be relaxed, e.g. 100 mg/dm^3 BOD for low volume effluents discharged into waters with a high rate of flow or be more stringent, e.g. 5 mg/dm^3 BOD for high volume effluents discharged into waters with a low rate of flow.

There are relatively few intensive animal production units in the region which do not have sufficient land available for waste disposal and in general these units are not sited close to rural or urban centres of population. Consequently, there is greater concern about water pollution than air pollution and odour control. More recently a greater interest has been developed in the effects on land resulting from high rate disposal (utilization

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of waste. The need to maintain natural waters free from gross pollution in an area of Britain well-known for leisure activities such as fishing and its natural wild-life, and the lesser need for odour control is in contrast to the requirements of other countries where factors such as climate and population density create different priorities. For example, in the United States discharge to a watercourse is not permitted, storage for a six month winter period is essential and subsequent land disposal of the stored waste during summer releases the odorous gases which have developed during storage — therefore odour control is a major priority. In Holland odour and water pollution control are equally important because intensive animal production units are frequently located in centres of population and there are numerous watercourses.

Studies of aerobic processes for the stabilization or treatment of piggery wastes have been examined by staff of this Institute since 1968 with the aid of financial support from a variety of sources such as the Pig Industry Development Authority, Meat and Livestock Commission and the Department of Agriculture for Scotland. Throughout the studies there has always been a multidiscipline approach involving primarily the Departments of Chemistry, Engineering, Farm Buildings and Microbiology. At first the major aim of the project was to determine the feasibility of aerobic treatment as a means of producing an effluent suitable for direct discharge to a watercourse. Inevitably this aim changed during the life of the project in response to outside pressures, such as change in legislation, and to the results obtained and experience gained.

The purpose of this paper is to outline the various studies which have been undertaken and show how the knowledge obtained has been used to achieve greater process efficiency. Adaptations of the aerobic process and its association with anaerobic treatment/storage processes in order to achieve different degrees of stabilization are also discussed. These combined processes demonstrate how a variety of aims such as maximum treatment for discharge, nitrogen retention denitrification or limited stabilization for odour control can be achieved.

2. RESEARCH FACILITIES AND EQUIPMENT

It was recognised at the outset that answers to problems occurring in aerobic stabilization could be obtained only by studying the nature of the biological and engineering problems followed by separate examination of each of these in isolation from other inherent variable factors in the system. Two approaches were therefore adopted:

a) Laboratory studies aimed at developing a detailed understanding of the biological processes involved in aerobic stabilization and the influence of environmental factors such as substrate concentration, pH and oxygen upon the micro-organisms responsible for stabilization,

b) Field-scale studies operated under controlled conditions and designed to test, in addition to an examination of the stabilization process itself, a variety of aspects such as the efficiency of the mechanical equipment, its influence on the animals and their environment and, the value of treatment on the management of wastes.

Throughout the programme there was continuous interchange between the two approaches such that problems created in one were clarified in the other and then rested.

2.1. LABORATORY FACILITIES

At first, only very simple equipment was used to determine the changes which occurred in composition during aeration of batches of waste. Later, equipment was constructed which permitted limited control of operating parameters such as loading rate, aeration and temperature and thus enabled the stabilization process to be examined during continuous operation. This latter system was used to examine the changes which occurred in the microbial population following alterations in the frequency of loading, quantity of waste added and changes in the composition of the waste [15].

The limitations of simple cultural equipment eventually necessitated its replacement by commercially-available-continuous-culture equipment (Chemap, Switzerland) which would permit more precise control of environmental conditions such as rate of aeration, dissolved oxygen concentration, pH and agitation and enable some parameters to be monitored continuously.

It was considered essential for valid comparison of laboratory and field experiments that the operating conditions for both should be as identical as possible. The most important and greatest difficulty occurring with reduction to laboratory scale was with aeration. The aeration rates which can be achieved by conventional rotors such the Pasveer cage rotor at field-scale are very much smaller than those possible in laboratory stirred tank reactors and low aeration rates in the laboratory could be achieved only by careful control of both agitation and the rate of air supply.

The continuous culture apparatus used is shown diagrammatically in figure 1.

This apparatus was used primarily to study an automatic system for the control of raw waste additions based on the maintenance of selected values of either pH or dissolved oxygen.

2.2. FIELD-SCALE FACILITIES

The first facility constructed for the study of aerobic waste treatment was an in-house oxidation ditch. The number of treatment units and ancillary facilities was increased gradually to permit study of both **aerobic** and **anaerobic** treatment methods and also combinations of these methods. Eventually the site contained an in-house oxidation ditch, an independent oxidation ditch, a surface aerator, two anaerobic digesters, an anaerobic lagoon and solids separation equipment.

The waste for the treatment units was obtained from a large piggery adjacent to the site. Where possible, consideration was given to the construction of treatment units which

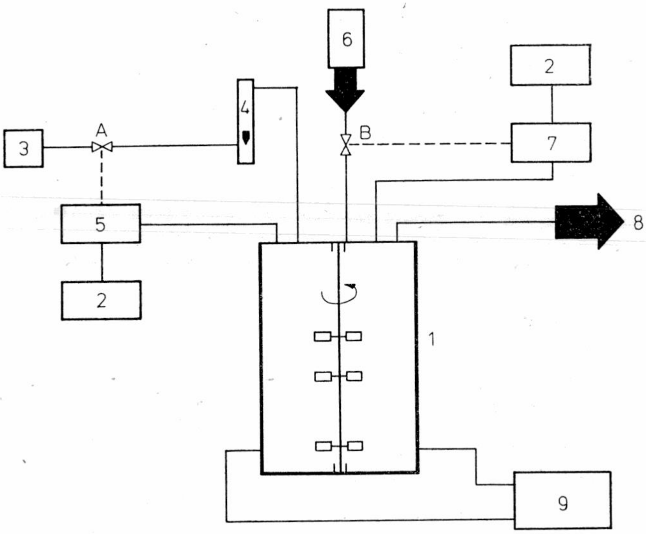

Fig. 1. Laboratory-scale continuous culture apparatus

A — flowvalve open continuously or operated by dissolved oxygen meter *B* — flowvalve operated by timer or pH controller; *1* — treatment vessel, *2* — recorder, *3* — airpump, *4* — airflow meter, *5* — dissolved oxygen meter-controller, *6* — untreated waste supply, *7* — pH meter-controller, *8* — effluent removal

Rys. 1. Urządzenie do hodowli ciągłej w skali laboratoryjnej

A — zawór przewodu odprowadzającego otwarty w sposób ciągły lub sterowany dozownikiem rozpuszczonego tlenu *B* — zawór przewodu odprowadzającego, sterowany regulatorem gazu lub regulatorem pH; *1* — komora reakcji, *2* — przyrząd rejestrujący, *3* — pompa powietrzna, *4* — rotametr, *5* — miernik-dozownik rozpuszczonego tlenu *6* — dostawa nieoczyszczonych ścieków, *7* — miernik-dozownik pH, *8* — odprowadzenie ścieków

were compatible in size so that the demand for waste did not exceed the supply and so that different units could be operated in combination. With the exception of the second anaerobic digester the various facilities have been described in detail elsewhere [12, 11, 14, 5] and are summarized here in table 1. Details of the construction and operation of anaerobic digesters [10, 8] have been specifically excluded from this paper. At the time of writing most of the units for aerobic treatment have either been dismantled or converted to other uses since major emphasis is now being given to anaerobic digestion/ /methane generation.

2.3. ANALYSIS

In the early part of the research programme, in both the laboratory and field, analysis was concentrated primarily on chemical determination of the soluble and insoluble solids and the soluble and total Chemical Oxygen Demand (COD) of the raw and treated waste. Analysis was gradually extended to incorporate, on a regular and frequent basis total, organic, NH_4^+, NO_2^- and NO_3^- nitrogen and less frequently analysis for minerals such as Ca^{++}, Mg^{++}, Na^+, K^+ and trace elements, e.g. Cu^{++} and Mn^{++}: In addition to chemical analyses pH and dissolved oxygen were monitored continuously using suitable probes and chart recorders.

Table 1

Field-scale treatment units
Urządzenia stosowane w warunkach naturalnych

	Dimensions (m)	Working capacity (m^3)	Aucillary equipment
Lagoon	$19\times 7\times 1.8$	209	—
Independent oxidation ditch	$19.57\times 1.22\times 0.3$	14.66	Inlet storage supply tank; solids separator; cage/disc rotor
Primary in-house oxidation ditch	$20.22\times 1.066\times 0.3$	12.90	Cage/disc rotor; rotary screen separator; cyclone; tile drain separator
Secondary in-house oxidation ditch	$17.09\times 1.066\times 0.3$	10.75	—
Surface aerator	4.27×1.52	21.76	Cone-shaped aerator at surface; 2 conical solids separation tanks; rotary screen separator
Below-ground aeration tank	$(0.91\times 0.76\times 0.61)\times 2$	0.42×2	Submerged aerator; rotary screen separator

3. RESULTS AND DISCUSSION

In the period since 1968 a series of Reports and Publications has described in detail the progress of specific aspects of the research programme. This paper provides an opportunity to correlate, summarize and discuss the major findings of the project.

Before proceeding to a discussion of the results it is useful first to consider the general concepts which might be involved in the biological treatment of wastes since early recognition and understanding of these concepts could have been essential for adequate interpretation of the results and for the programme to reach a successful conclusion.

3.1. WASTE TREATMENT AS A METHOD OF CONTINUOUS CULTURE

The treatment or stabilization process may be regarded as a form of continuous culture in which a population of micro-organisms is developed which can metabolise the raw waste and is maintained at a high population density and metabolic efficiency by the provision of stable environmental conditions in the treatment vessel. The maintenance of optimum conditions is simpler if the continuous culture contains only one species/ /strain of organism growing on a defined medium. Such systems are common in industry and the laboratory but the high quality equipment necessary would be noneconomic for farm waste stabilization and also much too complex to operate without the use of highly trained personnel and the support of laboratory analysis. Furthermore, animal wastes are complex and the types and proportions of the different substrates which they contain may vary with the age and type of animal and with the composition of the diet.

It seems reasonable to assume that a mixed microflora capable of adaptation to differences in substrate composition would therefore be required.

Farm waste treatment systems of the type currently in use are simple and offer very little opportunity to control the environmental conditions of the microflora. For example, a fixed aeration rate does not allow for differences in oxygen demand of the substrate; a fixed working volume must result in changes in dilution rate (retention time) as the volume of substrate increases or decreases due to alterations in the number, size and age of the animals and, in the absence of temperature control the microflora would be subjected to large daily and seasonal temperature fluctuations.

Since it can be reasonably assumed that each member species of a mixed microbial population will have its own optimum growth conditions, it is highly improbable that the total microbial numbers or the balance of species will remain stable if environmental factors such as oxygen availability, temperature and nutrient supply are themselves unstable. It is inevitable that such inherent instabilities will aggravate existing problems and introduce new ones, e.g. pH variation which would make it even more difficult to obtain a highly active „steady-state" population.

In view of the many problems it seems that in any attempt to develop a farm waste treatment system that would approximate most closely the ideal steady-state continuous culture and operate with maximum efficiency it would be necessary to accept that

a) some operating parameters could not be made constant,

b) some variables could be eliminated,

c) it might be possible to use the adaptability of the microflora to compensate for loss of efficiency caused by non-stable operating parameters.

3.2. EXPERIMENTAL AND DEVELOPMENT WORK ON BIOLOGICAL STABILIZATION

The experiments conducted in both laboratory and field divide into two main groups:

a) Phase I — experiments intended to develop an understanding of specific aspects of the treatment process and establish design criteria.

b) Phase II — utilisation of the results obtained in Phase I to produce a farm waste treatment system which would be simple to operate and give a known product quality.

PHASE I

The possible involvement of the environmental conditions for the microorganisms on the efficiency of the biological stabilization process has been indicated. In the following sections the results obtained have been used to illustrate the importance of each aspect of the environment and speculate on improvements or changes which might lead to greater efficiency.

PIG WASTE AS A SUBSTRATE

Pig slurry comprises two distinct fractions: suspended solids from the faeces and a liquid fraction containing dissolved solids derived from the urine and faeces. The biological availability of these two fractions is quite different. For example when washed suspensions of suspended solids were aerated throughout a period of 30 days there was virtually no change in COD indicating that, relative to the retention times which might be used, they were non-biodegradable. In contrast the COD of the dissolved solids fell rapidly in the first 48 hours of aeration and even more rapidly when the material was inoculated with organisms from a similar liquor, which had already been aerated.

When washed and dried suspended solids were subjected to particle size analysis, only 5–6% would pass through a mesh screen having 75 μm apertures and more than 90% was retained using apertures of 150 μm. The larger particles were clearly identifiable as fragments of barley husk.

The suspended solids had a high COD which was not biologically available. Nitrogen was present as organic nitrogen in the very small particles. The solids also contained high concentrations of the trace elements Cu^{++} and Zn^{++}. These elements were present due to the addition of copper and zinc salts included in the dry ration of the pigs. The trace elements appeared to be firmly bound to the faecal solids and therefore did not occur in solution in toxic concentrations during aeration. However, some copper was found in solution after storage of the slurry anaerobically in a lagoon.

The concentration and type of components occurring in the soluble phase of slurry was dependent upon the extent of dilution by wash water, leaking drinking water bowls and water intake by the animals, and the storage period of the slurry. Thus, in fresh slurry organic nitrogen compounds and urea could be detected but urea degraded rapidly on storage [13] and NH_4^+—N occurred as the major source of soluble nitrogen. The concentration of NH_4^+—N increased on storage due to anaerobic degradation of insoluble nitrogenous solids.

The variable nature of stored raw waste, particularly the suspended solids content is illustrated in table 2.

Further important evidence on the role of waste as a substrate was obtained in the first two experiments with the in-house primary oxidation ditch. Firstly the solids could not be maintained in suspension and secondly highly anaerobic conditions were found in the deposited sludge. An effective aerobic microflora was not developed and undoubtedly the sludge contributed to the inability to develop a suitable microflora in the circulating liquid. Practical experiences with the ditch confirmed the analytical data about the non-biodegradability of the suspended solids and also showed that their presence in the ditch was a serious disadvantage to successful operation. These disadvantages were overcome by the use of a simple rotary screen (figure 2) which was operated regularly and frequently to remove gross particulate solids. Thus it was found possible in a subsequent trial to operate the ditch continuously for almost two years. During this period there was no solids deposition, stabilization improved and there was a reduction

Table 2

Mean composition of stored raw pig waste
Przeciętny skład magazynowanych surowych ścieków z chlewni

	Raw waste I*	gl^{-1}	Raw waste II*	
COD (total)	66.21	(14.03)**	57.20	(8.68)**
COD (dissolved)	18.46	(2.61)	16.56	(2.57)
Suspended solids	44.89	(10.28)	33.35	(12.47)
Dissolved solids	9.42	(0.93)	9.00	(1.59)
K_jN	3.15	(1.12)	3.49	(1.24)
NH_4^+-N	2.21	(0.29)	2.25	(0.18)
P	—		0.5	
K	—		1.5	
Cu	—		26.46***	

* Raw waste samples from underfloor storage channels used to supply I the independent oxidation ditch, II the lagoon
** Standard deviation
*** mg l^{-1}

in the frequency and degree of foaming (formerly a major problem) and this could be controlled by the addition of an antifoaming agent.

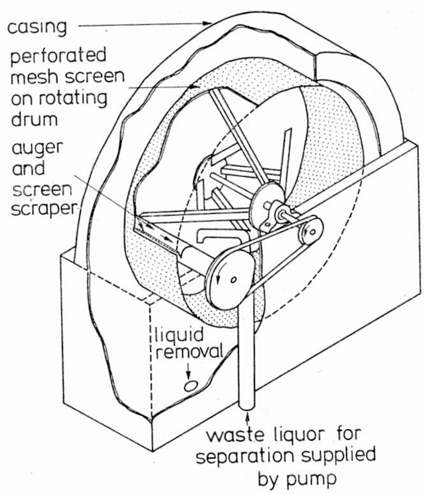

Fig. 2. Cutaway sketch of rotary screen solids separator
Rys. 2. Szkic przekroju perspektywicznego bębnowego przesiewania dla oddzielenia części stałych

OXYGEN AVAILABILITY

The need to supply oxygen for the maintenance of aerobic microbial metabolism is well recognised. However, it was not until the early 1960's with the development of the polarographic electrode and continuous culture techniques that detailed studies into the influence of oxygen on microbial metabolism became possible [6]. Even today, using pure cultures of microorganisms, understanding of the mechanisms involved is still rudimentary. The availability of oxygen is dependent upon its solubility, its rate of transfer from the gaseous to the dissolved state, and its rate of utilisation by the microflora. It is necessary that availability is considered not only for the biological treatment process as a whole but also in terms of the many microenvironments which make up the process in which diffusion of oxygen into microbial flocs may be important in determining the metabolic activity of the floc.

The saturation constant (C_s) of oxygen in a liquid, compared with C_s for clean water, is known to be reduced by the presence of dissolved substances e.g. sodium chloride, glucose. In attempts to determine C_s for piggery wastes it was found that the Winkler method [1] was unsatisfactory because of the presence of interfering chemicals and, in undiluted solutions, pigments which prevented the determination of an endpoint. Despite these problems, increasing concentrations of the soluble clarified phase of stabilised waste in water were found to decrease C_s and by extrapolation its value for undiluted waste was calculated to be only 1–2 mg O_2 $(dm^3)^{-1}$. This finding had two important implications. Firstly, that liquids with a low oxygen concentration at saturation would be incapable of providing buffering capacity to shock loads, and secondly, oxygen partial pressure readings monitored by oxygen electrode could not be converted accurately into oxygen concentration.

The influence of loading rate and low oxygen buffering capacity was observed on many occasions during both field-scale and laboratory experiments where it was found that even small additions of concentrated waste to aerating cultures produced marked reductions in oxygen partial pressure. Recovery to the partial pressure concentration prior to waste addition, was invariably slow. The influence of loading frequency on oxygen availability in an oxidation ditch is shown in figure 3. Respirometric measurements confirmed that the fall in oxygen partial pressure was due to an immediate increase in the respiration rate of the microflora, that respiration rate declined with the decrease in oxygen concentration, and that even in the absence of further raw waste additions, the respiration rate did not return to normal for several hours.

The inference from these findings is that waste additions should be small and frequent.

Studies on oxygen transfer in the field were limited to comparison of the transfer capacities of a variety of cage and disc rotors using a range of operating conditions [2] and to the routine determination of oxygen transfer rate prior to the commencement of a waste treatment trial in any of the fieldscale units. Oxygen transfer was measured by monitoring the rate of increase in oxygen partial pressure after it had been decreased to zero by the addition of sodium sulphite. Transfer rates were calculated from the corrected equation of Jones, Day and Converse [7].

$$K = \log C - C / C - C_2 \times 2.3 / t_1 - t_2 \quad (1)$$

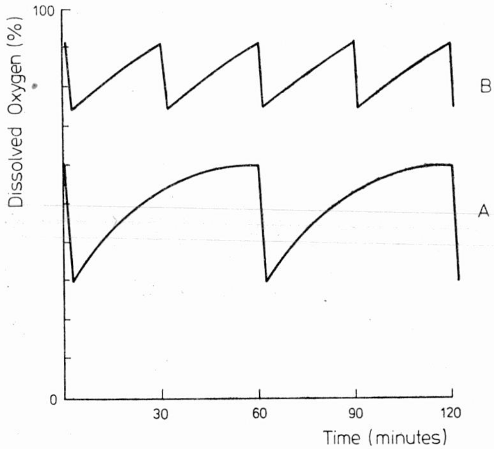

Fig. 3. Fluctuation of dissolved oxygen with loading frequency [2]
A — full load applied at 60 minute intervals *B* — half load applied at 30 minute intervals

Rys. 3. Fluktuacje rozpuszczonego tlenu w zależności od częstości obciążenia
A — obciążenie pełne stosowane co 60 min, *B* — obciążenie połowiczne stosowane co 30 min

where C_s—O_2 partial pressure at saturation; C_t — O_2 partial pressure at time t and K_T — slope of the plot of $C_s - C_t v$ time on semilogarithmic paper.

More extensive studies of oxygen transfer were conducted in fermenters in order to determine rates which were equivalent to those obtained in the field-scale treatment units. These studies also made it possible to examine, separately, the influence of aeration rate, agitation and temperature on K_T. Results showing the oxygenating efficiency (kg O_2/kWH) in water of cage and disc rotors are presented in table 3.

It can be seen that for cage rotors efficiency increases with speed of rotation and depth of immersion, however, at higher speeds of rotation, there is a reduction in the rate of increase. Disc rotors were much less efficient than cage rotors and only marginal increase in efficiency was observed with depth of immersion and speed of rotation.

Table 3

Oxygenating efficiency of cage and disc rotors [2]

Wydajność wirników klatkowych i tarczowych w natlenieniu

Depth of immersion (mm)	Efficiency (Kg O_2/kWh) Cage rotor 102	Cage rotor 127	Cage rotor 152	Perforated disc rotor 152	Perforated disc rotor 203	Perforated disc rotor 254
Rotor speed (rpm)						
60	0.82	1.54	2.68	—	—	—
80	1.49	2.83	4.04	0.61	0.74	0.52
100	2.11	4.41	6.48	0.62	0.60	0.63
120	2.57	4.10	6.59	0.47	0.76	0.47
140	—	—	—	0.53	0.71	0.69

The results showing the influence of aeration rate, agitation and temperature on K_T for clean water in fermenters are presented in figure 4. The results demonstrate that K_T increases with both aeration rate, temperature and agitation rate. It is clear that agitation rate has most influence but, unexpectedly, K_T is not proportional to agitation rate [4] and the decreases are more pronounced at lower rates of agitation.

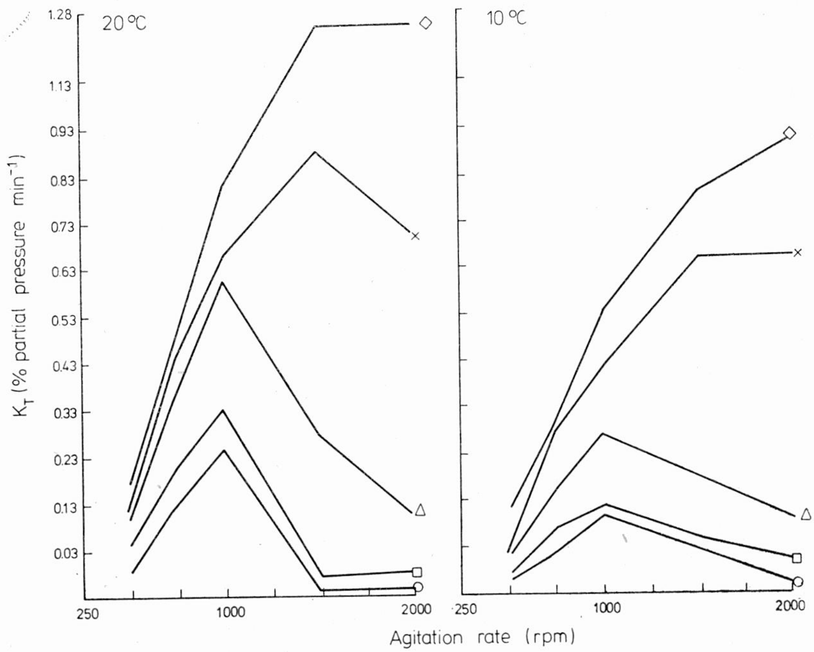

Fig. 4. Comparison of aeration, agitation, and temperature on oxygen transfer in a fermenter. Aeration rate (dm^3/min^{-1})

◇ –12, x – 6, △ – 2, □ – 1, O – 0.5

Rys. 4. Porównanie wpływu napowietrzania, mieszania i temperatury na przenoszenie tlenu w zbiorniku fermentacyjnym. Szybkość napowietrzania (dm^3/min^{-1})

◇ – 12, x – 6, △ – 2, □ – 1, O – 0.5

It should be noted that poorer performance at higher rates of agitation is exhibited both in the fermenter experiments and for agitators used in field-scale treatment units. The necessity to establish optimum operating conditions for each aeration system is emphasised by the data presented here.

Aeration has been the subject of a great deal of research by the fermentation industry in recent years and readers are advised to consult the review by Tsao and Lee [16].

DILUTION RATE–RETENTION TIME

If an organism is to establish itself and remain as a member of a mixed population, it is necessary that its growth rate is equal to or greater than the rate at which the contents of a system are displaced by incoming raw waste.

It has been our experience that the dilution rate is not constant. For example the daily output of faeces and urine has been shown to vary from 3 to 6 dm^3 day^{-1} depending upon the food and water intake of the pig and its weight [12].

Thus in early experiments, using the in-house ditch, in which batches of 40 pigs were retained in the house until their weight had increased from 45 to 95 kg the retention time decreased progressively from 123 days at the commencement of an experiment to 61.5 days at completion. Eventually a policy of continuous stocking was adopted which reduced the deviation in retention time.

A particular disadvantage of in-house systems is that loading frequency is entirely dependent upon the excretory habits of the animals. Observations showed that urination/defaecation normally occurred when the animals were disturbed e.g. at feeding times and these times could be correlated with large depressions in the dissolved oxygen concentration of the ditch contents. Fortunately, with the long retention times of the in-house system, the effect of intermittent loading appeared to be less important than for systems operating at short retention times (figure 3) since the primary in-house ditch was continuously-operated successfully for a period of 16 months.

The combined effect of variations in the biological availability of the waste, loading rate and retention time is to indicate that the performance of the stabilization process could be improved by the provision of a preliminary reservoir.

MICROFLORA

One of the initial primary objectives was to determine the changes which occurred in the microflora of the waste from the time of its excretion to the establishment and maintenance of an aerobic treatment microflora.

The details of these studies have been reported by SAXON [15]. Aeration of small batches of untreated waste resulted in a change during an 8–10 day period from a flora dominated by dut microorganisms to one in which *Acinetobacter* spp. were dominant. The findings observed in batch culture were observed later in continuously operated systems and these studies also showed the influence of substrate composition on both the composition of the microflora and its activity (figure 5). A wide range of different species were isolated from continuously aerated waste with varying degrees of regularity (table 4), but there were undoubtedly others, e.g. nitrifiers which were not isolated by the procedures used.

The occurence of pathogenic microorganisms in waste and their fate during aerobic stabilization is an important matter for consideration. The dissemination of such organisms into the environment in aerosols produced by aerators or in discharged effluents is a potential hazard. Limited trials were conducted to test the ability of some bacterial pathogens, e.g. *Salmonella*, *Staphylococcus*, and *Streptococcus* to survive aeration. Although large reductions in the numbers of each of these pathogens was observed death did not occur rapidly. It was concluded that the potential hazards due to the waste were smaller after stabilization than before but that in order to eliminate the risks entirely it would be necessary to sterilize the waste before discharge or land application.

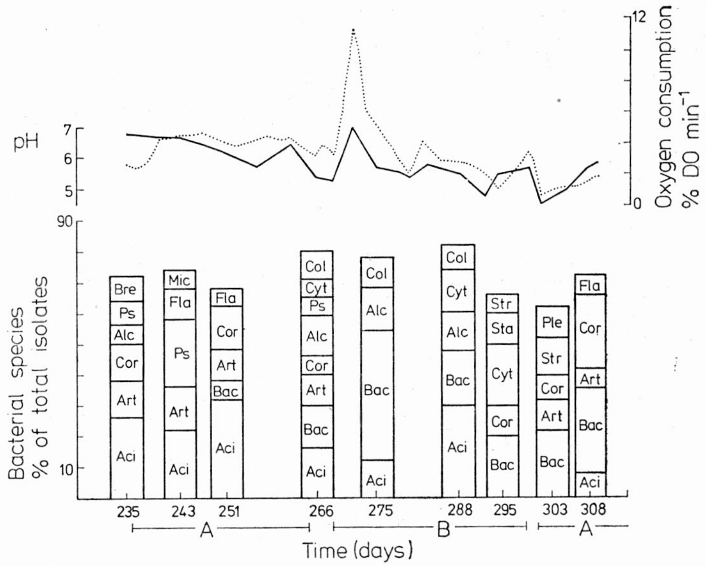

Fig. 5. Changes in bacterial species during continuous culture [15] ———— pH, ... oxygen consumption

A — freezedried, *B* — urea as feed, Aci = Acinetobacter, Art = Arthrobacter, Alc = Alceligenes, Bac = Bacillus, Bre = Brevibacterium, Col = Coliform, Cyt = Cytophaga, Fla = Flavobacterium, Ple = Plesiomonas, Ps = Pseudomonas, Sta = Staphylococcus, Str = Strephococcus

Rys. 5. Zmiany gatunków bakterii w trakcie hodowli ciągłej
———— pH, ... zużycie tlenu *A* — biofilizowanie, *B* — mocznik jako pożywka

Table 4

Bacterial species occurring in continuous aerobic cultures of pig waste [15]
Gatunki bakterii występujące w ciągłych hodowlach tlenowcowych w ściekach w chlewni

Frequency of isolation from samples examined (%) 0–34	35–67	68–100
Sarcina	*Coliform*	*Cytophaga*
Vibrio	*Brevibacterium*	*Pseudomonas*
Lactobacillus	*Staphylococcus*	*Coryneform*
Aeromonas	*Micrococcus*	*Flavobacterium*
Kurthia		*Arthrobacter*
Plesiomonas		*Alcaligenes*
Streptococcus		*Bacillus*
Chromobacterium		*Acinetobacter*

INORGANIC NITROGEN TRANSFORMATION AND pH

Wide fluctuations in pH (an important factor determining selection and activity of the microflora) were observed during experiments with field-scale systems and those in the laboratory. The changes in pH could be attributed to transformation reactions involving NH_4^+—N, NO_2^-—N and NO_3^-—N [9].

Ammonium nitrogen is the major source of biologically available nitrogen in the raw waste. The initial effect of aerating raw waste was to raise the pH to 8.5–9.0 and under these conditions nitrogen was lost from the system as free ammonia gas. The release of ammonia continued throughout the early batch trials in the oxidation ditch in which solids separation was not used and the dissolved oxygen concentration remained at low levels. When the ditch was placed on a system of continuous operation and had residual dissolved oxygen, the nitrate-nitrogen accumulated and there was an acid pH. The pH decreased further to less than 5 when supernatant from the primary stage of the in-house ditch was aerated in the secondary stage; the nitrate concentration also increased. Between these extremes conditions were developed in which ammonium, nitrite and nitrate nitrogen were all present at the same time.

The critical conditions required for the production of oxidized nitrogen appeared to be a sufficient excess of dissolved oxygen and the presence of a nitrifying microflora. At the onset of aeration, biological activity is high because of the large concentration of available COD (figure 6) and it is not possible for the nitrifying bacteria to develop until this initial stage of activity has begun to decline — this development is illustrated in figure 6. These observations led to the development of a start-up procedure in which a batch of waste at the working concentration for the ditch e.g. 1–1.5% suspended solids was aerated **without further loading** until the pH had first increased to a maximum and then declined to approximately 7.0–7.5. Using this procedure it was found that loading at the calculated rate could commence at pH 7.0 and the ditch contents would remain in 'steady-state'.

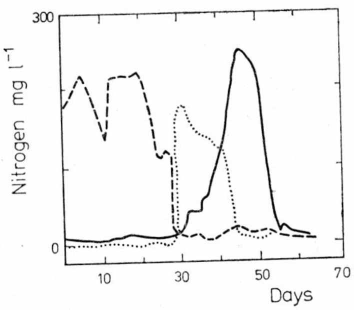

Fig. 6. The development of nitrification in aerated pig waste 2 ---- NH_4^+—N, ... NO_2^-—N, —— NO_3^-—N

Rys. 6. Przebieg nitrifikacji w napowietrzanych ściekach z chlewni ---- NH_4^+—N, ... NO_2^-—N, —— NO_3^-—N

For a situation in which the waste is to be discharged to a watercourse it is desirable to reduce the concentration of oxidised nitrogen in the effluent.

Preliminary studies in which the highly nitrified contents of the secondary stage ditch were subjected to intermittent aeration showed that denitrification of such effluents was feasible. In subsequent more detailed studies [5] it was established that efficient denitrification could be achieved on a continuous basis by means of a single 8 hour period of aeration and without the addition of glucose or other carbon source since residual COD from the primary treatment stage provided an alternative energy source. In addition denitrification was also effective in reducing the soluble COD, soluble inorganic phosphorus and total and dissolved solids.

FOAMING

The production of large quantities of foam was observed regularly during early studies in both laboratory and field. It appeared from these observations that the problem occured most commonly in systems which were being loaded but which were not in steady-state. Foaming could also be produced by applying a shock load to a steady--state process. It was considered that the primary cause of foaming was gas production resulting from elevated biological activity. An automatically controlled foam sensor//antifoam dispenser was found to be satisfactory for foam control in the in-house ditch in which loading was entirely dependent upon the excretory habits of the pigs. For other systems which had more controlled loading procedures foaming, although it occured occassionally, did not become a major problem nor was control so essential for independent ditches because the foam did not constitute a hazard for the animals.

4. CONCLUSIONS

Studies into the biological nature of processes for the aerobic stabilization of pig waste have examined the influence of a range of environmental factors such as the nature of the substrate, aeration, retention time, loading rate, pH and nitrogen transformation on the development of a treatment microflora, its maintenance in steady-state and its activity. The primary aim of these experimental studies was to develop an understanding of the treatment process and its problems in order that a system or systems of treatment could be development which were robust, simple to operate, function efficiently without the aid of skilled scientific staff and monitoring and which could be adapted to provide a range of requirements such as odour control, land application or the discharge of an acceptable effluent. The development of findings involving such systems will be described in a subsequent paper.

The results highlighted the difficulty of attempting to obtain an active, steady-state, mixed continuous culture because of the inherent variability of some of the operating parameters e.g. temperature and raw waste composition, but ways in which the treatment process could be improved were indicated.

For example

a) A preliminary reservoir prior to the treatment stage would reduce the effect of variable waste composition and also provide additional storage in the event of mechanical failure.

b) Loading to the treatment stage should occur frequently and in small quantities.

The effects of loading could probably be improved further by relating it to microbia activity rather than to arbitrarily selected time periods.

c) The provision of an efficient process for the removal of nonbiodegradable solids from waste undergoing treatment or from waste prior to treatment.

d) Use of start-up procedures which permit the development of a treatment microflora before loading commences.

e) Modification of treatment rates or processes to enable nitrogen to be retained or lost as required and at the same time assist in the maintenance of a uniform pH.

f) Prevent the addition of extraneous water so that retention time is primarily a function of substrate concentration and not hydraulic load.

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ROZWÓJ BADAŃ NAD AEROBOWĄ STABILIZACJĄ I UŻYTKOWANIEM ODPADÓW ZWIERZĘCYCH W PÓŁNOCNO-WSCHODNIEJ SZKOCJI: PRZEGLĄD

Część I

TŁO, URZĄDZENIA DOŚWIADCZALNE I BADANIA BIOLOGICZNE

Przedstawiono w zarysie czynniki prowadzące do zapoczątkowania wielodyscyplinowanego planowania aerobowej stabilizacji ścieków z fermy świń. Opisano laboratoryjne i polowe urządzenia, opracowane i stosowane do badania różnych aspektów procesu stabilizacji. Prace koncentruje się na wstępnych doświadczeniach laboratoryjnych i polowych, zaprojektowanych w celu lepszego zrozumienia biologii stabilizacji oraz dla wniknięcia w operacyjne zagadnienie procesu. Wnioski wyciągnięte z uzyskanych wyników dotyczą modyfikacji projektowania i działania, które mogłyby doprowadzić do większej wydajności procesu.

FORTSCHRITTE DER AEROBEN STABILISIERUNG UND VERWERTUNG VON ABFÄLLEN TIERISCHER HERKUNFT IM NORDEN OST-SCHOTTLANDS

Teil I

GRUNDLAGEN, VERSUCHSEINRICHTUNGEN UND BIOLOGISCHE REINIGUNG

Die Faktoren, die zu einer multidisziplinären Planaufstellung zwecks Stabilisierung vom Abwasser aus Schweinezuchtbetrieben führen sollen, werden im Umriß besprochen. Beschrieben werden sowohl Labor- wie Feldeinrichtungen die zur Untersuchung verschiedener Aspekte der Stabilisierung dienen. Die bisherigen Arbeiten konzentrierten sich auf Vorversuchen im Labor- und Pilotmaßstab, was zur besseren Verständnis der Stabilisierungsbiologie und zur Eindringung in die Operationsverfahren beitragen sollte. Die Folgerungen aus diesem Versuchsabschnitt sollen der Modifizierung der Entwurfsphase sowie der Intensivierung des Prozesses dienen.

РАЗВИТИЕ ИССЛЕДОВАНИЙ ПО АЭРОБНОЙ СТАБИЛИЗАЦИИ И УТИЛИЗАЦИИ ОТХОДОВ ЖИВОТНЫХ В СЕВЕРО-ВОСТОЧНОЙ ШОТЛАНДИИ: ОБЗОР

Часть I

УСЛОВИЯ, ИСПЫТАТЕЛЬНЫЕ УСТАНОВКИ И БИОЛОГИЧЕСКИЕ ИССЛЕДОВАНИЯ

Кратко описаны факторы, приведшие к созданию многодисциплинной исследовательской программы по аэробной стабилизации сточных вод со свиноводческой фермы. Описаны лабораторные и полевые испытательные установки, разработанные и применяемые для всестороннего исследования процесса стабилизации. Работы сосредоточены на предварительных лабораторных и полевых опытах, направленных на лучшее изучение биологии стабилизации и более глубокое ознакомление с оперативным вопросом процесса. Заключения сделанные на основе полученных результатов, касаются модификации проектирования и операций, которые положительно повлияли бы на выход процесса.