PN-ABX-073

FOOD & FERTILIZER TECHNOLOGY CENTER

TREATMENT AND UTILIZATION OF ANIMAL WASTES IN JAPAN

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EXTENSION BULLETIN 382

September 1994

FOREWORD

Japan is a densely populated country. The average farm sisze is small, and there are strict regulations to prevent environmental pollution. This means that livestock farmers in Japan face a difficult problem in disposing of livestock wastes. This important Bulletin describes methods of waste treatment, includ. ; the composting of solid wastes, and the major problems which remain, such as the need for low-cost teatments to remove nitrogen and phosphorus from wastewaster.

The Bulletin is based on a paper first presented at an international workshop on "*Development Approaches for Livestock Based Rural Enterprises*", held in the Philippines in May 1994. The workshop was co-sponsored by the Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (PCARRD), and the Department of Agriculture of the Philippines

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(Chinese Abstract)

摘　　要

由於牲畜生產迅速的擴展及農場範圍的擴大，導致大量牲畜廢物的產生，如何處理這些廢棄物成爲一個嚴重的問題。由於環境污染要求嚴格控制，牲畜的廢棄物應該被用於農業，再回收當做有用的資源。廢棄水很難用在農業上，應妥善處理以防止環境的污染。

做成堆肥是利用固體廢棄物一個有效方法，製造堆肥方法已被有效地發展，但是堆肥品質管制尚未達到。目前尚未有一快速方法來測定堆肥的品質，近外光譜分析可能是一個有效的技術。

低成本除去牲畜廢棄物中N和P的方法已被發展，N可用脫氮方法除去，磷應該被恢復成有效性磷而被利用，用間歇性通氣及TBX反應器可以活化污泥，但仍需進一步研究。

(Japanese Abstract)

摘　　要

日本では、畜産の振興並びに農家の規模拡大に伴って大量の家畜排泄物が発生しており、これらの排泄物の管理方法等多くの問題をかかえてきている。法的な規制もますます厳しくなっている。家畜排泄物は農業において利用されるべきものであり、有用な資源としてリサイクルされるべきである。また、農業利用が困難な畜舎排水については、環境汚染を防止するために、適切な処理を行わねばならない。

コンポスト化は、固形状の排泄物を利用するための効果的な処理法である。家畜排泄物からコンポストを製造する技術は確立されており、一般的に実施されている。しかし、コンポストの品質管理はまだ達成されていない。コンポストの迅速な品質評価法もまだ開発されていないが、近赤外分光分析法は品質の簡易評価法として見込みある技術と考えられる。

畜舎排水から大部分の窒素やリンを除去できる低コストの技術はまだ確立されていない。窒素は脱窒によって除去されるべきであるが、リンは有効な形態のまま回収し、利用すべきである。窒素の除去やリンの回収には、間欠嫌気方式の活性汚泥法やTBXリアクターが有効と考えられるが、さらに研究が必要である。

(Korean Abstract)

초　　록

일본축산업의 확산과 농가규모의 확대로 축산분뇨의 발생이 막대해지고 있어 이의 처리가 심각한 문제로 대두되고 있다. 한편 환경법 역시 점차 까다로와지고 있어 축산분뇨는 이제 가치있는 비료자원으로 농업안에서 재활용되는 방안이 강구되어야 할 것이다. 액체분뇨는 환경보호차원에서 철저히 처리되어야 하겠으나 고체분뇨는 퇴비화가 효과적일 것이다. 일본에서는 퇴비발효기법이 잘 발달되어 이용되고 있으나 아직 비료의 품질관리체계가 잡혀있지 않고 특히 손쉽게 비료질을 판가름 할 방법이 개발되지 못하고 있다. 다만 적외선 측정법이 있어 개발의 여지가 많다. 한편 고체적 측면에서도 어떻게 하면 저렴하게 축산분뇨로 부터 질소와 인을 분리해 내느냐 하는 것도 미완의 단계에 있다.

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ABSTRACT

As the animal industry has expanded in Japan and the scale of farms has grown, a vast amount of animal wastes is being produced. The management of these wastes has become a serious problem. The legal constraints on environmental pollution have become stricter. Animal wastes should be utilized in agriculture, and recycled as a valuable resource. Wastewater, which is difficult to use for agricultural purposes, should be treated properly to prevent environmental pollution.

Composting is an effective method of utilizing solid wastes. The technology for making compost from waste materials is well developed and practical. However, quality control for compost has not yet been attained, and there are no rapid methods of estimating compost quality, although near infrared spectroscopy analysis is a promising technique.

The development of low-cost techniques which remove most of the nitrogen and phosphorus from animal wastewater is yet to be achieved. Nitrogen should be removed by denitrification, while phosphorus should be recovered in an available form and utilized. Although activated sludge units using intermittent aeration and TBX reactors are available, further research is needed.

POLLUTION PROBLEMS CAUSED BY ANIMAL WASTES

The animal industry in Japan has expanded rapidly over the last few decades. While the total number of animals has increased, the number of livestock farms has decreased. Consequently, the average number of animals kept on each farm in 1992 was 25.7 times greater than in 1970.

Such a rapid increase has inevitably resulted in pollution problems from livestock wastes. The total number of pollution complaints reached 2,861 in 1993 (Table 1), most of them concerned with malodor and water pollution. Pollution problems in the swine industry are particularly serious, because swine producers usually have little or no cropland to which they can apply the manure.

The number of complaints increased rapidly to reach a peak in 1973 and then gradually decreased, so that in 1993 there were only one quarter as many as in 1973 (Fig. 1). However, the average number of pollution problems per 1,000 farms has tended to increase, especially on pig farms (Fig. 2).

Legal Aspects of Pollution Control

The discharge of wastewater into public waterways in Japan is controlled by the Water Pollution Prevention Act. Under this Act, nitrogen and phosphorus were added to the list which already included criteria such as BOD (biochemical oxygen demand), COD (chemical oxygen demand) and SS (suspended solids) (Table 2). Although the criteria for nitrogen (260 mg/L) and phosphorus (50 mg/L) in animal wastewater are provisional at present, criteria covering these will be applied to livestock farms after 1995.

Malodor is controlled by the Malodor Control Law. The regulation standards govern the permissible concentration of various

Keywords: composting, livestock production, livestock wastes, pollution, TBX reactors, wastewater

Table 1. Pollution problems caused by livestock wastes in Japan, 1993

	Malodor	Water pollution	Destructive insects	Other problems	Total
Swine	725	550	30	23	1,055 (36.9%)
Poultry	361	103	187	24	631 (22.1%)
Dairy cattle	508	374	38	43	836 (29.2%)
Beef cattle	147	124	21	12	264 (9.2%)
Others	36	19	12	13	75 (2.6%)
Total	1,777 (62.1%)	1,170 (40.9%)	288 (10.1%)	115 (4.0%)	2,861 (100%) (100%)

Source: Animal Industry Bureau, Ministry of Agriculture, Forestry and Fishery, Japan

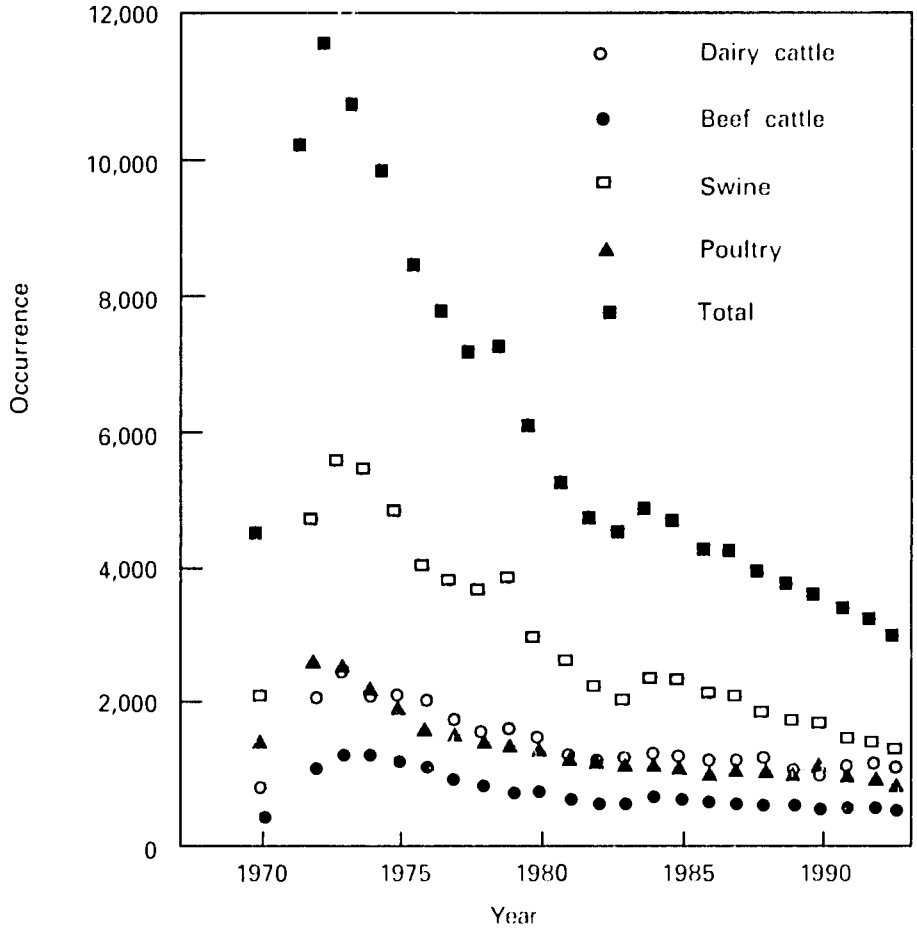


Fig. 1. Occurrence of pollution problems from animal wastes in Japan, 1970-1993

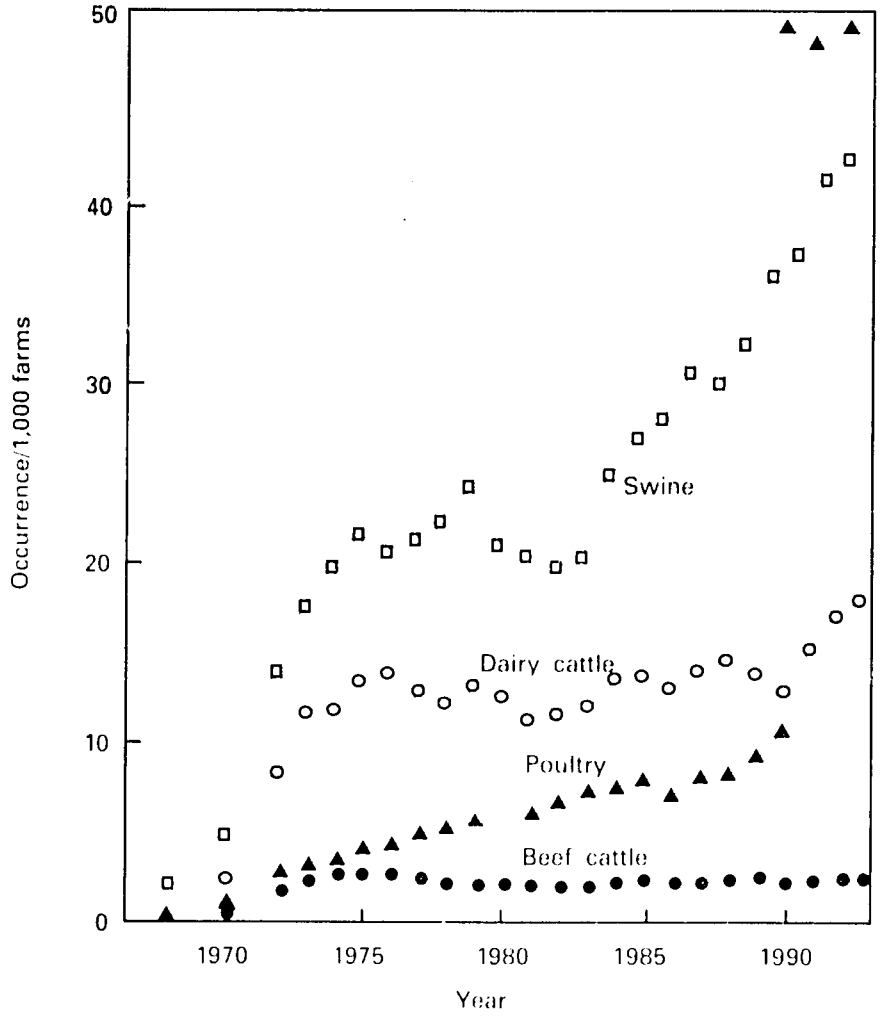


Fig. 2. Occurrence of pollution problems per 1,000 farms in Japan, 1970-1993

Table 2. General criteria for discharged wastewater under the Water Pollution Prevention Act of Japan

Item	Unit	Limit
pH	-	5.8 8.6*
Biochemical oxygen demand	mg/L	160 (daily av. 120)*
Chemical oxygen demand	mg/L	160 (daily av. 120)
Suspended solids nitrogen	mg/L	200 (daily av. 150)
Nitrogen	mg/L	120 (daily av. 60)
Phosphorus	mg/L	16 (daily av. 8)
Caliform bacteria	No./mL	daily av. 3000

malodorous compounds at the boundary of livestock farms. In 1990, four volatile fatty acids (VFA) were added to the list of substances regulated by this Law, which already included eight substances such as ammonia, methyl mercaptan and hydrogen sulfide (Table 3). These fatty acids emit an offensive odor if even small amounts are present in animal wastes, especially swine wastes. An additional ten substances, including propanealdehyde, isobutyl aldehyde and isobutyl alcohol, were added to the list in 1994.

Quantity of Animal Wastes

The total production of animal wastes in Japan was estimated in 1993 to be 93 million mt per year (Table 4). These animal wastes contain large amounts of nutrients, including nitrogen, phosphorus, potassium, and various other minerals. The total amount of nitrogen contained in these wastes has been estimated at 616,100 mt/yr. The nitrogen contained in livestock wastes is 108% of the total nitrogen used in the form of chemical fertilizer (570,000 mt/yr).

Table 3. Concentration of regulated malodor substances by odor intensity (ppm)

Malodor substance	Odor intensity		
	2.5	3	3.5
Ammonia	1	2	5
Methyl mercaptan	0.002	0.004	0.01
Hydrogen sulfide	0.02	0.06	0.2
Dimethyl sulfide	0.01	0.04	0.2
Dimethyl disulfide	0.009	0.03	0.1
Trimethylamine	0.005	0.02	0.07
Acetaldehyde	0.05	0.1	0.5
Styrene	0.4	0.8	2.0
Propionic acid	0.03	0.07	0.2
n-Butyric acid	0.001	0.002	0.006
n-Valeric acid	0.0009	0.002	0.004
i-Valeric acid	0.001	0.004	0.01
Toluene	10	30	60
Xylene	1	2	5
Ethyl acetate	3	7	20
Methyl isobutyl ketone	1	3	6
Isobutyl alcohol	0.9	4	20
Propionaldehyde	0.05	0.1	0.5
n-Butylaldehyde	0.009	0.03	0.08
Isobutylaldehyde	0.02	0.07	0.2
n-Varelaldehyde	0.009	0.02	0.05
Isovarelaldehyde	0.003	0.006	0.01

Table 4. Calculated animal waste production in Japan 1993

	Number of animals ($\times 10^3$)	Excreta ($\times 10^3$ t)			Nutrients ($\times 10^3$ t)		
		Feces	Urine	Sum	Feces	Urine	Sum
Dairy cattle	2,067	16,669	11,331	28,000	80.7	82.6	163.3
Beef cattle	2,956	16,130	11,296	27,426	68.3	80.7	149.0
Swine	10,783	7,931	14,600	22,531	51.4	74.6	126.0
Layer	188,704	8,456		8,456	103.8	-	103.8
Broiler	135,221	6,416		6,416	74.0		74.0
Sum		55,602	37,227	92,829	378.2	237.9	616.1

LOADING OF ANIMAL WASTES ONTO CROPLAND

The hypothetical average loading of nitrogen from animal wastes onto cropland is estimated at 116 kg/ha, assuming that animal wastes are uniformly applied to cropland all over Japan. The average recycling capacity of nitrogen on cropland is considered to be 200 kg/ha. Therefore, potentially all animal wastes could be applied onto cropland in Japan, without any environmental pollution. However, animals are not uniformly distributed throughout the country. Loading of nitrogen (Fig. 3) is particularly high in Kagoshima prefecture (400 kg N/ha) and Miyazaki prefecture (600 kg N/ha). These values may exceed the recycling capacity of nitrogen. To decrease nitrogen loading, it is important to redistribute animal wastes from regions where they are abundant to those where they are scarce. However, animal wastes are unsuitable for transportation or storage unless they are processed. Composting can solve the problem to some extent, and is an effective way of promoting the agricultural utilization of animal wastes.

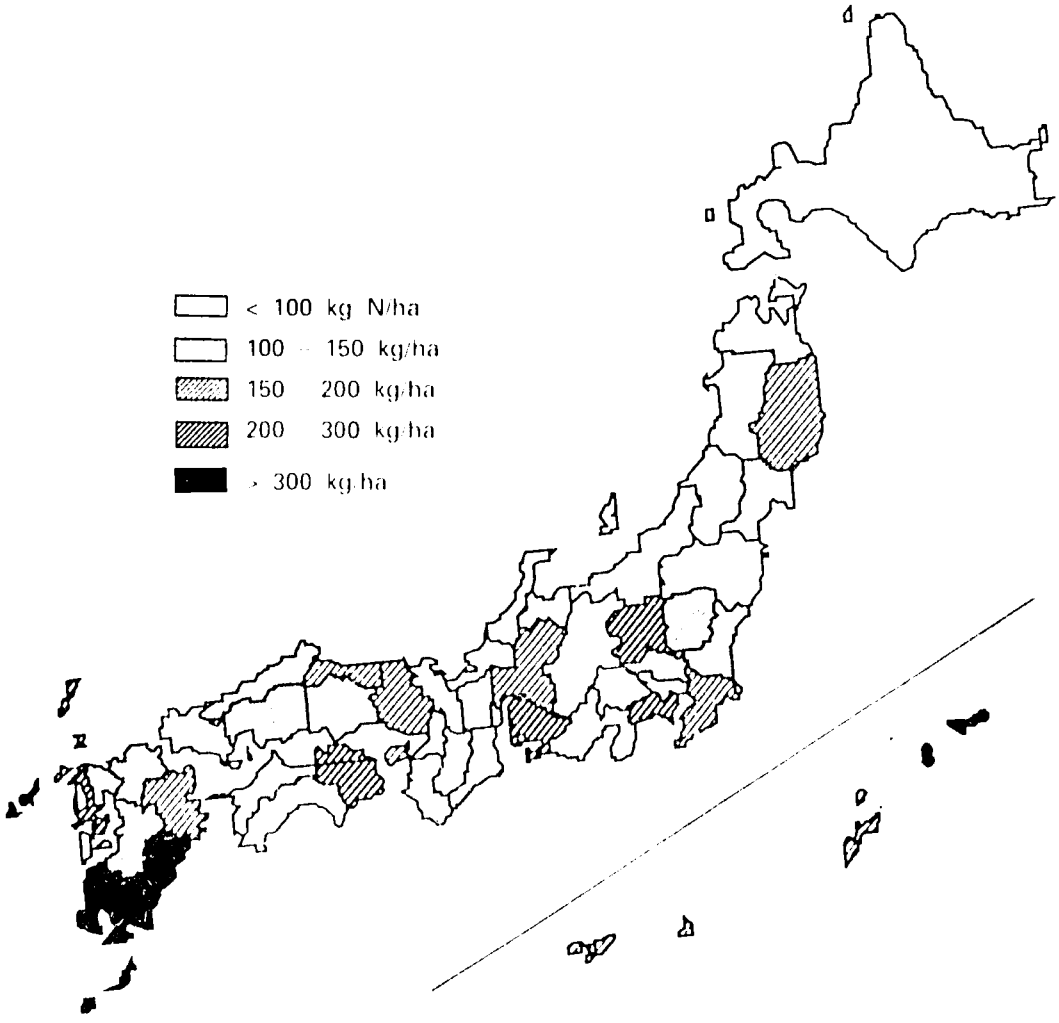


Fig. 3. Loadings of animal waste nitrogen onto cropland in each prefecture

Source: Harada and Tsuiki 1994

TREATMENT OF ANIMAL WASTES

Proportion of Animal Wastes Treated

In 1992, solid wastes were composted in 10% of dairy and beef cattle farms (Table 5). The remaining 85 – 90% of cattle farms treated the wastes by piling. Although this may be regarded as a kind of composting, adequate composting management is not necessarily practiced. To promote the utilization of animal wastes, proper composting should be carried out on a greater number of farms. There are very few livestock farms which adequately treat wastewater and slurry (Table 6).

Composting

Composting is a solid waste management strategy whereby the organic component of solid waste is biologically decomposed under controlled conditions to a state in which it can be handled, stored, and/or applied to cropland without adversely affecting the environment (Golueke 1977). Composting reduces offensive odors, reduces difficulties in handling due to stickiness, inactivates pathogens, parasites, and weed seeds and stabilizes the organic constituents, thus producing a uniform organic material suitable for soil application (Harada 1990).

Various types of composting are being carried out on Japanese farms, and in compost centers organized by several farms. They can be classified as the pile type, the box type, the open elongated type with a conveyor belt for turning, the open elongated type with a rotating turning device, the rotary kiln type, and the enclosed vertical type (Fig. 4). For the composting of cattle wastes, the pile and the open elongated types are most often used. For swine wastes, the box and open elongated types are most commonly used. For poultry wastes, the rotary kiln and enclosed vertical types are generally used.

Compost quality is very important in the recycling of animal wastes. Quality standards have not yet been set for animal waste composts in Japan, but such standards are

Table 5. Treatment of solid livestock waste in Japan, 1992

Unit: % of total farms

	Composting	Drying	Piling etc.	Incineration
Dairy cattle	9.9	3.5	85.3	–
Beef cattle	9.4	1.3	96.4	–
Swine	37.9	12.4	25.6	–
Layers	11.5	63.9	24.4	0.6
Broilers	5.1	15.0	67.0	13.0

Table 6. Treatment of animal wastes (liquid and slurry) in Japan, 1992

Unit: % of total farms

	Storage	Activated sludge process	Liquid composting	Untreated & others
Dairy cattle	64.0	1.3	1.7	33.1
Swine	55.1	12.9	6.9	25.2

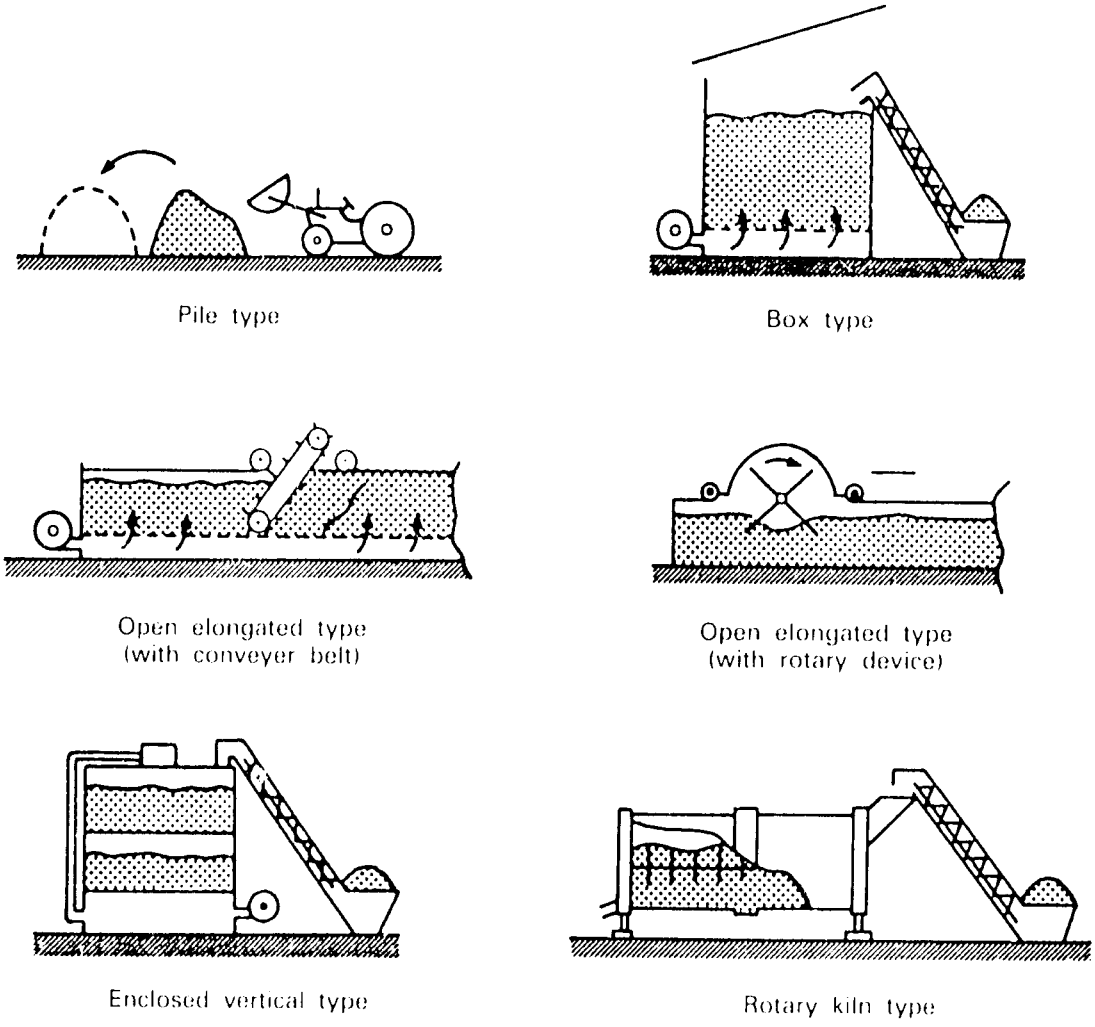


Fig. 4. Composting facilities for animal wastes

Source: Kuwana and Fukumori

needed in order to maintain and improve the quality of composted products. It is, however, difficult to establish standards because the levels of chemical constituents in these composts vary widely according to the type of animal, the kinds and ratios of bulking agents, and the type of composting used. However, if the nutrient content of compost is unknown, it is very difficult to plan fertilizer applications. Compost should be sufficiently mature, because the application of immature compost to soil may cause severe damage to plant growth. Therefore, a rapid method of estimating the nutrient content and the degree of maturity of compost is required. Although many methods, using various indices for estimating the degree of maturity, have been proposed, a more practical and reliable method is still needed (Harada 1991).

The rapid estimation of the quality of cattle waste compost using near infrared spectroscopy analysis (NIRS) was investigated (Harada *et al.* unpublished). The levels of total carbon, total nitrogen, ash, cellulose, hemicellulose and lignin of the cattle waste compost and its cation exchange capacity could be measured by this method (Fig. 5). Its biological activity, in terms of inhibition of seed germination, was assayed using *Brassica campestris* seeds, and an attempt was made to estimate this by NIRS. Although the accuracy of the estimation was not high, at least severely inhibitory activity could be detected by NIRS (Fig. 6).

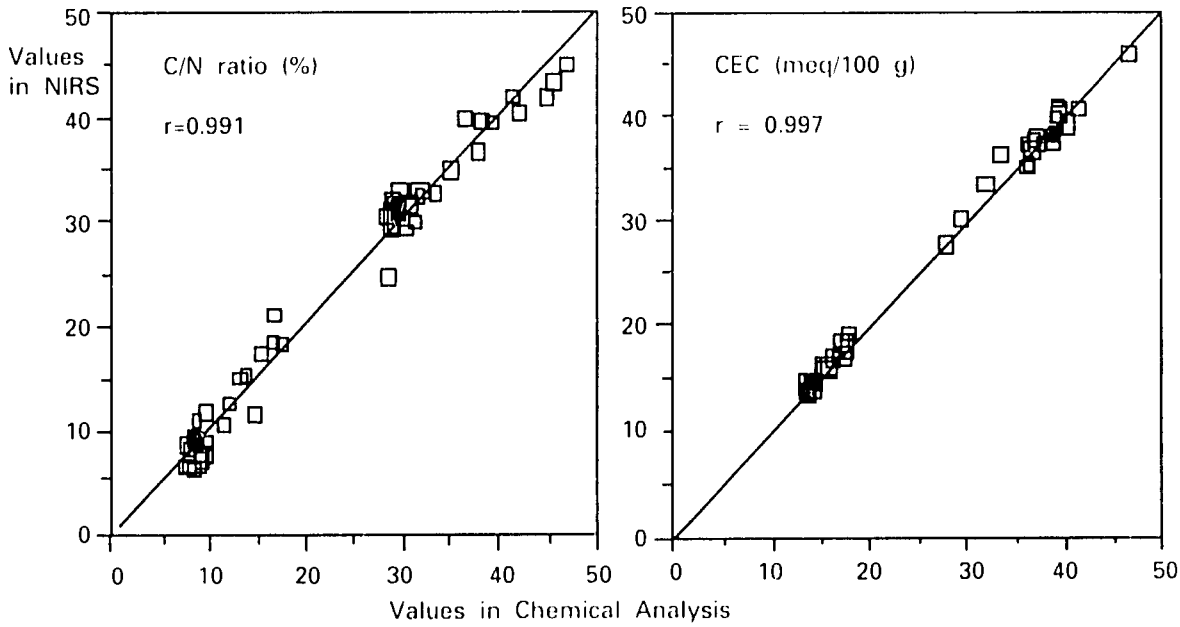


Fig. 5. NIRS estimation of C/N ratio and CEC of cattle waste compost

Source: Harada *et al*

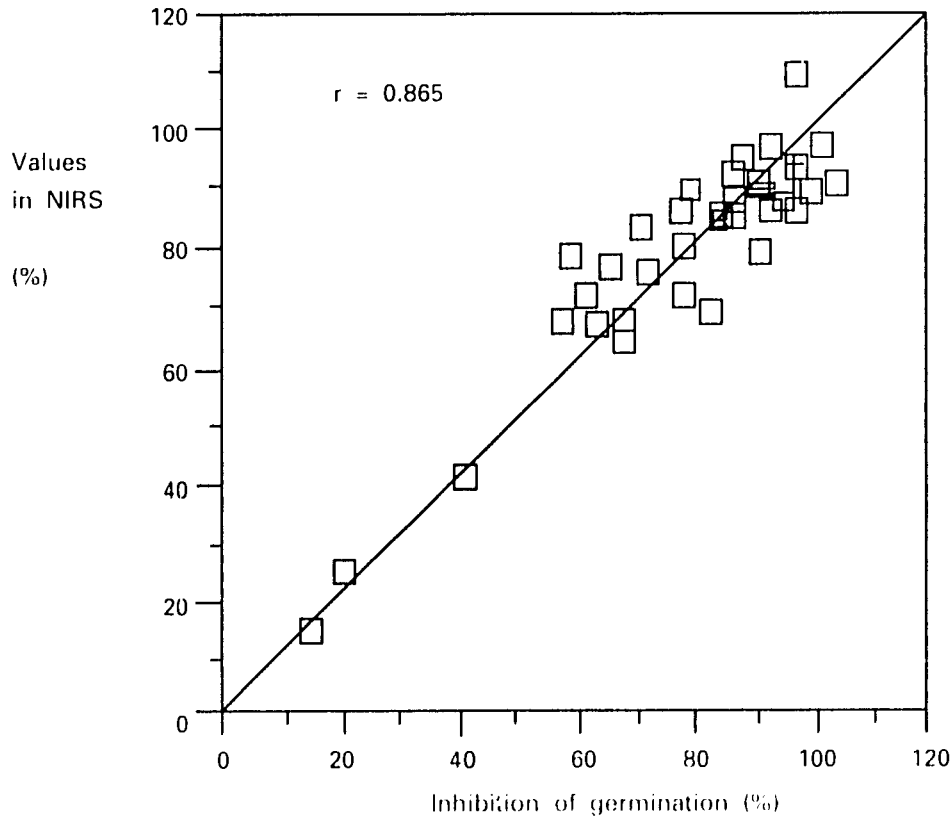
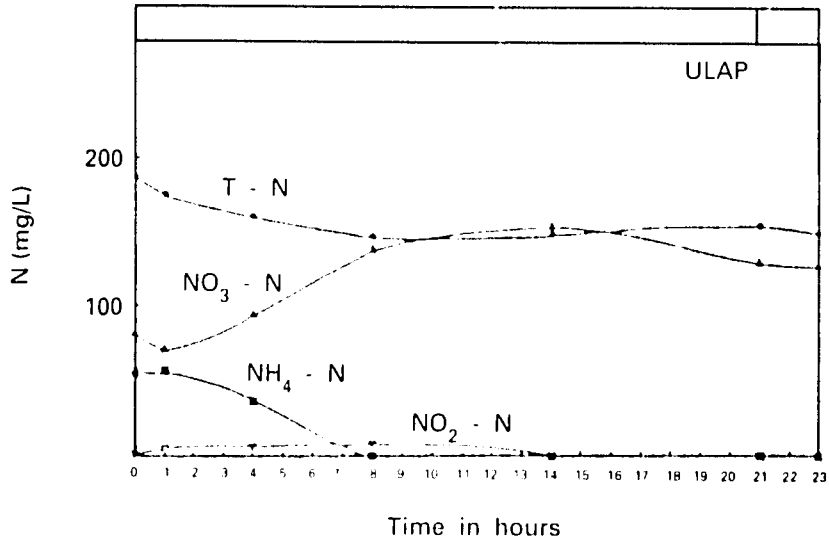


Fig. 6. NIRS estimation of the effect of cattle waste compost on the germination of *Brassica campestris*

Source: Harada *et al*



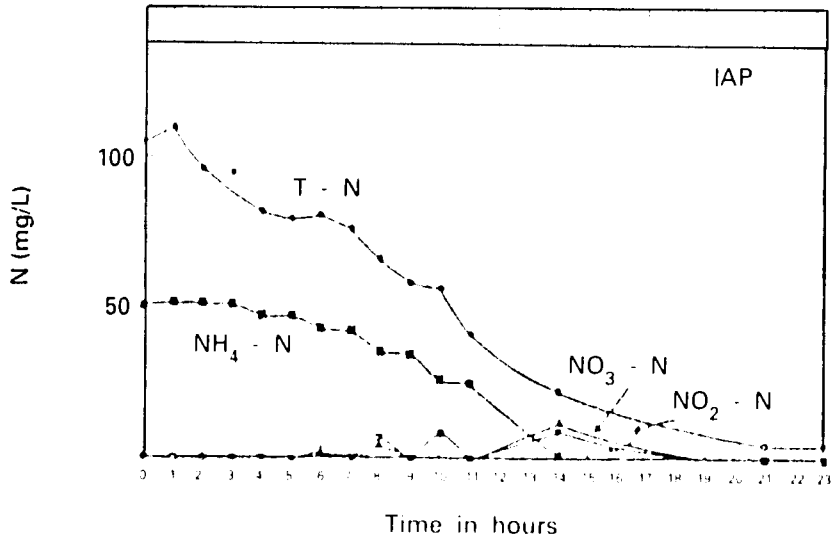


Fig. 7. Changes in nitrogen concentration during ULAP and IAP operations

ULAP : Unlimited aeration process
IAP : Intermittent aeration process

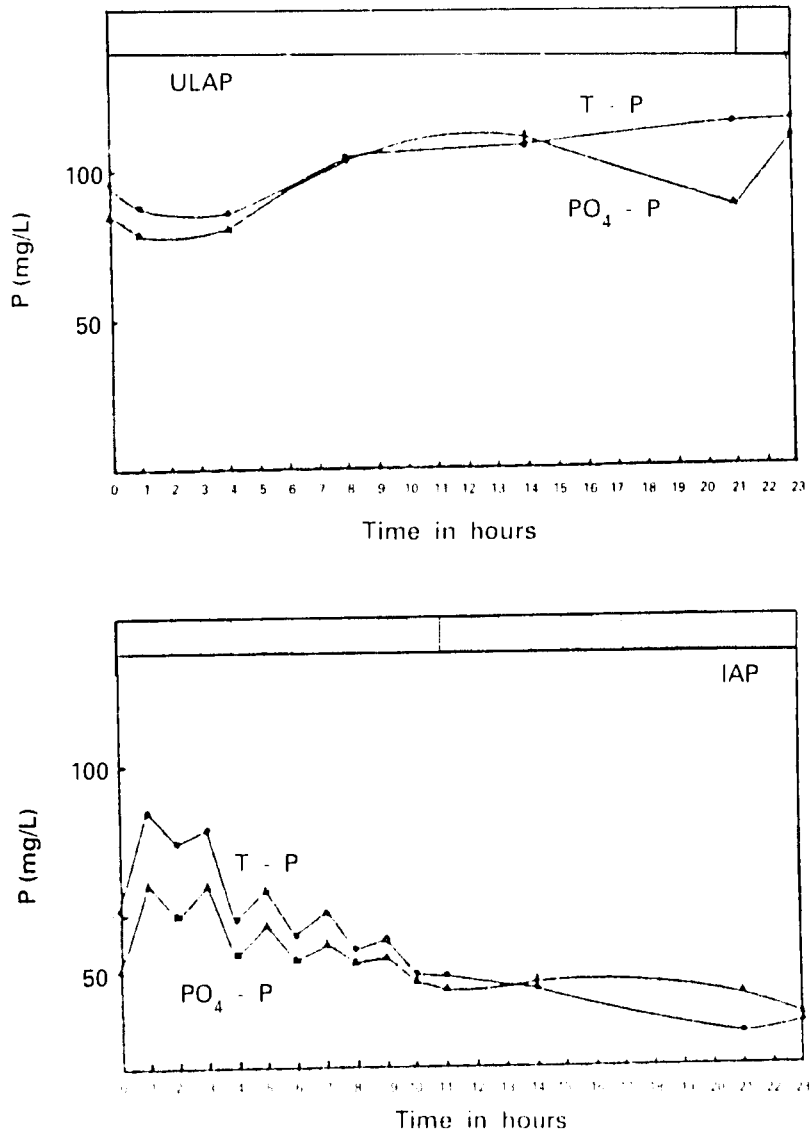


Fig. 8. Changes in phosphorus concentration during ULAP and IAP operations

ULAP : Unlimited aeration process
IAP : Intermittent aeration process

Wastewater Treatment

Although solid wastes can be utilized as compost, the utilization of animal wastewater is very difficult because of transportation and storage problems. Wastewater should be treated properly to prevent environmental pollution. A common treatment is the activated sludge process. Although the efficiency of wastewater treatment is high, treatment is costly and requires some expertise to operate successfully. Small-scale farms sometimes treat their wastes by drying them. Wastewater is evaporated by the heat generated from fermentation of compost and/or wind or solar power, or by the use of a fan. In all these treatments, however, there are problems of offensive odor and the emission of ammonia.

The removal of nitrogen and phosphorus from swine wastewater is very important, since these nutrients can contribute to the eutrophication of surface water and ground water. However, it is difficult to remove these two elements efficiently from swine wastewater by the conventional activated sludge process, because such wastewater is rich in these elements compared to the carbon

source. As described above, the criteria for nitrogen and phosphorus in discharged wastewater have become strict under the Water Pollution Prevention Act. More efficient treatments to remove nitrogen and phosphorus are required to enable farmers to meet these criteria.

Removal of nitrogen and phosphorus from swine wastewater was investigated in a fill-and-draw type activated sludge unit with an intermittent aeration process (IAP) (Osada *et al.* 1991, and Harada *et al.* 1991b). In the intermittent aeration process, nitrogen was removed efficiently through nitrification and denitrification under alternately aerobic and anaerobic conditions (Fig. 7). The efficiency of phosphorus removal using IAP was higher than when an unlimited aeration process (UAP, conventional process) was used (Fig. 8). Phosphorus was removed by the excess uptake in activated sludge.

Several other methods of removing nitrogen and phosphorus from animal wastewater have been tested, including the soil column system (Harada *et al.* 1990, 1991a), the IBX bioreactor system (Takahashi *et al.* 1989), and the membrane treatment system. Although the soil column system has the ability to remove nitrogen, phosphorus and other pollutant from concentrated wastewater, the practical usefulness of this system has yet to be verified on a large scale. The IBX bioreactor for removing phosphorus is available, and its usefulness has been verified on a practical scale. The membrane treatment system, using ultra-filtration membranes or reverse osmosis membranes, has posed problems of both cost and management.

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DISCUSSION

Dr. Harada was asked for more information about the IBX bioreactor referred to in his paper. He explained the mechanism of removing the phosphorus by the IBX bioreactor. The IBX is a kind of light-weight concrete, mainly composed of calcium silicate. The phosphorus in wastewater reacts with the calcium in IBX, and calcium apatite crystallizes on the surface of the IBX. The phosphorus is removed from wastewater by the growth of the crystals. In addition, the IBX can act as a carrier of microorganisms, and can also remove BOD and COD. He was asked whether the IBX could be regenerated. The calcium apatite crystal cannot be recovered alone. IBX saturated with calcium apatite is crushed and applied to cropland as a soil amendment.