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SWINE WASTE TREATMENT IN TAIWAN

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FOREWORD

In the past, livestock were mainly raised in small numbers on Asian farms, and their manure was regarded as a valuable resource for the crop production which was the mainstay of the farm economy. Today, there are many specialized livestock farms raising large numbers of animals on a limited land area. The pollution of waterways with wastewater discharged from these farms is becoming an increasing problem.

In Taiwan, a densely populated island with large numbers of pig farms, there has been active research into ways of treating livestock wastes at a cost which small-scale farmers can afford. This Bulletin describes the development of some treatment systems for pig wastes. A three-step treatment has been adopted by more than a thousand farmers since 1987. It includes the separation of liquid and solid wastes, anaerobic treatment, and aerobic treatment. The treated wastewater meets national regulatory standards, while the treated solid wastes can be used as compost. Biogas is another useful by-product of the process. A low-cost manure bed system has been developed for small pig farms, or for areas where water resources have special protection. One third of the pen is dug out into a shallow pit which is filled with rice husk or wood chips to absorb excreta. This is cleaned out when the batch of pigs is sold and is usually made into compost.

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

1975年臺灣畜產研究所首先利用紅泥塑膠（RHP）製成水平式無氧醱酵槽進行豬廢棄物處理。經過幾年的改良，自1987年已推廣給農民。此一系統主要三個處理的步驟，包括固－液體分離，無氧處理及有氧處理。此一系統特別適用於臺灣狀況。根據官方統計自1993年，超過飼養200頭豬的養豬户9,108家中，有6,827家已裝有此種處理設備。蓬帳式無氧分解槽約有2,000户農家採用，而三步驟廢物處理系統已超過1,000户農家採用，經過三步驟處理，廢水BOD及SS都低於100 mg/liter，已符合國家管制的標準。

省畜產研究所也發展一種廄肥床豬舍，此豬舍特別適合用於位在水源保護區的小型養豬户（少於200頭），豬床1/3挖深30cm，鋪以稻殼或木屑來吸收豬排泄物，另外2/3豬床留爲飼養及其他活動，這種廄肥床不會產生廢水。當豬出售時，需要清理，豬廄肥和稻殼或木屑可以聚成堆肥，經過一個月堆積，可用做肥料栽培作物

(Japanese Abstract) 摘　要

1975年に台湾畜産研究所(TLRI)は豚のふん尿処理用の水平型無気的発酵装置を開発した。その後改良を重ね、1987年には固形物と液体の分離、無気的処理、有気的処理の3段階処理システムを開発して養豚農家に普及した。1993年の官庁統計に依れば、200頭以上の養豚農家9108戸のうち6827戸が水平型を採用している。テント型の無気処理型は2000戸以上、3段階型は1000戸以上で使われている。3段階型では処理水のBODとSSの値は、ともに100mg/ℓで国の基準値をみたしている。

TLRIではトイレ付き豚舎を開発した。これは水質保全地区の養豚業者や200頭以下の保有農家に向いている。豚舎の3分の1の床を30cmの深さに掘り、籾がらもしくはチップを詰め豚のふん尿を吸着させ、残りの床は豚の摂食や運動用である。トイレの掃除は豚を売却したときにすればよい。豚のふん尿が混入した籾がらやチップは、約1か月堆肥化した後には作物の肥料として使用できる。

(Korean Abstract) 초　록

1975년 대만축산시험장은 (TLRI) 은 첫번째로 재생의 황토색 플라스틱탱크에 (RMP) 돼지분뇨를 넣어 비호기성 발효를 시키는 소위 수평형 분뇨처리법을 개발하였었다. 그후 수년간의 개량을 거쳐 3단계 처리법 (고체 유체 분리단계, 비호기성발효단계, 호기성발효단계) 이 개발되었는 데 이 처리법이 1987년 이후 지금까지 농가에 보급되어 대만농가에게 가장 적절한 형으로 평가되고 있다. 1993년도 공식통계에 의하면 200두 이상의 양돈농가 9,108 농가중 6,827 농가가 분뇨처리시설을 갖고 있는 것으로 집계되었는 바 이중 2000농가이상이 텐트타입의 처리시설을, 1000농가이상이 간축한 3단계 타입을 쓰는 것으로 나타났다. 특히 이 3단계타입처리 이후의 BOD 와 SS치는 국가기준보다 낮은 1리터당 100mg이하의 수치를 보였다. TLRI 는 또한 수질보호구역안의 양돈농가나 200두 이하의 농가, 즉 경제적으로 분뇨처리가 어려운 농가를 위하여 돈사바닥에 왕겨나 톱밥을 까는 형의 분뇨처리방법을 개발보급하였다. 이 방법은 돈사바닥 약 1/3을 30cm 두께로 파내고 여기에 왕겨나 톱밥을 깔아넣는 것으로 나머지 바닥은 사료공급등 다른 용도로 사용된다. 이런 돈사바닥에서는 액체분뇨가 생기지 않았고 청소도 돼지를 팔 때만 하면 되는 등 편리하였다. 또한 이 처리분뇨는 바로 퇴비로 이용할 수 있으며 일개월 후 유기비료로 사용할 수 있게 되었다.

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ABSTRACT

In 1975, the Taiwan Livestock Research Institute (TLRI) developed the first horizontal-type anaerobic fermenter using a bag of red mud plastic (RMP) in which hog wastes were treated. After many years of improvement, a three-step treatment system, which includes solid-liquid separation, anaerobic treatment, and aerobic treatment, was developed. This system has been extended to hog farmers since 1987, and is considered most suitable for Taiwan's conditions. According to the official data from 1993, out of the 9,108 hog farms that raised more than 200 pigs, 6,827 have installed waste treatment facilities. Tent-type anaerobic digesters have been adopted on more than 2,000 farms, and a three-step wastewater treatment system has been adopted on more than 1,000 farms. After the three-step treatment, the BOD and SS of treated water are both below 100 mg per liter, which meets national regulatory standards.

TLRI has also developed a manure-bed pig house which is especially suitable for pig farms located in water resource protection areas or for farmers raising less than 200 pigs, for whom elaborate waste treatment facilities are not economical. One third of the pigbed is dug out into a 80 cm deep pit filled with rice husks or wood chips to absorb the pig excreta. The other two-thirds is left for feeding and other activities. The manure-bed pigpens do not generate wastewater. Cleaning is required only when the pigs are sold. The mixture of hog manure and rice husk or woodchips is made into compost. After one month of composting, the mature compost can be used as fertilizer for crops.

INTRODUCTION

Swine production has become very important in the agriculture of Taiwan (Fig. 1), with a total of 9.75 million head being raised at the end of 1993 on 33,247 pig farms. Fig. 2 shows changes in the number of pigs and pig farms over the past 20 years. If the amount of wastewater for each pig is estimated as 20 liters per day, the total wastewater produced by pigs is 19 tons per day, making this the third most important pollution source in Taiwan, after sewage and industrial wastewater.

Since 1987, the quality of waste water draining from livestock farms has been required to meet government standards (Table 1). A great variety of wastewater treatment methods have been tried. Of these, the three-step waste treatment system developed by the Taiwan Livestock Research Institute (TLRI), which includes solid-liquid separation, anaerobic treatment, and aerobic treatment, is accepted as one of the best systems for Taiwan, and has been extended to hog farms since 1987. By the end of 1993, 6,827 out of the total of 9,108 hog farms that raised more than 200 pigs had invested in waste treatment facilities. Tent-type anaerobic digesters were being used on more than 2,000 farms, while three-step waste treatment systems were in use on more than 1,000 farms. After the three-step treatment, the Biochemical Oxygen Demand (BOD) and Suspended Solids (SS) of treated water were both less than 100 mg per liter.

Key words: Aerobic treatment, anaerobic treatment, BOS, manure-bed pig house, SS, swine wastes, three-stage digester, wastewater treatment

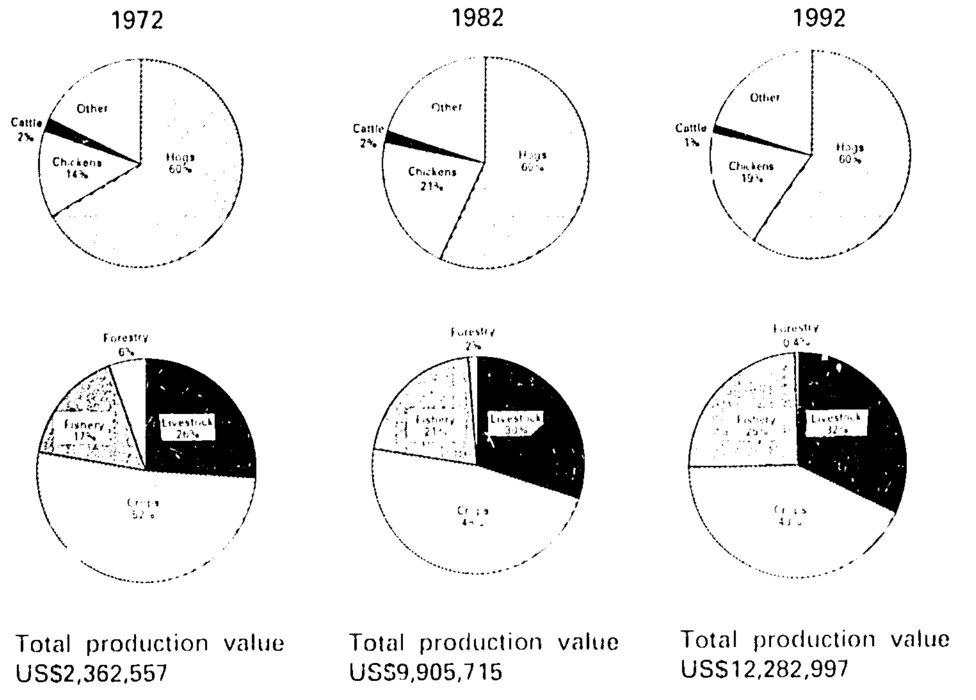

Fig. 1. Agriculture and livestock production in Taiwan

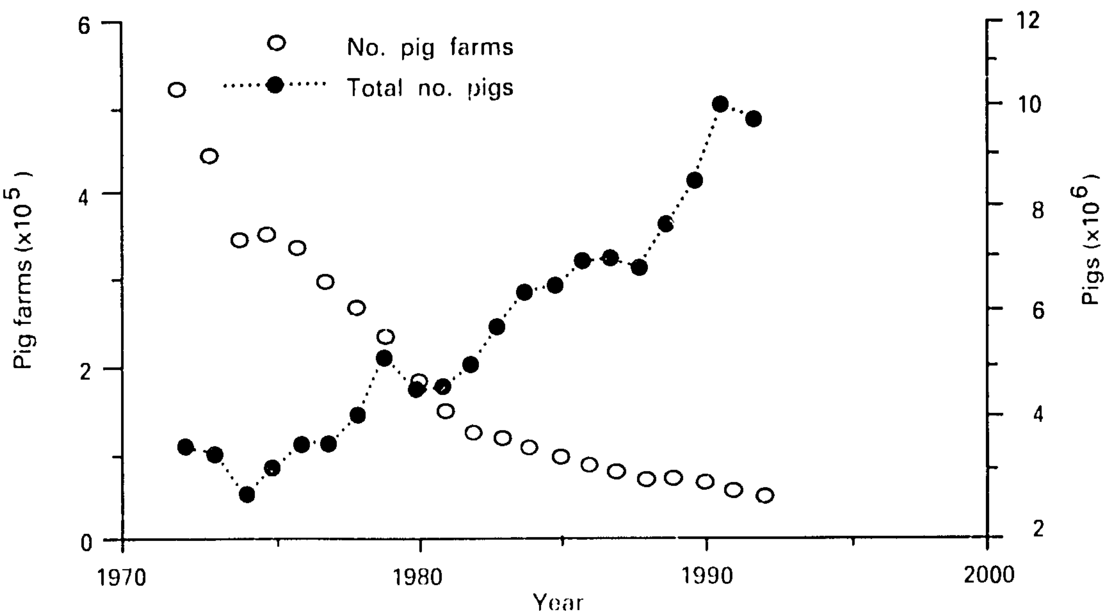

Fig. 2. No. of pigs and pig farms in Taiwan, 1970-1990

Table 1. National regulations for drainage from livestock farms

Classification	Standards for drainage entering waterways								
	1987			1992			1998		
	BOD	COD	SS	BOD	COD	SS	BOD	COD	SS
	mg/L			mg/L			mg/L		
Livestock 1[a]	200	-	300	100	400	200	80	250	150
Livestock 2[a]	400	-	400	100	650	200	80	450	150

The different standards of 1987 were related to the scale of livestock farm. Livestock 1 applied to farms with more than 1000 pigs. Livestock 2 applied to farms with 200 - 999 pigs, or more than 50 cattle or dairy cows, or more than 10,000 broilers, or more than 5,000 layers.

The different standards of 1992 and 1998 were related to the species of livestock raised. Livestock 1 were farms with non-herbivorous animals. Livestock 2 were farms with herbivorous animals.

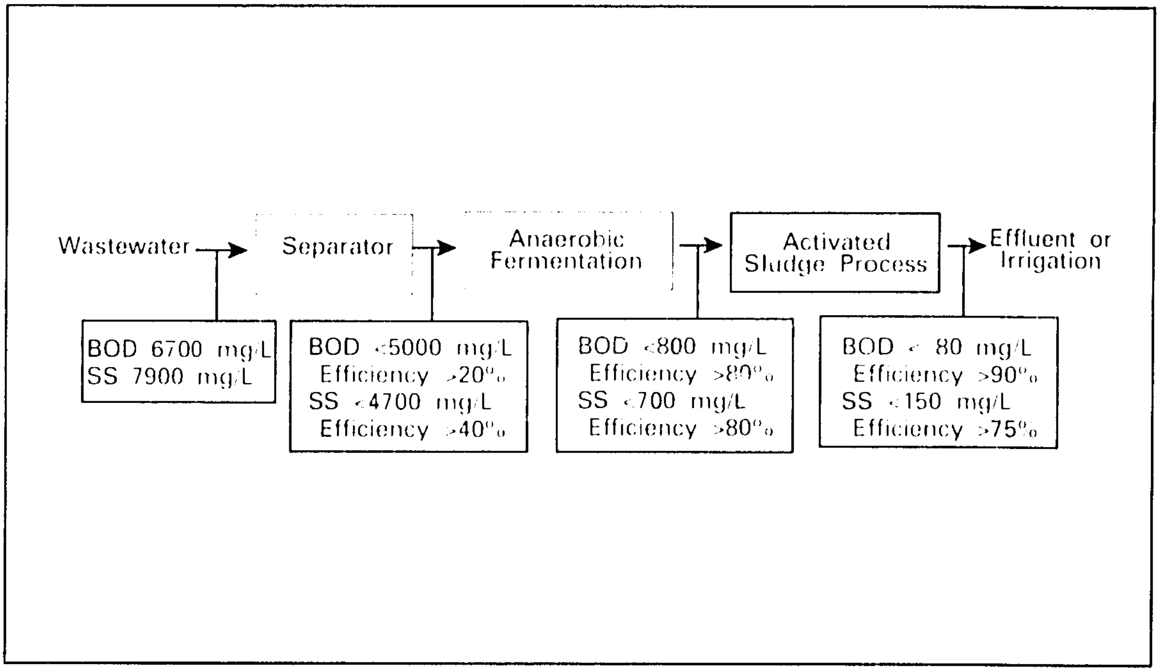

Fig. 3. Expected performance of three-step swine waste treatment

THREE-STEP SWINE WASTE TREATMENT

Three-step swine waste treatment consists of solid-liquid separation, anaerobic treatment, and aerobic treatment. In some cases, composting, biogas utilization and sludge treatment are also included. The expected performance of this three-step treatment is shown in Fig. 3.

Solid-liquid Separation

Separation of the solid fraction from the wastewater is used to reduce the content of solids for subsequent handling and treatment, and to recover the solids for using as fertilizer etc. This physical process is accomplished by using various kinds of screens and scrabblers. The efficiency of this treatment is a 15-30% decrease in BOD, and a 50% decrease in SS. The moisture content of the separated solids is 70-80%. An extruder is often added, to reduce the water content of the solids to below 70% so that the material is suitable for composting.

Anaerobic Treatment

Since hog wastes are biodegradable, biological treatment is generally an economical way of handling them. The horizontal tent-type anaerobic fermenter is a modification of the Red Mud Plastic (RMP) bag fermenter which was also developed by the Taiwan Livestock Research Institute. Among its merits are the fact that it is easy to construct, has a low investment cost, is easy to maintain, and can be separated into several divisions as desired. These fermenters can be sealed from either inside or outside. The four sides of RMP sheet which make up the top of the fermenter are tubular in shape, so that PVC pipes may be inserted inside them to give extra strength. The strengthened sheet is then fixed to the wall of the fermenter with hooks.

The hydraulic retention time (HRT) is calculated according to the amount of water used to wash the pig houses, following the following formula:

$$\text{HRT} = \frac{\text{Volume of fermenter}}{\text{Volume daily (manure + washing water)}}$$

A 1:3 ratio of manure to washing water is suggested, which can easily be achieved with a flushing tank system. According to work by Hong (1985) the daily excreta of a 100 kg pig comes to around 5 liters, so that the total wastewater from one pig may be estimated as 20 liters. A HRT of 12-15 days is common for hog wastewater treatment.

A tent-type fermenter should consist of no fewer than two digesters. The volume of the first digester is usually 1.2 times the daily wastewater. Both acidogenesis and sedimentation take place in this first digester. Most of the methanogensis reaction occurs in the rear digesters. Biogas may be collected for use as fuel. The excreta of each pig can generate 0.1-0.3 m³ of biogas per day. Biogas may be used in cooking stoves, water heaters, water pumps, electric power generators, gas lamps, for warming piglets, in vehicles, mowers, in incinerators for dead animals, etc.

Aerobic Treatment

There are many types of aerobic treatment that may be utilized for livestock wastewater. Considering the environmental conditions of Taiwan and its subtropical climate, activated sludge processing and oxidation ditches are recommended. In aerobic treatment, organic matter is decomposed solely through aerobic oxidation.

Activated sludge processes are versatile and flexible. Effluent of any desired quality can be produced by varying the processing parameters. These processes require less land but more skilled management than simpler processes such as oxidation ditches. Activated sludge is a complex biological mass that results when organic wastes are aerobically treated. The sludge will contain a variety of heterotrophic microorganisms, including bacteria, protozoa, and higher forms of life. The relative abundance of any particular microbial species will depend on the type of waste that is being treated and the way in which the process is operated. For optimum treatment, raw waste must be balanced nutritionally. In three-step treatment, most of the easily biodegradable matter has already been decomposed in the anaerobic digester, so that operating an activated sludge treatment requires intensive care for good performance. It is best to control the BOD of anaerobic effluent at around 1000 mg/l. The growth conditions for microorganisms in activated sludge tanks are usually measured according to mixed liquor suspended solids (MLSS) and sludge volume index (SVI). The HRT for an aerobic tank is normally 1.0-1.5 days.

While activated sludge tanks have a water depth of 2.5 m, this should not exceed

1.5 m in oxidation ditches. Oxidation ditches therefore require a larger land area, but have the advantages of being easy to operate and of generating less sludge.

A final clarifier to settle the activated sludge before the discharge of treated water is required in aerobic treatment. The settled sludge may be removed by mechanical methods for return to the aerobic unit, or be dehydrated for disposal. Usually the HRT in the clarifier should not exceed 6 hours.

The Three-Step Swine Waste Treatment System at TLRI

The three-step waste treatment plant at TLRI was built in 1988, and was designed to treat wastes from 3000 hogs weighing 100 kg each. In 1991, the system was modified so that it could be operated automatically, thus improving efficiency and saving labor. It is now able to handle wastes from 1,600 pigs, 5,500 chickens, 500 ducks, 3,500 rabbits and 180 cows raised in the Institute.

The system includes (1) liquid-solid separation (2) anaerobic fermentation, (3) activated sludge process, (4) composting and (5) biogas utilization unit. After the first three treatments, the quality of discharged water is able to meet statutory requirements.

Fig. 4 shows a flow diagram for the system, and automation control points. Most pig houses at TLRI have concrete floors which are washed manually in the morning, between 8 am and 10 am. This period has the highest wastewater flow. For wastewater of pigs only, it is about 250 liters per minute. Wastewater flows into the treatment system by gravity alone.

The solid fraction in the wastewater is separated out by a screen and an extruder to reduce its water content to 60-70%, a level suitable for composting. This screening unit can treat more than 250 L per min in order to meet requirements for the time of greatest water flow. The treatment efficiency for this step is a 70-85% reduction in BOD.

The total volume of a tent-type anaerobic fermenter is 100 m³, divided into eight digesters. The rear part of the first digester is uncovered, so that the removal of scum and settled sludge can be easily accomplished. Biogas generated from the anaerobic fermenter is collected to generate electricity which provides power for the treatment system.

The aerobic treatment plant at TLRI includes four units: an adjustment tank, a flow rate controller, an activated sludge unit, and a sedimentation tank. The liquid in the activated sludge tank has a mixed liquor suspended solid (MLSS) content of 2,000-2,500 mg/L, while the dissolved oxygen (DO) value is maintained at 0.5-1.0 mg/L.

The system has performed well over the past five years. Water quality over the last eight months is shown in Table 2.

Automation

The system has been modified so that it can be automatically operated, in order to save labor and improve operational performance. A supervisory computer and a programmable logic controller (PLC) has been installed in a central control room. The supervisory computer, together with a color monitor and the programmable logic controller, are used to monitor and control the whole system (Figs. 5 and 6).

The major functions of the supervisory computer are: (1) To display dynamically the on/off status of all equipment in the system. (2) Monitoring and controlling variables such as mixed liquor suspended solids (MLSS) and dissolved oxygen, and activating an alarm system when critical conditions are detected. The programmable logic controller is responsible for receiving and transmitting signals between on-site equipment and the supervisory computer.

The MLSS and DO levels in the activated sludge tank are monitored on-line and selected as the control variables in feedback control. The set points are specified as in the range 2,300-2,500 mg/L for MLSS and > 1.0 mg O_2/L for DO. These points may be changed by entering the desired values on the keyboard if operational requirements change. When the values of the control variables monitored are outside the specified range, the signals for adjustment are generated by the supervisory computer and transmitted to the relevant control elements, e.g. sludge pumps are turned on in order to recycle the sludge.

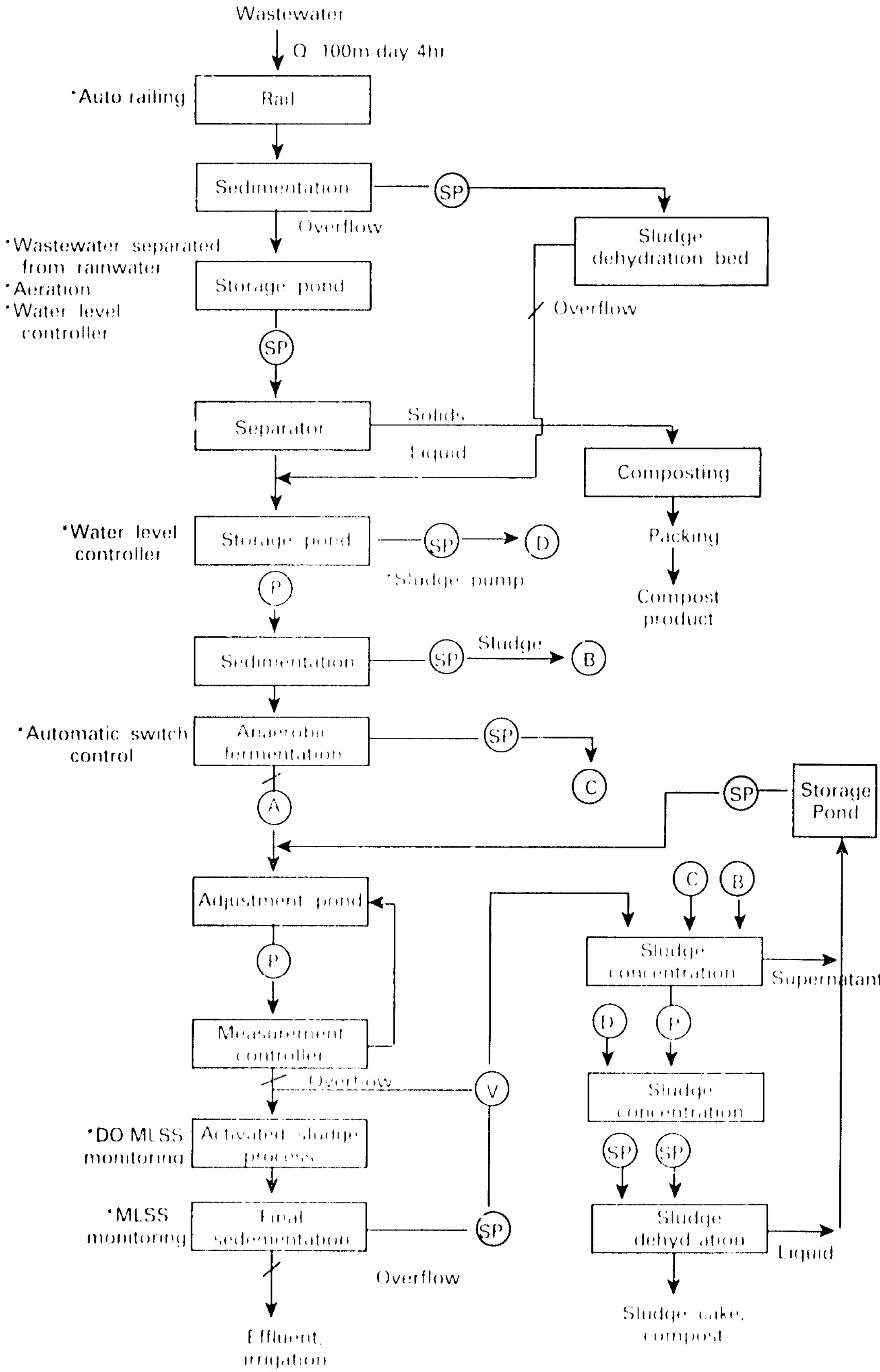

Fig. 4. Flow diagram of automatic controls and operations of swine waste treatment system developed at TLRI

Table 2. Efficiency of three-step waste treatment plant at TLRI

Treatment	pH	BOD	COD	SS
			mg/L	
Separation	7.18 ± 0.27	1527 ± 594	3971 ± 2296	2592 ± 1606
Anaerobic treatment	6.80 ± 0.23	89 ± 51	398 ± 175	56 ± 54
Aerobic treatment	7.49 ± 0.37	45 ± 31	182 ± 110	22 ± 20

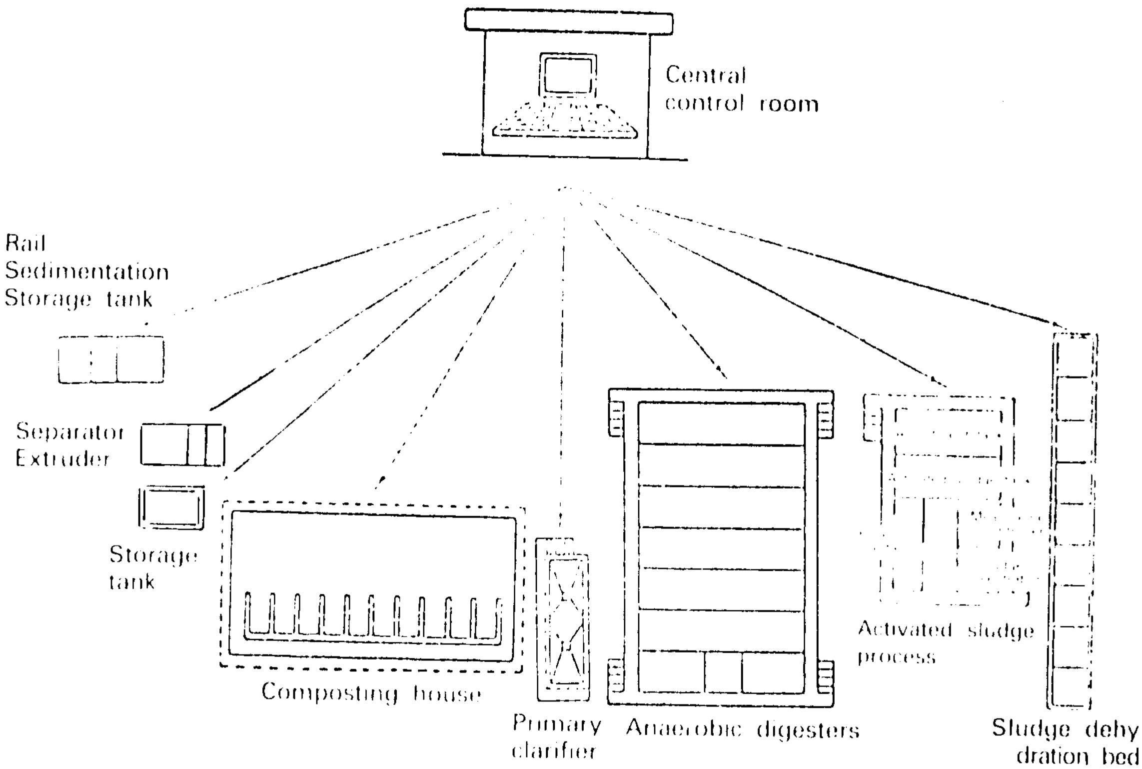

Fig. 5. Automated units for three-step waste treatment at TLRI

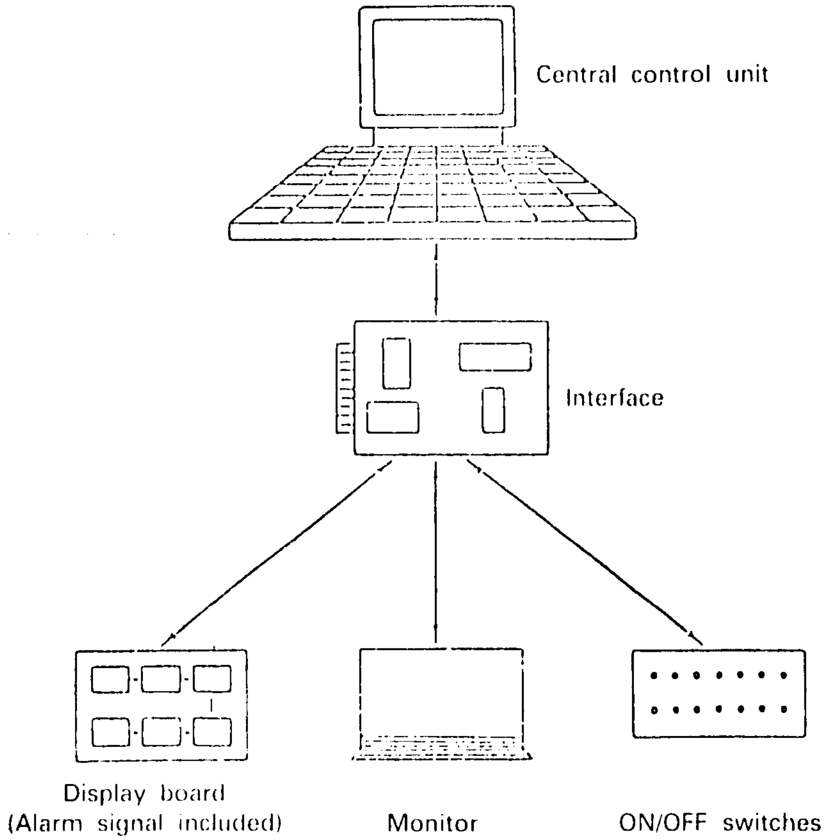

Fig. 6. Automated control of the system

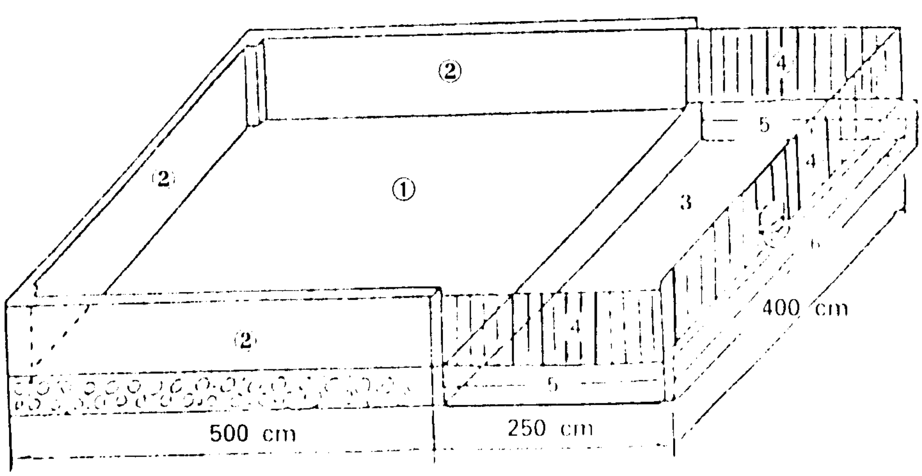

Fig. 7. Design of manure-bed pig house

1. Concrete floor. 2. Solid wall. 3. Manure bed (with a layer of rice husk on the floor). 4. Railing. 5. Movable wood backing. 6. Drinking device.

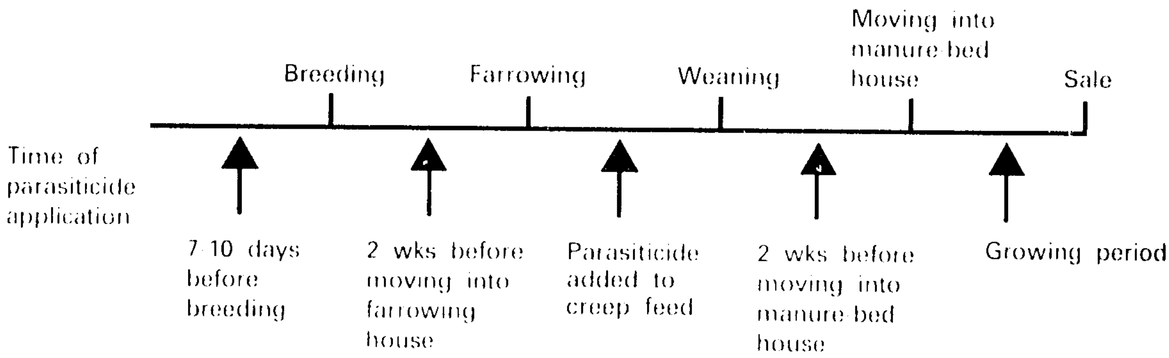

Fig. 8. Suggested timetable of parasiticide application for pigs raised in manure-bed houses

MANURE-BED PIG HOUSES

Manure-bed pig houses are especially suitable for areas where water resources are protected or for farmers raising less than 200 pigs, for whom waste treatment facilities are not economical.

One-third of the pen area is dug out to make a pit 30 cm deep. This is filled with rice husk or wood chips to absorb the pig excreta. The other two-thirds of the pen is left for feeding and activity (Fig. 7). Manure-bed pig houses do not use or generate washwater, and are cleaned out only after each batch of pigs is sold. This cleaning can be easily done mechanically, and the mixture of hog wastes and rice husk or wood chips is sent to a composting house. After one month of composting, the mature compost can be used as fertilizer for crops.

Sanitation is particularly important for manure-bed pig houses, since no washing or disinfection is carried out. A suggested timetable for parasiticide application is shown in Fig. 8.

CONCLUSION

The three-step hog waste treatment system is considered most suitable for Taiwan, and has been adopted on more than 1,000 farms. Manure-bed pig houses are in use on a number of small-scale farms. The demand for environmental protection is an international trend. It is the responsibility of those in the livestock industry to manage animal wastes in such a way as to prevent environmental pollution. However, the solution to the problem of livestock wastes does not depend on technical development alone. Legislation and government action, and the willingness of farmers to invest in, and operate well, waste treatment facilities, are also important.

DISCUSSION

Dr. Sheen was asked the approximate cost of the digester described in his paper which could handle wastes from 1600 pigs or 180 cows. He explained that the average cost in Taiwan is NT$1000-1500 (US$40-60) per cubic meter of digester. Wastes from one pig require about 0.3 m of digester, while those from a cow require four or five times as much. However, the exact construction costs depend on the local situation, including labor costs and the underground water level. Dr. Na referred to a similar project for swine waste treatment in Korea and pointed out that some years ago, waste treatment plants had been used to produce biogas. However, it had been found that the Korean climate is too cold for biogas production, especially in winter when biogas is most needed. Dr. Sheen felt that the lower temperature limit for anaerobic fermentation is around 14°C, which means that it is best suited to tropical or subtropical climates. He suggested that in a cooler country like Korea, anaerobic fermentation plants needed insulation or should be of the vertical digester type widely used in Northern Europe. However, this would make the digester ten times more expensive. Dr. Na asked how the solid and liquid wastes are separated, and Dr. Sheen explained that this is done by physical methods such as nets and screens. Farmers should not use too much water when they wash down the floors of pens, to minimize the water content of the wastes.

Dr. Kim asked whether sawdust could be used in the manure bed pighouse, and whether this type of housing had any effect on pig performance. Dr. Sheen replied that sawdust which pigs have been using for some time has a water content of 60-70%, which would be high enough for fermentation to occur. This would release ammonium and other gases, which would not be good for growing pigs. Wood chips have a lower water content, and there is no difference in the growing rate between pigs kept in a manure bed pighouse or on a conventional bed. Dr. Sheen explained that in winter, the pigs may like to sleep in the wood chips or rice hull, while in summer they can keep cool on the concrete floor. Dr. Harada asked about the recycling in Taiwan of nitrogen, an important nutrient but also a potential pollutant. Dr. Sheen replied that formerly in Taiwan, pollution parameters focussed on the levels of COD, SS and BOD, which meant that only the carbon was removed and there was little attempt to remove the nitrogen. There is now an attempt to remove the nitrogen from wastewater, and three pilot plants are in operation for this. One possible solution is to reduce the hydraulic retention time, so that some nitrogen and carbon remain for the next treatment. Mr. Ahmad asked whether swine wastes have a high phosphorus content, and whether this causes any pollution problems. Dr. Sheen replied that there is considerable discussion in Taiwan about standards for wastewater, including phosphorus content. It seems that operations to remove nitrogen are different from those to treat phosphorus. Treatments which give good removal of nitrogen give only poor removal of phosphorus. Dr. Sheen emphasized that work is still continuing in Taiwan, where this problem is not yet solved.

Dr. Sheen was also asked about the possibility of prolonging the anaerobic treatment of swine manure and using the solids as cattle feed. He emphasized the need for good pretreatment of cattle wastes, because these contain a lot of straw. This should be removed or it will fill up the digester. He did not recommend using the digested solids to feed live animals, because after drying they have a high mineral concentration. He felt that it is better to use them for compost.

He was also asked the most efficient waste treatment method for small livestock farms raising only 10-12 pigs. He suggested that the manure bed pig house can be used for very small livestock farms, and the solid wastes collected manually. Another method is to build an integrated treatment center. A storage tank is installed in the pig house, and the wastes periodically collected by truck and taken to a central treatment plant. In this way, several small livestock farms can share a single processing facility. Mr. Adonay described a traditional system of waste disposal used in the Philippines, in which a deep pit is dug near the pig house so that the wastes flow down into the pit. However the smell is often offensive, especially during the hot season, and Dr. Sheen was asked for suggestions on how to solve this problem. Dr. Sheen pointed out that animal wastes contain organic matter, and under suitable conditions microorganisms will begin to degrade the organic materials, generating gases such as ammonia and hydrogen sulfide. He suggested that the smell can be reduced by keeping down the water content so that there are fewer microorganisms. He also suggested that wastes should be collected while they are still fresh, and not left lying for a long time.

Dr. Pravee asked whether bacterial cultures are added to the wastes in the digester, and Dr. Sheen replied that they are not, since he and his colleagues feel that these do little to assist the fermentation process. Wastes in the digester contain large numbers of microorganisms which are already adapted to the type of materials and plant. However, if a new digester is being used for the first time, sludge from the operating digester can be added to get the reaction started. Even if this is not done, fermentation will still be working well after one week. Dr. Sheen was also asked about commercial microbial products which are claimed to reduce smell and improve fermentation efficiency. Dr. Sheen felt that in his experience, these were not very effective, although extravagant claims are often made for these products. Dr. Harada commented that he had found that the microorganisms in microbial products sold in Japan were not very effective, and that he and his colleagues had begun a project to select effective microorganisms. Director Koh of the Food and Fertilizer Technology Center mentionned that some claims had been made that the addition of 5% zeolite to swine rations could reduce the foul smell of swine manure. Dr. Pravee said that one product on sale in Thailand, EM (standing for Effective Microorganisms) is now being tested by Kasetsart University, in response to pressure from farmers who claim it is effective. More than 24 different species of microoganism had been isolated in this product. The results are still being evaluated, but the product does seem to be effective in reducing the offensive smell of livestock wastes.