Disposal of Animal Waste-The Magnitude of the Problem in Asia and Australasia[1*] - Review -

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ABSTRACT : Even though the development of livestock industry in Asia and Australasia has brought the economic growth and thus elevated the living standard in these areas, it has also brought the pollution caused by the increasing amount of animal wastes. Among them, Japan probably is the first country that suffered from the animal waste pollution as early as in 1970s. Nowadays, the animal waste pollution has been a common problem for almost every countries in this region. To solve it, different measures and regulations have been implemented in many countries. In this paper, different methods for animal waste disposal are discussed, including: manure-bed animal housing, composting, anaerobic treatment, odor control, utilization of biogas, aerobic treatment, three-step process, N and P removal, land application, cultivation of algae, anaerobic treatment of dead animals. It is hoped that an animal industry without pollution can be achieved in the future. (*Asian-Aus. J. Anim. Sci. 1999. Vol. 12, No. 4 : 597-603*)

Key Words : Animal Waste, Disposal, Manure-Bed, Composting, Anaerobic Treatment, Odor, Biogas, Aerobic Treatment, Three-Step Process, N and P Removal, Land Application, Algae Cultivation, Anaerobic Treatment of Dead Animals

INTRODUCTION

Basically, livestock holdings are in the hands of small-hold farmers in the most parts of Asia. The trend still holds true in many rural communities. For a large section of the rural population in this region, livestock represents not only a source of food and protein, but also a source to boost rural incomes. With this, both the developing and the undeveloped countries see animal industry as a potential industry to contribute to economic growth and alleviate poverty. The establishment of livestock enterprises is then considered as an attractive option. It is evident that there is a rapid increase in the growth of animal industry in Asia and Australasia (FAO, 1998).

As the technology and knowledge of animal production improved, many animals are raised within small areas and buildings to produce the greatest weight gain in the shortest period of time. Such operation inevitably resulted in the occurrence of pollution problems. The pollution problems are especially worsened in those countries where the animal industry is highly developed and the land is limited such as Japan, Korea, and Taiwan.

POLLUTION PROBLEMS CAUSED BY ANIMAL WASTE

In Japan, the animal industry has expanded rapidly in the last few decades. Accompanying with the prosperous growth of animal industry, the complaints of animal waste pollution increased rapidly and reached a maximum in 1973 (Harada, 1994). Due to the severe legal constraints, the total number of pollution complaints gradually decreased since then. However, the average number of problems occurred per farms has rather increased especially in the pig industry. Table 1 documents the complaints caused by animal wastes in 1996 (Kinosita, 1997). The frequency of pollution occurrence was 6% for pig farms. The pollution caused by animal farms is still a serious problem.

In Taiwan, the pollution caused by livestock waste became serious in the late 1980s. It is estimated that a total amount of 7,844,980 tons of manure is produced in 1996 (table 2). The government started to regulate the quality of discharged water of livestock farms since 1987. After that, the successively tightened legislation has been implemented by EPA in 1993 and 1998. The pig farmers is facing an increasing pressure for proper waste disposal.

The size of livestock population has continually increased in Korea since 1970 (Han, 1996). The percentage of large farms are 85% for pigs and 96% for chickens. The yearly production of animal manure has reached 43 million mt in 1995. The breakdown include: 58.5% for cattle, 32.6% for pigs, and 8.8% for chickens. Most of these wastes are produced by small-sized cattle farms, and large-sized pigs and chicken farms. According to the study by The Rural Development Cooperatives (RDC, 1994), it was found that 6% of water pollutant was come from animal wastes.

In India, the problems are mainly caused by the slaughterhouses (Biswas, 1996). There are about 3,600 slaughterhouses and only a small fraction of those facilities are treating their wastes. It is estimated that nearly 2 million mt of by-products in raw form, 600 million gallons of liquid effluents and 2 tons of solid

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Table 1. The pollution caused by animal wastes in Japan[a,b]

Animal	Thousand Farms	Water pollution	Malodor	Destructive Insects	Other Pollution	Total
Swine	16.0	448	646	38	19	944 (36.7%)
Chicken	19.6	72	282	148	20	488 (18.9%)
Dairy cattle	41.6	351	523	36	43	817 (31.7%)
Beef cattle	154.9	107	149	30	12	265 (10.3%)
Othes		9	40	2	13	62 (2.4%)
Total	232.1	987	1,640	254	107	2,576 (100%)
Percentage	100%	38.3%	63.6%	9.9%	4.2%	

[a] Kinosita, 1997.
[b] from July 2, 1995, to July 1, 1996.

wastes are produced annually. Though it has contributed to environmental pollution, the government has not yet implemented regulations.

The annual animal wastes produced in Malaysia and Philippines was estimated to be about 10 and 25 million mt, respectively. In Thailand, the figure is also high 79 million tons per year.

Table 2. Production of livestock manure in Taiwan

Livestock	Number[a]	Daily manure	Yearly manure	Total manure
		kg/day/ animal	ton/year/ animal	ton/year
Dairy cattle	125,471	30	10.9	1,137,634
Beef cattle	37,643	15	5.5	207,036
Pigs	10,698,366	1.1[b]	0.43	4,279,346
Layers	31,463,000	0.12[c]	0.044	1,384,372
Brioilers	74,065,000	8.19[d]	0.008	606,592
Total	116,389,480			7,844,980

[a] DAF, 1997; [b] Hong, 1985; [c] Lin, 1994.
[d] Average manure production for the broilers is estimated as 8.19 kg per bird.

In Australia, owing to the vast farmland, the waste is under controlled. Even though, the rapid expansion of some feedlots still arouse the concerns from the general community (Lott, 1995). The future viability and expansion of the industry may be limited. Thereafter, the feedlot operators are very conscious of creating a right imageboth for their industry and products.

ANIMAL WASTE COLLECTION

Collection of animal wastes is the first step in waste disposal. The properties of collected wastes is determinant in the choice of disposal options. Most of the beef cattle and chicken waste is in solid or semi-solid form, therefore, it can be removed easily by a scraper or a conveyer. If the manure has to be cleaned by water, such as pigs or dairy cattle raised on concrete floor, then a separator is required for solid waste collection. This physical process is accomplished by using various kinds of screens, scrapers, *etc.*. The efficiency of this treatment is a 15-30% decrease in BOD, and a 50% decrease in SS. An extruder is often added, to reduce the water content of the solids to below 70% so that the material suitable for composting.

With a declined-slope or a V-type pit under the slotted pig-bed, the separation can be performed inside the pig houses. The former may be cleaned by labor, while the latter has to be equipped with a scraper and the investment cost is then comparatively higher. About 76% of pig farms in Japan has adapted a V-type pit in the pig house (Honda, 1997). The manure-bed house is is also a good choice for easy manure collection (Hong et al., 1989; Hong et al., 1990) .

The animal farms that can collect most of their solid wastes tend to choose composting as waste disposal option for its simplicity and cheapness. While for farms with a big quantity of wastewater, wastewater treatment is an inevitable choice. General speaking, wastewater treatment is costly.

DISPOSAL OF ANIMAL WASTES

There are a large number of ways for animal waste disposal. The choice is highly dependent on the housing design and ways of cleaning, in some region, the religious taboo is also an important factor. Since animal manure is rich in nutrients, *e.g.* nitrogen (N), phosphorous (P) and potassium (K), therefore, the most economical and environment-friendly way is composting and recycles the stabilized compost back to the cropland. Thus, dilution with a big amount of washing water would largely decrease the practicableness of the method. Also, the Moslems would not accept compost made of pig waste applied to their cropland.

According to the differences in livestock house structures, the treatment of livestock waste may be classified into several ways, as shown in figure 1. In fact, treatment technologies is also included in the figure. Among these, the most common applications used in Asia and Australasia include organic compost making and application (both in solid and liquid forms) and biogas production through anaerobic fermentation. The diversity of disposal adapted by Japanese farmers was shown in figure 2.

Manure-bed animal housing

The manure bed pig house was constructed to eliminate the daily wash and save labor (Hong et al., 1989; 1990). Each pig requires about 1 m^2 of concrete floor and 0.5 m^2 of manure-bed in the pig house. One-third of the pigbeds area is constructed into a

30-cm deep pit and paved with rice husk or woodchip to absorb the pig excreta; the other two-thirds of pigbeds area is left for feeding and activity (figure 3).

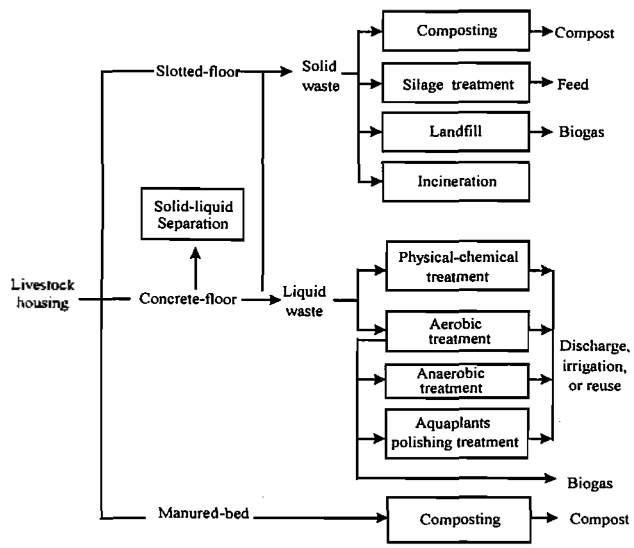

Figure 1. Disposals applied for animal wastes

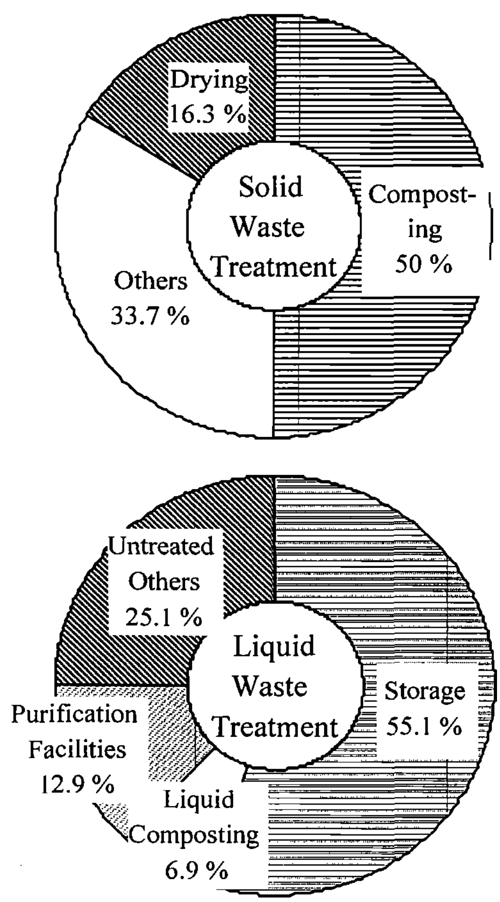

Figure 2. Disposal of animal wastes in Japan (Honta, K., 1997)

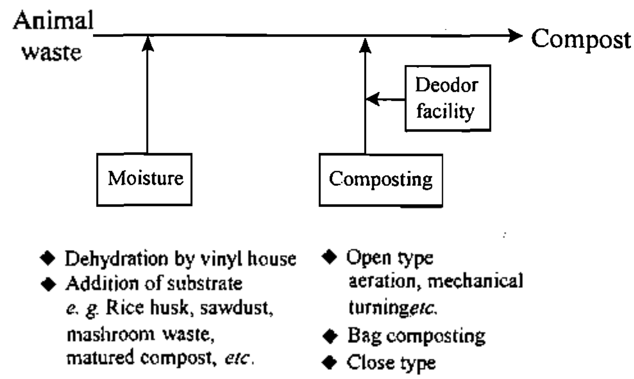

Figure 3. Composting of animal wastes

Neither wastewater nor annoying odor is generated in this housing. Moreover, in winter the manure-bed can keep pigs warm and enhance their growth; in summer the manure-bed does not suffer from a high temperature problem. The manure-bed can also save about 4.8% (equivalent to 11.5 kg) of feed per pig, and recover a ripened compost of about 80 kg per pig, with a water content of about 30%. Furthermore, the manure-bed does not need any commercial products of probiotics, and the pig house can be completely disinfected and easily constructed or reconstructed.

It is not only suitable in both hot and cold areas, but also suitable for both big and small-hold farmers for the latter waste treatment systems are usually not economically accessible. About 100 pig farms have adopted this type of pig house in Taiwan. In addition, in order to reach a goal of eliminating daily wash in pig houses, Taiwan Livestock Research Institute (TLRI) has also completed the construction a demonstration farm of manure-bed houses at a size of 25 sows.

In general, the cattle manure of 12 to 14 kg per head with a water content of 45% is produced daily in the manure-bed cattle house. After cleaning, the waste can reach a ripened stage after a period of 60-day composting. The construction cost of these house is low, and the management and operation are fairly easy. Beef cattle grow well and tend to gain weight rapidly. Also, a good quality of compost is produced.

Composting

Through the biological oxidation of composting, the animal manure is transformed to a stable, homogeneous product-compost. The flow chart of animal waste composting is showed in figure 3. Water is essential to microbial activity and should be present in appropriate amounts throughout the composting. The moisture contents of livestock manure is varied with animal species, house design, season, bedding-materials, *etc.*. In Taiwan, the moisture contents is 80-85% for dairy cattle manure, 70-80% for pig manure, 30% for broiler waste which is a mixture of broiler manure and rice husk. During composting, the water content is adjusted to 60-70% so that the fermentation can proceed. Methods for moisture adjustment include, (1) dehydration by mechanical force, (2) dehydration in vinyl house, and (3) mixing with low water-content material such as rice husk, wood chip, mushroom waste, matured compost, etc..

Table 3 summarizes the composting systems for livestock manure. The bag compost is commonly applied by the pig farmers in Taiwan. After 40-days of fermentation, the compost generated in bag will reach a ripened stage with a water content of below 35% (Lin et al., 1985). The container systems can yield good quality compost in shorter time, but the investment and operative cost is high. Farmers in different regions may select a proper system according to their own conditions and demands.

High temperatures were used to be considered as a necessary condition for good composting. On the contrary, experimental evidence in composting systems shows that mesophilic microorganisms encompass greater rate and range of metabolic capabilities (Finstein and Hogan, 1993). Most microorganisms involved in composting do not survive at temperatures above 60℃. This is particularly true for fungi which are strongly inhibited at high temperatures and which are useful in degrading cellulose and lignin in the composting substrate (de Bertoldi et al., 1984). The only benefit of elevated temperatures is rapidly inactivating pathogenic microbes and weed seeds. For this reason the processes allows the temperature to rise for a few days, and then air blowing, and/or mechanical turning are performed to continue the process. After two months of composting, most of the animal waste is transformed to stabilized and humified materialcompost (figure 4; Sheen and Wang, 1995).

Table 3. Summary of composting systems for livestock manure

Static windows	— No aeration
	— Aeration
Turned piles	
Open type	— No aeration
	— Aeration
Closed type	— Aeration

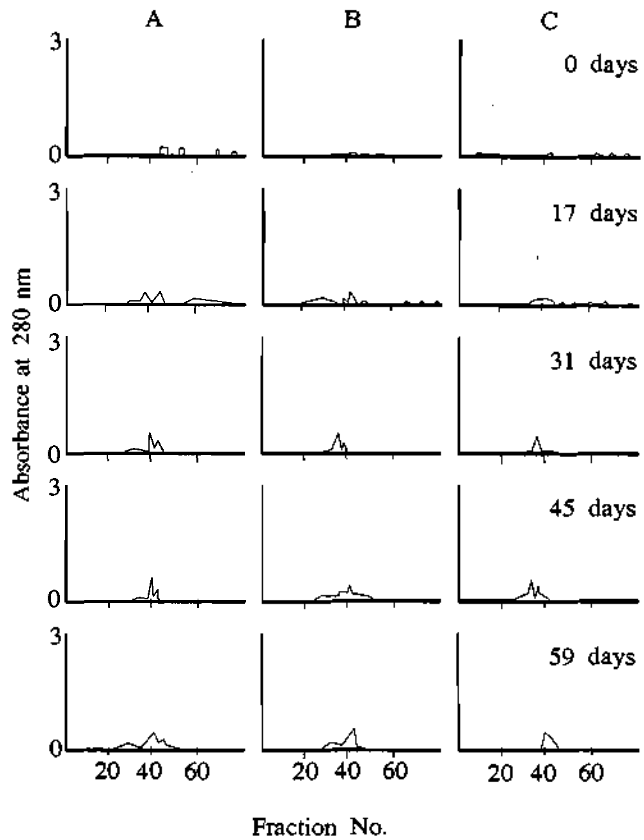

Figure 4. Changes of substrate cmposition during pig waste composting (A: inoculation with 10% sludge, B: inoculation with 5% sludge, C: no inoculation)

Anaerobic treatment

The anaerobic treatment is considered excellent for livestock waste treatment in hot weather areas. The anaerobic lagoon is popular in some southeast Asian countries. The efficiency of this treatment is not very good and biogas generated can not be collected and used, therefore, the lagoon system is not strongly suggested. It is only suitable for the animal farms with vast land.

TLRI has invented both bag and tent-type anaerobic fermenters for pig waste treatment (Hong, 1984a; 1984b). Their merits includes, easy to construct, has a low investment cost, easy to maintain, and can be separated into several parts as desired.

These fermenters can be sealed from either inside or outside. A tent-type fermenter should consist of no fewer than two digesters. A 1:3 ratio of manure to washing water is suggested by Hong (1985). Since the daily excreta of a 100 kg pig is estimated around 5 liters, so that the total wastewater from one pig may be estimated as 20 liters. A hydraulic retention time (HRT) of 10-15 days is common for the treatment. Thus, a digester volume of 0.3 m^3 is required per finished pig at a HRT of 15 days, and the excreta of each pig can generate 0.1-0.3 m^3 of biogas per day. The removal of BOD and SS is 80-90%, in some pig farms, the removal is higher than 90%. This treatment is suitable for the animal farms located in warm and hot areas. The operation of the anaerobic digester is simple. There are thousands of anaerobic digesters in regular operation in Taiwan. Various anaerobic digesters are also found in China, Philippines, Vietnam, etc..

Utilization of biogas

After anaerobic digestion of waste, not only the water pollution problem can be mitigated but the biogas produced can also served as energy source. In Taiwan, the waste excreted from a pig with a liveweight of 90 kg could generate 0.1-0.3 m^3 of biogas daily (Chung et al., 1975), which contains 60 to 70% of methane.

According to the studies done by TLRI (Koh and Tsai, 1976), it was found that one kwh electricity generated in a 2 kw and 30 kw of electrical generator consumed about 1.147 m^3 and 0.9 m^3 of biogas, respectively. For each kwh electricity generated in a 50 kw electrical generator with diesel engine 0.8 m^3 of biogas was consumed (Koh et al., 1988). Till now, 686 sets of electrical generators have been installed on pig farms in Taiwan. Meanwhile TLRI itself has been continuously using biogas to generate electricity since 1974.

Biogas can also used for other applications, including piglet warming, thermal lamp, furnace with an automatic ignition, water heater, air conditioning, mower, water pump, thermal plate, motor vehicle, and compression of biogas into a cylinder together with the use of *Spirulina platensis* to purify biogas (Koh et al., 1980; Chow et al., 1981).

Biogas utilization is one of the sustainable uses of animal waste except composting. It is particularly important for the people lived in the rural area in Asia where energy source is shorted.

Aerobic treatment

There are many types of aerobic treatment that may be used for livestock wastewater treatment, activated sludge process and oxidation ditch are the most common ones. In aerobic treatment, organic matter is decomposed solely through aerobic oxidation. Thus, electric power is required for the aeration and the operation cost is elevated.

These processes require less land but more skilled management than simpler processes such as anaerobic digestion. Activated sludge is a complex biological mass that results when organic wastes are aerobically treated. The sludge contains a variety of heterotrophic micro-organisms, including bacteria, protozoa, and higher forms of life. For optimum treatment, raw waste must be balanced nutritionally. For pig waste treatment, it is best to control the BOD of influent 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 generating less sludge. A final clarifier to settle the activated sludge before the discharge of treated water is required in aerobic treatment.

The theoretical removal of BOD and SS is estimated around 80-90%. But, the efficiency of treatment will be affected by factors such as temperature, influent concentration, oxygen supply and operation management. The management of these system is not easy for the ordinary farmers and the operation cost is high. Thus, the system is not economical for small and medium-size farms. It is not yet well accept in this region, except for Japan and Taiwan.

Three-step process

With the use of the successful horizontal type anaerobic fermentateer previously developed (Hong, 1984a; 1984b), TLRI proposed the three-step process for treatment of pig wastewater by adding a solid-liquid separator and the activated-sludge system before and after the anaerobic fermentateer, respectively. Later, this innovative system has been widely used in practice for treating pig waste in Taiwan. In general, the treated wastewater is clean enough for discharge or irrigation. Under the proper operation, the BOD and SS of effluent are both below 100 mg/L. The system is performed well in warmer areas, such as in Taiwan and in southeast Asia. TLRI are now worked on recycling the treated effluent for piggery washing and other uses.

N and P removal

In order to keep the rivers or lakes away from eutrophication, the amounts of nitrogen and phosphorus discharged from animal farm has to be restricted which are rich in animal wastes. TLRI cooperated with the van Aspert Consulting Inc. in the Netherlands to develop an treatment scheme (figure 5; Sheen et al., 1996). One pilot-scale treatment plant is installed in TLRI, and two in pig farms lacated at Meinung, Kaoshiung for treating the pig waste with flow rates of 1, 30, and 40 $m^3 \cdot d^{-1}$ (*i.e.*, equivalent to a running size of 1000 and 1300 head for the latter two plants), respectively. As the average influent concentrations of total nitrogen and phosphorus were 746 and 188 mg/L, the efficiency of removal were 62-89% and 66-79%, respectively. The treatment efficiency of ammonia nitrogen was as high as 98%.

Harada et al. (1994) has investigated the efficiency of nitrogen and phosphorus from swine wastewater in a fill-and-draw type activated sludge unit with intermittent aeration process. Both N and P are removed efficiently from the system. Other methods, such as soil column system, TBX bioreactor system, and membrane treatment system, have also been reported.

Land application

Animal manure is applied to agricultural land to obtain the nutrient and soil-conditioning value of the material. The quantity that is applied should not cause environmental problems or nuisances. The concentration of nutrient and salt are factors that determine the land area required and the application rate of the manure. As a concern over the possibility of groundwater pollution from over application of animal wastes, the regulations implemented by the government are based on the control of N and P. Some countries allow the application or injection of raw wastes directly to the soil, while others such as in Taiwan only the treated effluent is allowed for land application. Land application is a simple technique as long as there is enough land. In Australasia, land application is the method used by most of the feedlots for waste disposal.

Odor control

The problems of smell nuisance are mainly associated with intensive animal production and disposal of animal wastes. It is the pollution problem that gives the most offense to, and causes most complaint by the publics. It is also a global problem for all the animal farmers. Various solutions have been proposed for animal production and wastes disposal, including: chemical scrubbers, activated carbon filters, combustion, soil filters, iron oxide filters, and porbiotics, *etc.*. Michimune (1997) summarized methods of odor control in animal industry (figure 5). Usually, the units of smell emission source have to be enclosed with domes or enclosures for odor treatment. For land spreading, it is concluded that low pressure and low trajectory applications with immediate incorporation or soil injection are the more cost-effective way for odor controll (Berglund and Hall, 1987).

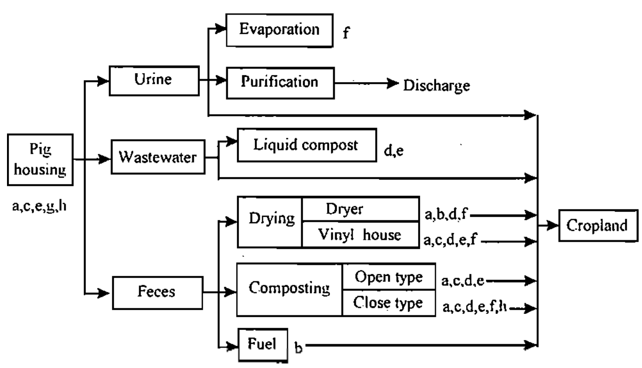

Figure 5. Methods of odor control of animal wastes (Michimune, N., 1997). (a: water scrubbing, b: incineration, c: adsorption, d: chemical treatment, e: biological treatment, f: air dilution, g: masking, h: ozone treatment

Cultivation of algae

The treated effluent of animal wastewater can be utilized to cultivate *Spirulina*, one kind of blue green algae. Nitrogen, phosphorus, potassium and organic acids in the treated effluent are contribute to the growth of *Spirulina*, meanwhile, *Spirulina* is helpful to polishing the animal waste treatment. An ammonium concentration of 20 mg/L is favorable for the growth of *Spirulina plentensis* (Cheng et al.,1982). Also, the highest growth rate, 55 $mg.L^{-1}.day^{-1}$, and production rate of *Spirulina plentensis* is obtained in culturing pond with depths of 10 cm and 40 cm, respectively. The production of *Spirulina* on dry basis was averaged 9.7 $g.m.day^{-1}$ in summer and 7.3 $g.m^2.day^{-1}$in winter. The crude protein content is 45% in *Spirulina plentensis* cultivated by pig wastewater. It is proved to be a good feed for both pig and fish. Therefore, this disposal may be adapted by farms of livestock-fishery integrated farming.

Anaerobic treatment of dead animals

The traditional methods of landfill and incineration are frequently used to treat dead animals. However, the major drawbacks in landfill include large land and long degradation requirement, while incineration suffers from problems of secondary air pollution and high capital and operation costs. Treating dead animals with anaerobic digester, the production of biogas increased with increasing degradation, and a decrease of 1 kg of meat produced 100 L of biogas. However, chemical composition of biogas remained unchanged (i.e., 65% CH4 and 35% CO_2 Based on the above results, dead animal sizes, effective volume and water quality of anaerobic fermentator, and ambient temperature affect the degradation rate. However, the water quality and the gross biogas production and its chemical composition are not affected. The anaerobic fermentator designed by TLRI has been patented in Taiwan, Republic of China and China.

CONCLUSION

In Asia and Australasia, the animal industry has been developed rapidly in the last few decades. Most of the countries in Asia is limited with land, therefore, the vast amount of animal wastes has made adverse impact on the environment. As the concern grows, the animal producers nowadays should establish a right sense of taking up the responsibility for proper waste disposal.

The attitude of government is also plays an important role in the work of disposal of animal waste. The success of some disposal of animal waste are attributed to a firm and clear policies enforced by the government and effective and practical measure implement by their respective government agencies. Some government support for waste treatment investment, some countries provides indirect incentives, while the rest have remote possibilities for government support.

Diverse strategies of animal waste disposal is developed, some are simple, some are highly efficient, some are costly, some require special condition, *etc.*, the farmers can adopt the one that most suitable for the condition of their farms and the local legislation. The innovative techniques for better treatment efficiency and easy operation at low cost needs to be accomplished. It is our goal to establish an animal industry which is environment friendly and sustainable.

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