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Anaerobic treatment of slaughterhouse waste and wastewater

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Technical Field:
- Energy / Environment (E)
- Water / Sanitation (W)
- Agriculture (A)
- Foodprocessing (F)
- Manufacturing (M)

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Within a series of processes, slaughter-houses produce large amounts of different wastes and wastewaters. The problems are complex: many slaughterhouses are located in the centres of the cities, traditional ways to make use of the wastes such as application to agricultural land are not applicable because transport distances have become too long.

The size of slaughterhouses can vary widely, small (rural) facilities with approx. 5 LSU (live stock units, 1 LSU = 500 kg) slaughtered per day, large industrial facilities may reach capacities from 100 to well over 1,000 LSU slaughtered per day.

The

have become too long. Direct disposal of highly polluted wastewater and organic residues into the sewerage system without prior treatment on the other hand is mostly not acceptable due to resulting environmental and ecological problems and the risk of clogging in the wastewater piping systems. An estimated 20% to 30% of the slaughtering costs are generated by the costs for water, waste treatment and energy. Here, anaerobic processes can contribute in an interesting way to improve the situation.

1 General aspects

Slaughterhouses are livestock processing industries that comprise a number of commercial operations:

Slaughtering of animals
Manufacturing of products derived from slaughter of animals including:

- Tanneries, fellmongeries;
- Rendering or fat extraction plants for the production of tallow, fat or their derivatives or proteinaceous matter;
- Plants for the production of hides, adhesives, pet food, gelatine, fertiliser

The process of slaughtering is very similar all over the world. The major activities involved in the operation of an abattoir are:

1. Receiving and keeping of livestock
2. Slaughter and carcass dressing of animals
3. Chilling of carcass product
4. Carcass boning and packaging
5. Freezing of finished carcass and cartoned product
6. Rendering processes
7. Drying of skins
8. Treatment of wastewater
9. Transport of processed material.

1.1 Generated waste fractions

1.1.1 Solid process wastes

The following production areas are the main sources of solid waste at abattoirs, generating different waste fractions:

Animal keeping areas:
manure, faeces and urine, sometimes mixed with straw and fodder (dependent on kind and duration of animal keeping before slaughtering)
Slaughterhouse and processing areas:
unwanted carcasses, unwanted hide, skins or pieces and other material not suitable for rendering; paper, cardboard and plastics.

fertiliser
or
meat
products

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Waste treatment plant:
sludge.

1.1.2 Liquid process wastes

The liquid wastes produced in slaughter-houses comprise a number of different wastewater streams as well as other non-solid wastes such as paunch manure and blood.

Wastewater

For hygienic reasons, abattoirs use large amounts of water in animal processing, thus producing large amounts of wastewater that have to be treated. Fig. 1 illustrates the wastewater streams originating from the different production areas.

The wastewater produced in animal slaughter areas typically has a high organic loading. Table 1 presents average values for

suspended solids and bacterial contamination.

Effluent salinity

Skin preservation by dry salting is a common procedure at small abattoirs that are remote from tanning operations and often export their hides and skins for tanning. After salting, often in converted cement truck mixers, the hides are hung to dry for a minimum of five days. During this period, the salt draws the moisture out of the hide, together with the protein-filled fluids contained in the attached flesh. The effluent from drying sheds is therefore highly saline, has a very high BOD (biological oxygen demand) and contains high levels of fluoride as the applied salt contains up to 1 % of sodium fluoride as a bactericide. This may lead to salinity problems if the effluent is utilised for irrigation values for wastewater amounts and composition.

Table 1: Slaughterhouse wastewater: average amounts and composition
(Source: Tritt, W.P.)

Specific amount of wastewater *	Unit	Average value
Wastewater/cattle	l	1,000 1,500
Wastewater/pig	l	200 600
Wastewater parameter		
COD	mg/l	1,000 6,000 (max. 20,000)
BOD_5	mg/l	1,000 4,000 (max. 10,000)
Total N	mg/l	250 700 (max. 950)
NH_4-N	mg/l	200 300
Total P	mg/l	80 120
Settleable solids	ml/l	10
Temperature	C	20 35

* Amount of wastewater in small rural slaughterhouses may be significantly smaller (approx. 300-400 l/LSU).

The average pollution level of the total wastewater stream of an exemplary slaughterhouse in Jakarta, Indonesia (see chapter 5.3), is around 7,200 mg COD per litre, other sources report similar values (see [3]). The wastewater is also very saline and has high levels of nutrients, irrigation purposes without treatment as well as to fluorosis problems for the vegetation, including tree death and destroy the aquatic fauna in receiving waterbodies.

Storm water
Storm water may become contaminated in case of getting into contact with pens and animal keeping areas, sludge stockpiles and wastewater irrigation areas. This contaminated storm water can have detrimental environmental effects on surrounding ecosystems and should therefore be integrated into the waste-water treatment system.

Paunch manure
The amount of stomach content depends on the kind of animal slaughtered and substantially on the time of last feeding and kind of last fodder. For example, in Europe an average of 50 kg is normally calculated per cattle while in West Africa, 75 kg were measured. The hygienic status of untreated paunch manure is critical. Rarely, species of salmonella were found in critical amounts in healthy animals besides bacteria, viruses and parasites (worms). Especially concerning salmonella,

2 techniques for treating paunch

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manure have to be considered for hygienic reasons.

Blood
The amount of blood also depends on the species of slaughtered animals and their live weight. Blood contains a large amount of protein and is too valuable to be discharged into the sewerage system. It is utilised as a raw material for blood meal, fibrin or blood serum, blood meal being used as fertiliser or animal feed. However, anaerobic digestion may a good reuse alternative for the blood, not least in times of BSE (mad cow disease), utilising the contained energy for electricity or heat production.

1.1.3 Non-process wastes
Non-process wastes originate from kitchens and offices, dispersed or uneaten food and from general

fuel consumption for processing needs (e.g. drying, evaporation) and methane (CH_4) emissions from manure and untreated organic waste and wastewater.

Fuel consumption should be minimised by means of heat conservation or combined heat-and-power appliances if applicable. A commonly applied treatment technology e.g. consists of anaerobic lagoons that reduce the nutrient content of the waste, but at the same time produce methane as by-product. In existing abattoirs, a strategy needs to be adopted to reduce the emission of ozone-depleting gases. To minimise the emission of CH_4 due to (uncontrolled) disposal of untreated waste, recycling and re-use strategies for the organic waste as well as sufficient storage capacity should be established in addition to further treatment options.

feed and from general maintenance of gardens and plant surroundings. The need for prevention, reduction and separation for recycling or composting applies to these wastes as much as to process wastes. Provided that they are suitable substrates, they can be integrated into the respective slaughterhouse waste treatment facilities.

1.2 Further environmental problems encountered in slaughterhouses

1.2.1 Epidemic precautions

A mass animal disposal area must be identified in case there is an outbreak of epidemic. This area should be located at a sufficient distance from surface water bodies and be designed in a way that reduces the risk of infection via ground water courses to a minimum, eventually realised by a sealed surface. The soil should be suitably loose to allow digging but also be as impermeable as possible (e.g. clay layer).

1.2.2 Greenhouse gases

Greenhouse gas emissions from slaughterhouses can result from two main sources:

2 Waste minimisation options

Prior to any planning step being taken with respect to treatment systems, there should be a comprehensive examination of process by-products and wastes to identify options for waste minimisation. Re-use or recycling of by-products will often reduce the total waste production, sometimes a substitution or change of raw material may lead to changes in the process, contributing to waste minimisation. The recovery of valuable materials from waste streams will in most cases be both economically and environmentally sensible.

Some general waste minimisation options to be considered during the planning stages are:

- change of processes or equipment;
- change of packaging of products;
- improvement of process control;
- improvement of material handling and cleaning operations;
- improvement of maintenance and repair of equipment;
- process-internal recycling of waste ;
- on-site re-utilisation of waste;
- recovery of materials from waste streams.

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However, waste minimisation options in slaughterhouses are rather limited, at least speaking of solid wastes such as feed leftovers, paunch and other manure. As the cattle owners are usually responsible for fodder provision and animal care, the only organisational measure that can be taken is to shorten the time between animal reception and the actual slaughtering date.

3 Treatment of slaughterhouse wastewater and waste

Once waste streams, process operations, raw materials, fuel supplies and product ranges have been identified, storage and handling methods for materials as well as ways of separation, treatment and disposal of wastes have to be focussed. The chosen measures and processes should aim at minimising the potential for air, water and ground pollution and contamination. Fig. 1 illustrates an example with separate treatment of liquid and solid waste fractions.
Anaerobic (or combined anaerobic-aerobic) treatment technology may provide highly appropriate solutions for slaughterhouse waste management.

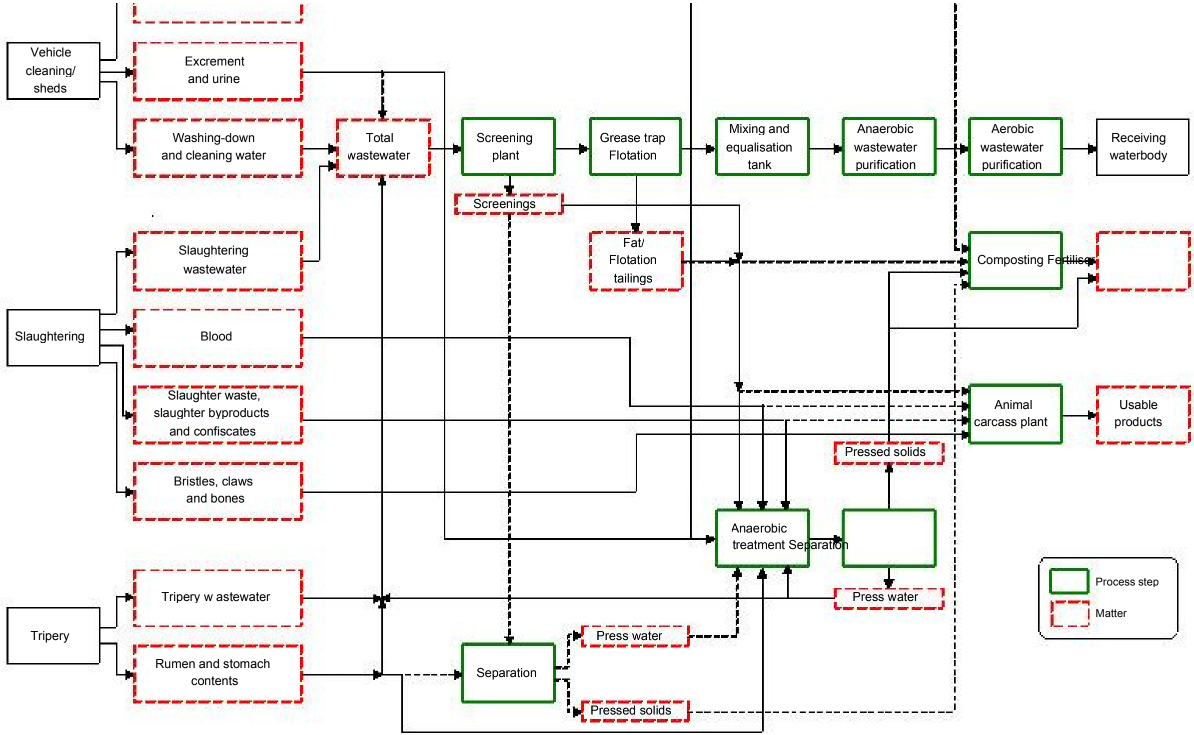

Fig. 1: Slaughterhouse waste and wastewater streams with recycling and reuse possibilities: example with separate anaerobic treatment of liquid and solid waste fractions.
(Source: TBW, modified after Schuchardt, Tritt: Inst itute for Technology (FAL), Germany)

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In general, the specific wastewater and waste streams are well suitable for anaerobic biological treatment due to their high organic pollution of mostly well degradable substances. However, the size of the slaughterhouses will have decisive influence on the respective process design.
Speaking of small facilities, simple biogas plants with digester volumes up to 50-60 m may be suitable, for big industrial abattoirs, process requirements will be considerably higher (pre-/post-treatment; level of mechanisation, compliance of treated substrates with local discharge standards etc.).

A strict separation of liquid and solid fractions as traditionally recommended for a better waste handling due to different process requirements of the different waste fractions is

Fig. 2: Pig slaughterhouse Phitsanulok, Thailand: Influent distribution system to UASB reactor
(Source: U. Gottschalk, GTZ)

Provided that anaerobic digestion steps are realised under appropriate process conditions.

waste fractions is not considered necessary any longer. Solid wastes e.g. from the animal keeping areas can generally be mixed and mashed with liquid waste fractions such as blood or wastewater from slaughtering areas, thus reducing the total dry matter content (making the substrate pumpable and stirrable) and achieving a certain degree of homogenisation of the substrate to be treated.

If plant size is a decisive factor e.g. due to limited area availability in central urban locations, it is however still an option to separate liquid and solid waste fractions in order to reduce the required digester volume as is practice e.g. in Phitsanulok, Thailand (Fig. 2; actual capacity: 120 pigs, planned: 400 pigs slaughtered per day; see also chapter 5.2).

Speaking of the liquid fraction, an average retention time of approximately 2-3 days will be sufficient, while the solid fraction will be subject to treatment in a separate digester with significantly longer retention time.

conditions; the high organic content of the wastes will lead to a high production capacity in terms of biogas that can be utilised for the provision of slaughterhouse process energy either for production (e.g. hot water production for removal of bristles, wash water) or treatment processes (substrate heating for anaerobic digestion of slaughterhouse waste is necessary even in tropical regions). As the energy demand of slaughterhouses is comparably high, on-site electricity or hot water production will in general be a sensible and economic solution provided that the utilisation of the produced energy is guaranteed. Aerobic treatment (composting) of solid slaughterhouse waste should only be taken into consideration if energy utilisation possibilities are deficient or entirely lacking or if investment costs for anaerobic treatment are considered to be too high. Composting is cheaper as plant requirements are by far lower than for the technical equipment of an anaerobic treatment plant, where stirrers, pumps and other mechanical equipment is needed.

If required for agricultural application of products or for hygiene reasons, aerobic treatment steps (e.g. composting of sludge and solid fractions; aerobic maturation

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ponds for anaerobically treated wastewater) can be applied in combination with anaerobic treatment. Psychrophilic and mesophilic fermentation alone will generally not guarantee sufficient hygienisation; with thermophilic treatment, a reduction of salmonella in 5-6 logarithmic folds was found e.g. for anaerobic digestion of a mixture of rumen content, cow manure and rinsed blood [4].

3.1 Wastewater

For the treatment of slaughterhouse effluent/wastewater, the following systems are most commonly used:

- anaerobic reactors;
- facultative ponds;
- mechanically forced aerated ponds;
- package treatment plants.

In addition to the good

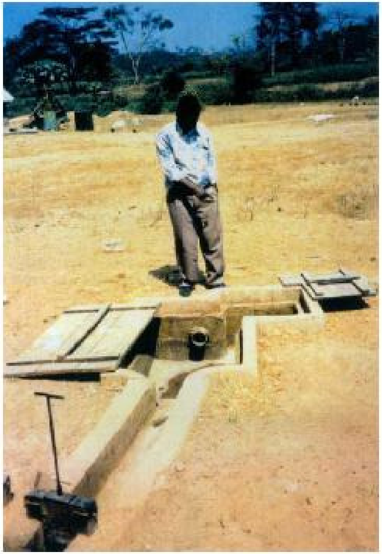

Fig. 3a: influent channel

of organic pollutants, anaerobic treatment options enable a reduction of the total organic solids volume of up to 50 80 %, whereas aerobic treatment with sludge digestion reduces the sludge volume only up to about 20 %. The sludge produced in anaerobic processes is biologically stable and can serve as a rich humus for agriculture after aerobic post-treatment. Recommendable anaerobic systems are high efficiency digesters with upflow regime, either sludge bed (UASB: upflow anaerobic sludge bed-system) or fixed bed reactors (anaerobic filters with fixed inert filter medium for growth of biomass). But also simpler treatment plants with lower efficiencies can significantly improve the hygienic, environmental and energy situation. In the region of Kumasi, Ghana, an anaerobic pilot plant for the treatment of slaughterhouse waste (rumen content, faeces, blood) was built at the University for Science and Technology (UST) following the fixed-dome design which principally consists of a concrete and/or brickwork digester operated batchwise, the gas collecting in the gas dome (see Fig. 3). The biogas is utilised as substitute for wood in the preparation of hot water.

Fig. 3b: effluent point; rear left: digesters, rear right: manhole of digester
Fig. 3: Biogas plant for slaughterhouse waste at UST, Kumasi, Ghana. (Source: TBW, [2])

High efficiency digesters allow a high rate of degradation with little energy input and simultaneous biogas production (with an average CH_4-content of 60-75%). The digester loading rate should be below 3 kg COD/$m_{digester}$/d. This leads to a necessary digester volume of 0,67 m/m wastewater daily, taking an average pollution load of 2,000 mg COD/l. Suitable systems are able to reduce the COD by 60

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to 75% with a biogas yield of approximately 0.3 m/kg $COD_{degraded}$. Facilities for effective mechanical primary treatment prior to secondary treatment steps will increase the overall effectiveness and efficiency of wastewater treatment systems: physical removal of fat (grease trap, flotation) and solids (screen, grid, sedimentation) is more economic than the application of elaborate secondary and tertiary treatment steps. Fig. 4 shows an example for waste and wastewater treatment of the above mentioned slaughterhouse in Jakarta, Indonesia (see also chapter 5.3).
If wastewaters from different points of origin are treated jointly, a treatment step for equalisation and/or homogenisation may be advisable due to the very different composition of wastewater streams in a slaughterhouse. When mixing different wastewater streams, a

pond for conversion to solid waste for potential recycling.
Depending on strategies and local possibilities concerning reuse of the recycled products (treated wastewater for irrigation purposes, digested sludge/ compost for fertilising/soil conditioning purposes), aerobic ponds or composting plants may be necessary or advisable as post-treatment.

3.2 Manure

3.2.1 Paunch manure

Paunch manure is the most difficult material for anaerobic treatment in slaughterhouses because of its strong tendency to form heavy scum layers. If it is mixed with wastewater for anaerobic treatment, process design therefore has to take care that the process requirements either wastewater streams, a suitable nutrient composition for anaerobic degradation processes has to be ensured; the C/N-ratio of the substrate to be digested should lie in the range of 20-40.

The highly saline effluent from drying sheds (see chapter 1.1.2) should be separated and diverted to an evaporation

for liquid or solid substrates are met.

Basically, there are three different possibilities for paunch manure treatment:

- Anaerobic treatment in batch systems
- Anaerobic treatment in continuous systems

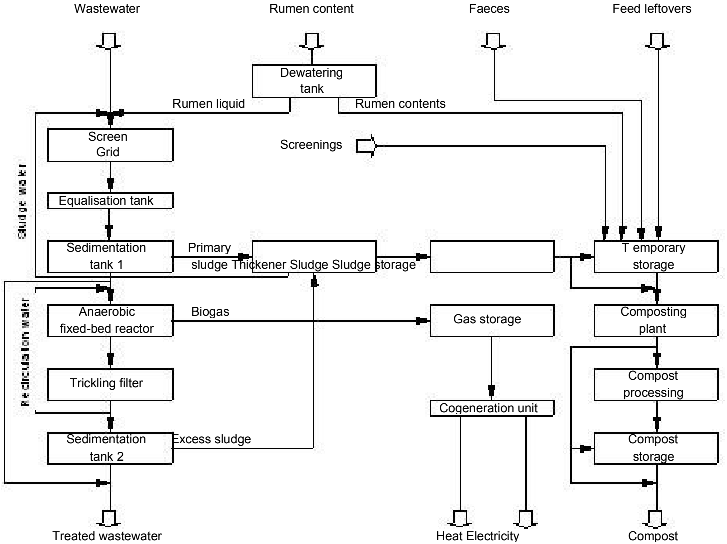

Fig. 4: Example for slaughterhouse wastewater and waste

Fig. 4: Example for slaughterhouse wastewater and waste treatment (Source:[6])

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- Dewatering of the paunch manure with following composting of solid and anaerobic digestion of liquid fraction

Batch systems are very labour-intensive, as the substrate has to be removed from the digester after treatment.

In continuous systems, heavy agitation is required to obtain a fully mixed and pumpable substrate. A biogas productivity from 370 to 600 l per kg of organic dry matter can be expected, a reduction rate of the organic matter of up to 90% is reported. Requirements for pumps and agitators are high because knives, ropes, wire, stones and other disturbing material may be found in the stomachs of ruminants, causing a lot of damage to sensitive plant components.

The separation of dry matter (DM) and liquid remains the most recommendable solution for biogas production. By means of a screw press, the

organisational measures have to be taken for its application to agricultural fields.

3.3 Blood

For anaerobic treatment, the blood should be mixed with other substrates of a higher carbon content such as paunch or manure. Blood is one of the most powerful nutrient media for anaerobic bacteria known in nature, it reaches a BOD-value of about 150,000 mg/l.

4 Biogas utilisation

In case of anaerobic treatment, the different slaughterhouse waste fractions show a comparably high gas productivity due to their composition and high organic content. Table 2 shows mean values of methane of a screw press, the water content is reduced to 65-70 %. The solids may now be composted or dried above 50C for hygienic reasons and sold. The liquid paunch juice has a DM-content of up to 6% and a chemical oxygen demand (COD) of up to 80,000 mg/l. It is a homogeneous, green coloured liquid that is highly suitable for digestion in an anaerobic plant, with a gas productivity of 0.3 m/kg COD $_{added}$. The DM content is reduced by over 60%.

Safe pathogen elimination in the paunch manure requires sufficient sterilisation at temperatures of 50 - 60 C for a certain time. These requirements can be met by anaerobic thermophilic digestion or composting. Mesophilic (30-35C) and psychrophilic (15-20C) fermentation do usually not guarantee a sufficient level of sterilisation ([9]).

3.2.2 Stable Manure

Faeces and urine are sometimes mixed with straw and fodder. Suitable stable manure may be mixed with paunch juice for anaerobic treatment and biogas production in biogas digesters. It has to be taken into consideration that storage capacities for the effluent of biogas plants, the liquid sludge, have to

capacity for different substrates.

Table 2: Estimated methane capacity of different slaughterhouse waste fractions (Source: Schuchardt, Tritt)

Substrate	**Methane capacity** l CH_4/kg DOM*
Rumen contents	300
Rumen press water	280
Screenings	650
Grease trap residues	710
Flotation tailings	700
for comparison: municipal sewage sludge	330

*DOM: dry organic matter

The produced biogas can mainly be utilised in three different ways:

- for heating or boiling water,
- for electricity production and
- for mineralisation (incineration) of solid slaughterhouse wastes.

Heating or boiling water:

Both in the actual slaughtering process steps as well as in waste treatment processes, heated water can be used for three main purposes:

Removal of pig bristles

This requires a large amount of water with a temperature of at least 60 C.

be provided and

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Water tanks can be equipped with special burners that utilise the produced biogas for heating or boiling.

Cleaning purposes

The heated water may be used for cleaning floors in the slaughterhouse, thus requiring less water to solve solidified blood. If the produced wastewater is integrated into the anaerobic digester, the substrate temperature will increase, allowing a faster and better digestion.

Digester heating

Even in tropical climate, substrate temperature of slaughterhouse wastewater and waste will usually not be sufficient for mesophilic (30-35C) or thermophilic (50-55C) anaerobic digestion. The demand for substrate heating can be met by utilisation of hot water.

5 Plant examples

5.1 Treatment of Slaughterhouse Wastewater using Anaerobic Sequence Batch Reactors

Psychrophilic anaerobic digestion in a Sequence Batch Reactor (SBR) process can effectively reduce the concentrations of BOD_5, COD and suspended solids as well as odour of slaughterhouse wastewater. The process can also eliminate the need for expensive air flotation and sedimentation processes currently used at some slaughterhouses. The cost-effective process justifies the use of anaerobic digestion on small and large slaughterhouse facilities.

The organic loading rate varies from 6.3 to 7.13 g COD/l mixed liquor/day, the bioreactor is operated at 20 C. Results indicate that the proposed process

Electricity production:
The produced gas can be used in a co-generation unit for electricity production, additionally utilising the waste heat from the combustion process to cover the own heat demand of the slaughterhouse or treatment facilities.
Alternatively, a gas turbine may be implemented for electricity generation via water vapour, produced by boiling water with the biogas.

Incineration of solid wastes:
Solid wastes from slaughterhouses mainly consist of bones, hooves and horns. If the calorific value of these wastes is not sufficient for a combustion process, they can be mineralised by incineration in a brick oven fired with biogas, thus being transformed into ash. The slaughterhouse of Gitega (Burundi) for example adds avocado kernels to the bones before burning. The resulting ash is well appreciated by chickens.

effectively reduces the pollution potential

of slaughterhouse wastewater, a high COD removal rate could be achieved. At 20 C, the process can achieve average removal rates of 95% of the total soluble COD and 31% of suspended solids (SS). The process produces large quantities of high quality biogas: gas production varies from 0.51-0.53 m CH_4/kg VS (volatile solids) fed at 20C, the CH_4 content ranges between 70% and 75% at all temperatures. The odour of the slaughterhouse wastewater is also substantially reduced.
Depending on the planned utilisation of the treated substrate, problems may however occur concerning the hygienic standards, as psychrophilic treatment will generally not be sufficient for pathogen elimination.

5.2 Municipal Slaughterhouse Phitsanulok, Thailand

Phitsanulok slaughterhouse presently slaughters up to 120 pigs per day. An anaerobic wastewater treatment plant has been built with a planned capacity of 400 pigs and a total wastewater quantity expected to be 60 m^3/day. Currently some 80 kg of LPG liquified petroleum gas (60 kWh/d) are used for the operation of

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the slaughterhouse, after the planned extension the energy demand will rise up to 260kg LPG/day (200 kWh/d).

From a total expected suspended solids content of 80 kg/d and a concentration of 1,300 mg/l (COD_{total} being 4,300 and BOD_5 3,000 mg/l), a total biogas production of 120 m^3/d, a LPG replacement of 55 kg/d and a biofertilizer production of 100 kg/day and 80 m^3/d purified water are expected to result after treatment. The treatment plant consists of a collection tank, a 200 m^3 channel digester with gas storage of 100 m^3, a UASB-reactor of 60 m^3 reactor volume, a sand bed filter, a stabilisation pond, 3 wetland cells and a water reservoir. For a flow diagram of the fully operational system, see Fig. 5.

top left: gas storage

top right: effluent stabilisation pond

bottom left: sludge drying beds

Fig. 6: Aspects of municipal slaughter-house Phitsanulok, Thailand
(Source: U. Gottschalk, GTZ)

5.3 Slaughterhouse Jakarta Cakung, Indonesia

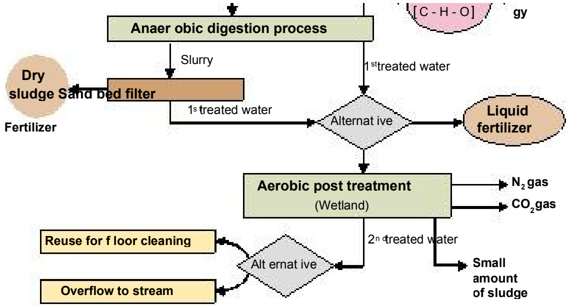

Fig. 5: Flow diagram for wastewater treatment of Pithsanulok municipal slaughterhouse
(Source: [4])

Since the plant has presently only been taken into operation at 30% capacity, and biofertilizer and treated water are not yet used, final efficiency statements can barely be made as yet.
However, the effluent water quality already achieves values exceeding the requested standards, and malodour and houseflies are substantially reduced.

[6]

Basic data concerning the status quo of the slaughterhouse:

545 cattle are slaughtered per day, 200,000 per year
Total land demand of the slaughterhouse: 70,000 m
Located in close vicinity to gardens and agricultural land
The cattle are kept on-site for 1-5 days before slaughtering (average 2.2 days)
The entire wastewater flows into a nearby surface waterbody without treatment
The solid waste fractions (stable and paunch manure, feed leftovers, faeces) are disposed of on uncontrolled disposal sites or are subject to uncontrolled incineration
Water demand (total: 1,000 m/d)

- in the slaughtering area: 0.71.0 m of water per slaughtered cattle (due to lavish handling with water and very bad water saving measures)
- in the stable area: 0.1 m per cattle (urine, cleaning water, rinsing water for channels), in rain season additionally large amounts of precipitation water

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The wastewater quantities to be treated may be significantly reduced by taking the following measures:

Separation of precipitation water from polluted water;

Application of high pressure equipment and hot water for optimisation of cleaning efficiency with a decrease in water consumption;

Installation of equipment for lower pressure in drinking water supply system, optimisation of water withdrawal.

Should the named measures be taken, a reduction in water consumption of approximately 50% to 500 m per day may be realised.

5.3.1 Treatment concept

Wastewater treatment

The wastewater is treated in a fixed-bed reactor with rings of

6 References and further information

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reactor with rings of bamboo (diameter 60-80 mm, height 50 mm) as filter material. Operation with solids-free wastewater from main slaughterhouse and paunch manure.

Results: treatment efficiency degradation of 67-70% COD with HRT of 0.5-2 days, specific gas productivity of 320 l biogas/kg COD influent (CH_4-content of biogas: 75%).

Composting

The entire undewatered sludge from wastewater treatment (primary and excess sludge) is utilised in the composting plant. Fresh paunch manure can be composted if it is sufficiently dewatered (dry matter content >20%). Process temperatures of >70C during composting allow hygenisation of the waste, after 6-7 weeks, the produced compost is ready to use. If the rumen contents is pretreated anaerobically, composting time will be reduced by 1 to 2 weeks, maximum process temperatures will decrease, but should still be sufficient for hygienisation. The solid waste fractions generated in a slaughterhouse (rumen contents, feed leftovers (Grass), faeces and rumen liquid) can also be composted jointly.

(Oral presentation) Biogas Advisory Unit (BAU), Chiang Mai University, Thailand, 2001.

[5] Marchaim, U.: Thermophilic anaerobic digestion system for slaughterhouse wastes: an economical and ecological solution. 5 th Internatonal Symposium on Anaerobic Digestion, Bologna, Italy, May 1988.

[6] Schuchardt, F.; Wulfert-Prahl, K.: Konzept fr die Abwasserbehandlung und Abfallverwertung am Schlachthof Jakarta/Indonesien. in: Korrespondenz Abwasser, Nr. 3 (44), p.511-518, 1997.

[7] Tritt W.P.: The Anaerobic Treatment of Slaughterhouse Wastewater in Fixed-Bed Reactors. in: Bioresource Technology No. 41, pp. 201-207. Elsevier Science Publishers. London, UK, 1992.

[8] Verink , J.: Short Term Mission to Jamaica. SRC-TBW-GTZ. Frankfurt, Germany, 1993.

[9] Zimmermann, C.: Treatment of Wastes and Feasibility of Biogas Production in Slaughterhouses. Biogas Forum No. 42. Bremen Overseas R esearch and Development Association (BORDA), Bremen, Germany, 1990.

6.1 Useful Links

http://www.iwap.co.uk

International Water Association (IWA)

gate Information Service / gtz, PO Box 5180, 65726 Eschborn, Germany
Phone: +49 (0)6196 / 79-3094, Fax: +49 (0)6196 / 79-7352, Email: gate-id@gtz.de, Internet: http://www.gtz.de/gate/gateid.afp

Technical Information W5e

Publications: Recent publications on wide variety of water-related issues.

http://www.ias.unu.edu/proceedings/icibs/ riggle/
Institute of Advanced Studies, United Nations University: Prodceedings of Internet Conference on Integrated Bio-Systems. Field of interest: Integrated bio-systems for treatment and utilisation of food industrial/municipal organic solid wastes and wastewaters.

http://www.fao.org/sd/EGdirect/EGre0015.htm
Food and Agriculture Organisation of the United N ations (FAO), Energy for Development section of Sustainable Development Department (SD): Report from Working Group on Environmental Aspects of Anaerobic Treatments (Workshop on Anaerobic Conversion for Environmental Protection, Sanitation and Re-use of Residues)

http://www.fao.or.th/News_and_Highlights/Biog

6.2 Institutions and Organisations

Deutsche Gesellschaft fr Technische Zusammenarbeit (GTZ) GmbH, German Appropriate Technology Exchange GATE Information Service
P.O. Box 5180, 65726 Eschborn, Germany
Phone: ++49 (0)6196 / 79-3094
Fax: ++49 (0)6196 / 79-7352
Email: gate-id@gtz.de
Internet: http://www.gtz.de/gate/gateid.afp

Naturgerechte Technologien, Bau- und Wirtschaftsberatung (TBW) GmbH
Baumweg 10, 60316 Frankfurt, Germany
Phone: ++49 (0)69 / 943507-0
Fax: ++49 (0)69 / 943507-11
Email: tbw@tbw-frankfurt.com
Internet: http://www.anaerob.com

Food and Agriculture Organisation of the United Nations (FAO)
Viale delle Terme di Caracalla, 00100 Rome, Italy

as/biogas.htm
Food and Agriculture Organisation of the United N ations (FAO), Office for Asia and the Pacific, Bangk ok, Thailand: Biogas for abattoir wastes. Plant example for anaerobic treatment of slaughterhouse waste in Phitsanulok , Thailand .

http://www.cepis.org.pe
http://www.cepis.org.pe/eswww/fulltext/anaerobi.html
Centro Panamericano de Ingeniera Sanitaria y Ciencias del Ambiente (CEPIS) Environmental technology centre of Panamerican health organisation (Organizacin Panamericana de la Salud). Papers about different aspects of anaerobic wastewater treatment.

http://www.biogas.ch/f+e/hygiene.htm
Swiss Biogas Forum. Comprehensive overview of Swiss biogas plants (in operation/under construction).

http://ce.www.ecn.purdue.edu/~alleman/w3-piwc/webpapers.html/#B8
Civil Engineering, Purdue University (U SA); Technical Papers of 1997 Purdue Industrial Waste Conference. (Field of Animal and Dairy Wastes: Anaerobic Sequencing Batch Reactor Treatment of Beef Slaughterhouse Wastewater).

Tel.: ++39 (0)657051
Fax: ++39 (0)657053152
Internet: http://www.fao.org/

University of Agricultural Sciences, Institute for Agrobiotechnology, Department of Environmental Biotechnology
Konrad-Lorenz-Strasse, A-3430 Tullin, Austria
(systematic pilot plant investigations with slaughterhouse wastes)

gate Information Service / gtz, PO Box 5180, 65726 Eschborn, Germany
Phone: +49 (0)6196 / 79-3094, Fax: +49 (0)6196 / 79-7352, Email: gate-id@gtz.de, Internet: http://www.gtz.de/gate/gateid.afp