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WASTE WATER TREATMENT AND SOLID WASTE HANDLING AT SLAUGHTERHOUSES IN YEMEN ARAB REPUBLIC (Y.A.R.)

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Report of mission to Yemen Arab Republic (Y.A.R.)
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1. INTRODUCTION

At the present time, March 1989, four slaughterhouses are operating in Yemen Arab Republic (Y.A.R.) in the cities of Sana'a, Dhamar, Taiz and Hodeidah. Two other slaughterhouses are planned, one in Al Baida which will be operating within a few months and one in Ibb, where the building activities will start in the course of 1989. The situation at these slaughterhouses differs from one another according to the number and species of animals slaughtered, the amount of waste and waste water produced and the possibilities for waste water treatment. The water used in the slaughterhouses is withdrawn from the groundwater at a depth of 50 to 150 meters. Due to the spraying of the carcasses, cleaning of floors and equipment, the water is loaded with organic and inorganic pollutants, but the degree of pollution may widely vary depending on plant design, processing activities, animal species, waste management methods and employee habits. After more or less treatment of the waste water the effluent is discharged into a wadi, to a nearby sewage treatment plant, or it is infiltrated into the soil.

The present handling of waste water and solid waste at the slaughterhouses gives some problems and raises some questions e.g.:

- aerobic biological treatment of the waste water with mechanical aeration consumes a lot of energy and frequently problems arise with failure of the pumps.
- aerobic treatment with mechanical aeration, especially the activated sludge system, requires high skilled staff to control the process of aeration and sludge handling, especially when sudden high loadings with organic material (e.g. discharge of blood) occur, which is quite common in slaughterhouses.
- discharge of the highly polluted waste water into a sewage treatment plant may give problems concerning acceptance by the local Sewage Authorities and the costs for treatment will be high.
- after treatment, the clarified effluent contains a lot of nutrients that may be used for agriculture, but a first attempt to grow crops on an infiltration field gave only poor results.
- infiltration of waste water or clarified effluent in the soil may create a groundwater quality problem on the long run.

The author of this report made a mission to Y.A.R. from March 5th to March 24th, 1989. The main purposes of this mission were:

- study the problems and possibilities concerning handling and treatment of waste water and solid waste at the slaughterhouses;
- advise on possibilities for relatively cheap water treatment methods, such as lagoon systems and land treatment;
- investigate possibilities for reuse of more or less clarified effluents and solid wastes in agriculture.

A brief description of the mission program is given in Annex 1. The findings and recommendations that resulted from this mission are described in this report.

2. QUANTITIES OF WASTE WATER AND SOLID WASTE

2.1. Waste water

It appeared difficult to get a good estimate on the quantities of waste and waste water in the slaughterhouses because only few data are available. Hardly any data were available on the quality of the waste water and the quantity of the waste material. Therefore only rough estimates could be made based on the number and species of animals slaughtered and literature data on waste production per ton of slaughtered weight or per ton of live weight killed (LWK). The daily LWK, expressed in kg/day, was estimated from the number and species of animals killed, assuming certain weights for the different categories of animals (see table 1).

Table 1. Daily live weight killed (LWK) estimated from the number and species of animals slaughtered in the first quarter of 1988 in slaughterhouses in Y.A.R. (slaughtering takes place seven days a week).
C&C = cows and camels L.c = large calves S.c = small calves
S&G = sheep and goats * = estimated

Slaughterhouse	Number of animals slaughtered per day				LWK(1) kg/day	Slaughtered weight (50% of LWK) kg/day
	C&C	L.c	S.c	S&G		
Sana'a	144	25	15	189	42,350	21,175
Taiz	13	21	23	174	9,225	4,613
Hodeidah	17	1	7	326	12,625	6,313
Dhamar	11	21	12	29	4,825	2,413
Al Baida*	6	1	-	17	1,975	988
Ibb*	21	13	13	20	6,725	3,363

(1) based on following average LWK per animal species:
cow/camel: 250 kg; large calf: 50 kg; small calf/sheep/goat: 25 kg

The main waste products from slaughterhouses are blood, stomach and intestine contents, slaughtering waste like heads, legs, bones, etc. and waste water containing blood, grease, meat particles, manure, etc. If blood and stomach contents also end up in the waste water, the biological oxygen demand (BOD) of the waste water is very high resulting in BOD_5-values of 3000-4000 mg/l, depending on the amount of water used.

The organic load measured as BOD_5 (=biological oxygen demand during 5 days at 20 °C) is presented in table 2 as average values for the different waste categories, derived from literature data (TEN HAVE, 1976; SWEETEN, 1980) and estimates available at the slaughterhouses.

Table 2. Organic load from slaughterhouses, given as BOD_5 (kg) per 1000 kg LWK and per waste category.

Waste product	Volume (m^3)	BOD_5 (kg)	BOD_5 (mg/l)
Blood	0.030	4.8	160,000
Stomach/intest.			
contents	0.125	6.2	50,000
waste water	3.5-6.2	4.0	650-1150
Total	4 - 6	15.0	2500-3750

From this table it becomes clear that it is very important to collect the relatively small volumes of blood and stomach contents for separate treatment, reuse or disposal. In that case the pollution of the waste water is considerably lower (BOD_5 about 1000 mg/l). In practice, the waste water will be more polluted because only the larger part of the blood can be collected separately. As far as the stomach contents are concerned, often only the solid material is collected while the stomach fluids flow into the water waste collection system. For these reasons, the BOD_5-value of the waste water is often in the range of 2000 mg/l, even when blood and dry stomach contents are collected separately.

If all the blood and stomach contents are washed away with the waste water, then the BOD_5 of the waste water may be as high as 4000 mg/l.

The quantity of waste water and the BOD_5 of the organics in the waste water are presented in table 3 for the four operating slaughterhouses and for the two planned ones. Furthermore, average values are

Table 3. Production of waste water at slaughterhouses in Y.A.R.

Slaughter-house	Daily LWK kg/day	Water used m^3/day	Waste water characteristics			
			Volume* m^3/day	BOD_5-values (kg/day) minimum	maximum	average**
Sana'a	42,350	150	135	169	635	318
Taiz	9,225	55	50	37	138	69
Hodeidah	12,625	45	40	51	189	95
Dhamar	4,825	30	27	19	72	36
Al Baida	1,975	15	13	8	30	15
Ibb	6,725	30	27	27	101	50
Total	77,725	325	292	311	1165	583
Mean	1,000	4.3	3.9	4.0	15.0	7.5

* 10% evaporation losses

** When blood and solid stomach contents are largely separated.

calculated and expressed per ton of LWK. The total BOD_5 discharged with the waste water, is expected to be about 7.5 kg per ton of LWK, if blood and solid stomach contents are collected and treated separately. If these materials are not separated from the waste water, then the total BOD_5 in the waste water amounts to 15 kg per ton of LWK.

2.2. Solid waste

The amount of solid waste is estimated by making a material balance of the slaughtering process. Based on experiences of the past, the next balance could be made. Per ton of live weight killed about 500 kg of carcasses (meat and bone) is delivered to the clients, 100 kg of (wet) skins and hides are collected, treated and sold, 30 kg of blood and 125 kg of stomach contents are released and the rest, i.e. the slaughtering waste, amounts to 245 kg. Based on this material balance the amount of products and waste material is calculated for the slaughterhouses and presented in table 4.

Table 4. Production of meat, skins and hides, blood and other waste products at slaughterhouses in Y.A.R.

Slaughter-house	Meat kg/day	Skins/hides* kg/day	Blood kg/day	Stomach** contents kg/day	Slaughtering waste kg/day	Daily LWK kg/day
Sana'a	21,175	4,235	1,270	5,295	10,375	42,350
Taiz	4,613	925	275	1,155	2,257	9,225
Hodeidah	6,313	1,265	380	1,580	3,087	12,625
Dhamar	2,413	485	145	605	1,177	4,825
Al Baida	988	200	60	245	482	1,975
Ibb	3,363	673	202	841	1,648	6,725
Total	38,865	7,783	2,332	9,721	19,026	77,725
Mean	500	100	30	125	245	1,000

* weight before drying

** slurry with about 5% dry matter content

Blood can partly be reused to produce cattle feed, as is being done in the rendering plant at Sana'a slaughterhouse. There the blood is used together with the slaughtering waste to produce cattle feed. However, not all the blood can be reused in this way. Part of it is dried to produce blood meal, but there is little demand for blood meal at the moment. For this reason, the blood is sometimes or always discharged with the waste water.

The solid waste material consists of solid stomach and intestine contents and slaughtering waste. It is estimated that about 16% of the stomach contents (total 125 kg per ton of LWK) can be separated as solid material. That means that about 20 kg of solid stomach contents per ton of LWK can be collected (with an estimated dry matter content of 30%). Based on these assumptions, the quantity of solid stomach and intestine contents is calculated for all the slaughterhouses (see table 5). This material consists of more or less fermented plant material and looks like manure, although it is somewhat less fermented.

The slaughtering waste is reused at Sana'a slaughterhouse in the rendering plant to produce cattle feed. This is not possible at the other slaughterhouses, because there are no rendering plants built.

Table 5. Production of solid stomach and intestine contents (=manure) at the slaughterhouses (based on average production of 20 kg per 1,000 kg LWK; derived from table 4).

Slaughterhouse	Daily LWK kg/day	Solid stomach contents* daily production ton/day	yearly production ton/year
Sana'a	42,350	0.847	309
Taiz	9,225	0.185	67
Hodeidah	12,625	0.253	92
Dhamar	4,825	0.097	35
Al Baida	1,975	0.040	14
Ibb	6,725	0.135	49

* contains 30% dry matter.

There, the slaughtering waste is dumped together with the solid stomach contents at a dumping site. In the case of reuse of solid waste material, for instance by producing compost, the solid stomach contents would probably be a good material. This is not sure for the slaughtering waste. This material should at least be pulverized in a hammer mill before it can be used for composting. Perhaps it should be mixed with other material to produce compost.

3. SELECTION OF WASTE WATER TREATMENT SYSTEMS

3.1. Selection criteria and treatment systems

Before starting a slaughterhouse one should select a treatment system for the waste water produced. Several treatment systems are possible but not every system is convenient for a certain location. In fact the selection is constrained by a number of engineering considerations, of which the most important are:

- investment costs;
- annual costs for operation and maintenance;
- complexity of the treatment system;
- availability of land;
- infiltration capacity of the soil and depth of the groundwater level;
- ultimate disposal or reuse of effluent and sludge;
- environmental aspects as odour emission and pollution of soil and groundwater.

The systems available for waste water treatment may vary considerably according to the criteria mentioned above. The most important waste water treatment systems are:

- waste stabilization ponds (also referred to as lagoons) including anaerobic, facultative and maturation ponds;
- land treatment methods;
- oxidation ditch, a simplified modification of the activated sludge process;
- extended aeration system, a low rate modification of the activated sludge process;
- activated sludge system, including small prefab plants;
- UASB-reactor (=Upflow Anaerobic Sludge Blanket reactor), in combination with a facultative lagoon or an oxidation ditch.

In table 6 the various treatment systems are compared according to a number of selection criteria. From this table it can be seen that in areas where land availability is no problem the waste stabilization ponds are lowest in investment and operational costs. Moreover, the system is simple to operate and consumes hardly any energy because in most cases hardly any mechanical equipment is needed (except perhaps a pump for lifting the water into the first lagoon). Also land treatment may be a good option but a larger land area will be needed in this case

Table 6. Comparison of treatment systems (after PREUL, 1983 and EUROCONSULT/DHV, 1988)

Treatment system	Land use	Operational Technology	Sludge removal and disposal	Evaporation	Environmental aspects	Flexibility	Operational costs	Quality of effluent (BOD in mg/l)
Waste stabilization ponds (anaerobic, facultative, maturation)	-	++	+	+	-	+	++	30
Land treatment	--	+	++	++	-	++	+	<10
Oxidation ditch	+	+/-	+/-	-	+	+	+	<10
Extended aeration active sludge syst. prefab treatment plant, e.g. biorotor	++	--	-	-	+/-	-	--	30
UASB-reactor + oxidation ditch or facultative pond	+/-	-	+/-	+/-	+	+	+/-	<10

++ = very favourable
+ = favourable
+/- = moderate
- = not favourable
-- = very unfavourable

and the groundwater level has to be deeper than 3 meters below the soil surface. In both cases, there is a risk of odour emission and groundwater pollution. As far as the latter is concerned, there is no risk of pollution with pathogenic bacteria or degradable organic compounds when the groundwater level is sufficiently deep. So, for the situation of the slaughterhouses where the groundwater level is more than 20 meters below the soil surface, pollution of groundwater mainly means pollution with inorganic salts.

For situations where the use of some technology (electric pumps and brushes) is no problem and where only little land is available the next best solution is an oxidation ditch. The system is relatively easy to operate and the removal of biodegradable material is excellent. The operational costs are definitely higher and qualified regular attendance is required for operation of the plant.

The other systems mentioned in table 6 require a high level of operational technology and also the costs for operation and maintenance are considerably higher than for the alternatives mentioned before. In areas where hardly any land is available, the ground water level is high, and when the required high level of technology seems no problem one could think of one of the following options: extended aeration, activated sludge system or prefabricated units for small scale treatment. However, in these cases it can also be interesting to look at possibilities for discharge of the waste water into the local sewage treatment system. Economic considerations are of course important for the final selection.

The UASB-reactor can be a promising alternative, especially for treatment on a small scale with high loadings. It has to be used in combination with an oxidation ditch or a facultative lagoon. The costs are lower than for the active sludge system, but it requires a relatively high skilled level for operation and maintenance.

3.2. Design criteria for the treatment systems

Anaerobic and facultative lagoons

Anaerobic lagoons are relatively deep (3 meters or more) in which anaerobic conditions are maintained by keeping loading so high that complete deoxigenation is prevalent. The raw waste water enters near the bottom of the lagoon and mixes there with the active microbial mass in the sludge blanket. The discharge pipe to the facultative pond has to be submerged below the liquid surface to keep the floating grease layer in the anaerobic lagoon. This grease layer is important for heat isolation, exclusion of oxygen and reduction of odour emission. Some emission of bad odours cannot be excluded. Some seepage of waste water into the soil may occur, but the waste products from the slaughterhouses are well degradable, so when the groundwater level is deep (in Y.A.R often deeper than 20 meters) this will present hardly any problem for the groundwater quality. Moreover, the bottom of the lagoon will soon be clogged with organic material.

The following lagoon, the facultative lagoon is of intermediate depth (about 1.5-2.0 meters) in which the waste water is stratified in zones, an anaerobic bottom layer, an intermediate zone and an aerobic surface layer. The aerobic surface layer, where oxygen is provided by natural reaeration and photosynthesis of algae, serves to reduce odours and to treat organic by-products from anaerobic processes near the bottom. A facultative lagoon is often operated in series, which means that the lagoon is divided in at least three compartments. In the case of the slaughterhouses in the Y.A.R, lining of the ponds with impermeable materials is supposed to be not necessary, unless the site is located in a vulnerable water catchment area (as in Ibb).

Concerning the treatment of waste water from the slaughterhouses in Yemen, the dimensions of the lagoons (see table 7) can be expressed per ton of live weight killed (LWK), assuming that average figures can be used for water use and BOD_5-load as mentioned in table 3.

The retention time in the anaerobic pond, which is normally for sewage water in the range of 1 to 5 days, has been chosen at 10 days because of the high BOD_5-loading. The BOD_5-load expressed in $kg/m^3.day$ is then in the same range as used for sewage water (see JAKMA et al., 1987). Compared to the anaerobic lagoon, the facultative lagoon is relatively large because of the required long retention time.

Because of the relatively long retention time in the anaerobic lagoon the BOD_5-removal in this lagoon may be as high as 75-85% depending on winter or summer temperatures. The combined effect of the anaerobic and facultative lagoons will result in a removal of about 90% of the BOD_5. Nevertheless, the BOD_5 in the effluent may still be in the range of 190-375 mg/l, the highest value referring to the situation where all the blood and stomach contents end up in the waste water.

Land treatment

When sufficient unoccupied land is available with a deep groundwater level and a high soil permeability, raw waste water can be treated by land treatment in the following ways:
- rapid infiltration on a relatively small area;
- slow rate infiltration on a large area;
- overland flow on sloping vegetated surfaces.

In all cases a considerable area of land has to be used.

Rapid infiltration can be done on deep and permeable soils (sand, sandy loam). The waste water is distributed in basins (fields surrounded by dikes) or, less frequently, is sprinkled over the surface. In the soil the waste water is treated by filtration, absorption and microbial degradation. In cases where the groundwater level is not too deep the renovated water can be intercepted with drains or reused by pumping wells. In the Yemeni situation, the treated effluent will eventually reach the groundwater. The effluent is generally of excellent quality after passage of a few meters of soil due to the long retention times (see table 7). For a good working land treatment system several basins or fields are needed to realize a cycle of flooding and drying. The drying period is necessary to maintain the infiltration capacity of the soil. Occasionally the top layer has to be loosened, preferably just before a second flooding when the soil is dry.

Slow rate infiltration is normally done on agricultural land where at the same time crops are grown. Application techniques include ridge and furrow irrigation and surface flooding. Some treatment of the waste water before application to the land is often wanted. In fact this system gives the best results of all land treatment methods. The vegetation transpires the water, uses the nutrients present in the waste water and prevents erosion and clogging of the soil. The method requires knowledge of agricultural methods of irrigation, crop growth, fertilization, etc. The area needed for this type of treatment is usually dependant on the content of nutrients in the waste water. Often the area of land used in this case is at least ten times larger than required for rapid infiltration (see table 7). According to HOLY (1979) the waste water from slaughterhouses contains about 290 mg N/l, 100 mg P_2O_5/l, 140 mg K_2O/l and 300 mg CaO/l. Assuming that two to three crops can be produced per year, then the total N-demand may be 1000 kg N/ha.year, which would mean that annually about 3450 m^3 of waste water can be supplied to one hectare. Additional supply with other irrigation water will be needed in this case.

Overland flow is used in relatively impermeable sloping areas. The waste water is treated as it flows in a thin water film over the vegetated surface to runoff collection ditches. Besides treatment of the water, a secondary objective is crop production by using water and nutrients from the waste water.

It will be clear that rapid infiltration on a relatively small area is the most simple land treatment method. The other two methods require a lot more attendance and knowledge of agricultural crop production. This can only be done in cooperation with local farmers who are willing to use the waste water on their fields.

The above mentioned land treatment methods can of course also be used for discharge of effluent from water treatment systems. The clarified effluent is often rich in nutrients and can be reused for crop production if farmers are willing to use it. Based on the amount of nutrients relatively large areas can be supplied with this effluent (slow infiltration). On the other hand rapid infiltration may also be combined with crop production if the water is supplied by the system of ridge and furrow irrigation. In fact the soil is heavily overfertilized in this case, but for certain crops this seems to be no problem. Production of crops for human consumption must, however, be avoided but production of fodder crops like maize or alfalfa is possible. An even better possibility for maximum disposal of effluent on a minimum area is perhaps wood production by growing Eucalyptus trees. CHABRA et al. (1986) descibe production of Eucalyptus with raw untreated sewage water in India, where they used the ridge and furrow irrigation system (ridges 1 meter wide and 30 cm high, furrows 2 meter wide).

Table 7. Dimensions of treatment systems, expressed per ton of daily live weight killed (LWK), for slaughterhouse waste water in the Y.A.R (land use inclusive dikes, edges, etc.)

System	Retention time (d)	depth (m)	Volume (m^3) per ton LKW	Land use (m^2) per ton LWK	BOD_5 loading ($kg/m^3.day$)
Anaerobic lagoon	10	3	40	15	0.19-0.38
Facultative lagoon (3 compartments)	40	2	160	90	0.006-0.012
land treatment					
rapid infiltration	*	-	-	200**	-
slow infiltration	*	-	-	3500**	-
Oxidation ditch	7	1.5	28	40	0.27-0.54

* The retention time before the water reaches the groundwater depends on the infiltration rate and the depth of the groundwater but may be in the range of 0.5 to more than 5 years.

** For rapid infiltration the land use depends on the infiltration capacity of the soil, while for slow infiltration the nutrient content of the water determines the area of land used.

Oxidation ditch

An oxidation ditch is an activated sludge treatment process, often operated in the extended aeration mode, i.e. the low rate modification of the activated sludge process. The oxidation ditch commonly consists of a closed loop channel (about 1.50 meters deep) with sloping side walls (concrete construction). The waste water is aerated and mixed in the ditch with mechanical aerators across the channel (brushes). The effluent flows into a final clarifier, from where sludge is returned by pump to the oxidation ditch. Surplus sludge is brought to sludge drying fields. Due to the relatively high retention time the treatment results are excellent. For sewage water retention times of 1-2 days are used. For the high loaded waste water from slaughterhouses higher retention times (5-10 days) will be needed.

The operation and maintenance requires skilled attendance but the system is simpler to operate than the standard activated sludge system and it also is cheaper. The system is especially useful in areas where little land is available.

UASB-reactor

The Upflow Anaerobic Sludge Blanket (UASB) reactor is a technical modification of an anaerobic lagoon. Provisions have been made to keep a large quantity of sludge in the reactor. Therefore the average sludge age is relatively high and consequently the excess sludge has good dewatering characteristics. The organics in the waste water are broken down by anaerobic bacteria, initially fatty acids are formed that will be digested to carbon dioxide and methane by methanogenic bacteria. Once the sludge in the reactor has been built up and has adapted to the waste water the loading of the reactor can be 4 to 5 times higher than for an anaerobic lagoon (see JAKMA et al., 1987).

The effluent usually needs a final aerobic treatment in an oxidation ditch or a facultative lagoon. Because of the high loadings the system is somewhat more sensitive to sudden changes in loading and the start-up or renewed start-up may present problems. It certainly requires more skilled personnel for operation and maintenance than a series of lagoons.

Activated sludge systems

Several systems are available, such as the extented aeration modification with a relatively low rate of loading, the standard system with primary clarification and a high loading, and several pre-fabricated units for operation at small scale. For the operation of these systems, especially with respect to the treatment of slaughterhouse waste water, the reader is referred to the reports of SCHUURBIERS (1984, 1986). If well operated the effluent of these systems can meet the quality standards for discharge in surface waters.

These activated sludge systems are expensive with respect to investment costs and annual operational costs. Moreover they require regular attendence by high skilled personnel both for operation and maintenance of the treatment system.

4. RECOMMENDATIONS FOR WASTE WATER TREATMENT AT THE SLAUGHTERHOUSES

4.1. General

Recommendations concerning the treatment systems are based on the present situation with respect to the number of animals slaughtered. Dimensions of systems are based on the daily live weight killed (LWK), as illustrated in table 7 where dimensions are given per ton LWK. In this way it is possible to recalculate the dimensions of systems for increased slaughtering activities in future. Moreover the dimensions of lagoons are based on the fact that the larger part of the blood is also discharged with the waste water. This means that 50% increase in slaughtering activities would be possible if blood is collected and treated separately.

4.2. Slaughterhouse Sana'a

The waste water is treated here in an activated sludge plant with an aeration basin of about 800 m^3, which means that the hydraulic retention time is about 6 days. On the average the loading with BOD_5 amounts to 318 kg/day, but may reach even 500 kg/day in incidental cases when large quantities of blood are discharged into the treatment plant. This means that the daily loading may vary between 0.40 and 0.63 kg BOD_5/m^3.day. When the treatment plant is operated as described in the reports of SCHUURBIERS (1984) then the system could work quite well. However, sudden heavy loadings with blood may always create problems.

In order to minimize problems in case of emergencies, e.g. when the treatment plant is out of order or a large quantity of blood has to discharged, an anaerobic lagoon could be built. According to table 7, the volume of this lagoon should be about 1700 m^3 to realize 75-85% BOD_5-removal. Concerning the situation at Sana'a slaughterhouse, where there is a water treatment plant available, this anaerobic lagoon could be smaller (e.g. 1000 m^3 with a retention time of about 7 days). It is recommended to direct the water (via the Rotostrainer if possible) into this anaerobic lagoon. The effluent from the lagoon can be brought into the aerobic treatment plant. The outflow of effluent from the lagoon should be constructed in such a way that the grease layer is left in the anaerobic lagoon.

The effluent from the water treatment plant can flow into the final lagoons, from where it is brought onto the nearby land for rapid infiltration.

The advantage of this anaerobic lagoon is that sudden high loadings with blood have less negative effects on the water treatment plant thanks to mixing in the anaerobic pond. Furthermore about 50% of the BOD_5-load may be removed in the anaerobic pond reducing the organic load of the water treatment plant.

In cases when the treatment plant is out of order, the effluent of the anaerobic lagoon has to be brought directly into the final lagoons. Of course the BOD_5-removal is not more than 50% then, and the final lagoons will receive a high BOD_5-loading. In this case the final treatment of the effluent will be realized by the rapid infiltration system on the land next to the lagoons. The BOD_5-removal in the final two lagoons will be minimum because the water volume in these lagoons is relatively small. In case when the water treatment plant is not operating, they will probably turn over into anaerobic lagoons.

The land treatment of the effluent can be done by rapid infiltration because the required land area of about 10,000 m^2 is available. The land has to be divided in fields surrounded by dikes, e.g. 10 fields of 1000 m^2. One field is flooded during 3 days (about 450 m^3), then the next field is flooded, etc. until after one month the cycle starts again on the first field. At certain moments it will be necessary to loosen the top soil by ploughing or ripping. This soil tillage should only be done when the soil is rather dry (to prevent puddling), so that will be just before the next flooding. Growing crops is not possible together with this system of rapid infiltration. There is a possibility for growing maize or trees when a system of ridge and furrow irrigation is used, but in that case probably twice the area of land is needed.

Slow infiltration with crop growth seems not possible near Sana'a slaughterhouse. For this method about 15 ha of land would be needed. Therefore this can only be done when farmers in the direct surroundings of the slaughterhouse are willing to use the water. Because the water is looked at as waste water it is hardly possible to get a financial compensation (in comparison: the price for irrigation water from wells is YR 2-3 per m^3). In view of the existing irrigation system (water supply via pipes from wells) it is not easy to mix the treated waste water with the irrigation water from wells. Furthermore, according to the farmers bad crop yields will always be the result of the waste water used. For these reasons and for the reason of water conservation the best choice will be discharge by rapid infiltration.

4.3. Slaughterhouse Taiz

The waste water treatment system at Taiz slaughterhouse consists of an extended aeration basin (about 1350 m^3), i.e. the low rate modification of the activated sludge system. After pre-treatment with screens and Rotostrainer the waste water is brought directly into the aeration basin. Primary clarification and final sludge settlement tanks are not used there. The daily loading is about 50 m^3 with a BOD_5 of about 70 kg, in incidental cases probably 140 kg (see table 3, chapter 2). This means that the hydraulic retention time is about 27 days, while the BOD_5-loading amounts to 0.052-0.104 kg BOD_5/m^3.day. There is no sludge return and surplus sludge is leaving the basin together with the effluent. However, in view of the low loading and long retention time, the production of sludge will be very low. The system seems to work quite well and the effluent seems of good quality.

The effluent is flowing in a small stream from the slaughterhouse site into a nearby wadi. Part of the water is used by local farmers for irrigation of agricultural fields. When discharge of effluent in this way will no longer be possible in the near future, other solutions will have to be found. Rapid infiltration is hardly possible at the slaughterhouse site because this would require an area of about 1850 m^2, which is not available. Further discussions with the local authorities and the local farmers should take place to convince the farmers that the effluent is of good quality and rich in nutrients, and could be used for irrigation.

4.4. Slaughterhouse Hodeidah

At the slaughterhouse in Hodeidah, there is no water treatment system available. After passage of a screen and a Rotorstrainer the waste water is discharged into the sewer system and transported to the local sewage plant. The daily flow is about 40 m^3 with a BOD_5-load of about 95 kg/day, but when blood and stomach contents are not separated from the waste water the BOD_5-load will be about 190 kg/day (see data in table 3, chapter 2).

In 1988, about YR 500,000 had to be paid for discharge of the waste water into the local sewage treatment plant, i.e. YR 2500-5000 per kg BOD_5 discharged per day or expressed in a different way about YR 35 per m^3 of waste water discharged. Treatment of the waste water in a treatment system at the slaughterhouse would cost about YR 10-20 per m^3 of waste water depending on the system selected. From these data it appears to be a good solution to remove as much BOD_5 as possible before discharge into the sewer system. Of course, this statement is only true on the condition that the Sewage Authority calculates the charge for treatment on the basis of BOD_5 discharged.

Treatment of waste water at Hodeidah slaughterhouse will be possible with an anaerobic lagoon of about 500 m^3 volume in combination with a facultative lagoon of 2000 m^3. If there is not enough land available for this facultative lagoon, the effluent of the anaerobic lagoon has to be discharged into the local sewage treatment plant. The anaerobic lagoon may reduce the BOD_5-load of the water discharged with 75-85%. Another possibility might be the construction of an oxidation ditch with a volume of about 350 m^3, possibly in combination with an anaerobic lagoon. In that case the effluent will be clean enough for discharge in the nearest wadi (if acceptable for the local Authorities) or for infiltration into the soil, e.g. via a soakaway.

Land treatment of the effluent, although possible in view of the depth of the groundwater, will not be possible here because there is not enough land available at the slaughterhouse site, not even for rapid infiltration (about 2500 m^2 needed). This means that effluent has to be discharged into the sewage treatment system, or in the nearest wadi, but in the latter case a complete lagoon system or an oxidation ditch must be present at the slaughterhouse to meet normal quality standards for discharge. In principle it would be possible that farmers use the effluent for irrigation but this is often difficult to organize when there is no irrigation system where effluent can be added to a main stream of irrigation water.

4.5. Slaughterhouse Dhamar

The waste water is treated here in a system of lagoons. The blood is washed into the first lagoon together with the waste water, total volume 27 m^3/day. This first lagoon (estimated volume 500 m^3) acts as an anaerobic lagoon with a grease and sludge layer at the water surface. The anaerobic lagoon is overdimensioned, since according to table 3 and table 7 the volume of this lagoon could be only 200 m^3. Nevertheless the BOD_5-load is supposed to be high enough (about 70 kg BOD_5/day, i.e. 0.14 kg/m^3.day) to keep this lagoon in an anaerobic condition. The dike between this lagoon and the second (facultative) lagoon is too low, since locally water flows over the dike into the second lagoon. Therefore it is recommended to raise this dike.

The two facultative ponds have a total estimated volume of about 800 m^3, which is about the theoretical volume calculated from tables 3 and 7. Effluent is not yet produced because seepage of water and evaporation from the ponds equals the daily inflow of about 27 m^3/day. Evaporation will be in the range of 3 m^3/day, so seepage must be about 24 m^3/day or about 40 mm/day. Part of this water seeps through the dike and has created a spontaneous lagoon next to the constructed lagoons.

It is expected that on the long run the seepage rate will further reduce to perhaps less than 10 mm/day by clogging of the bottom of the lagoons. This means that ultimately 15-20 m^3 of effluent has to be discharged, unless more lagoons would be built.

The BOD_5-removal in this lagoon system is supposed to be at least 85%, which still leaves an effluent BOD_5 of about 400 mg/l. This effluent could be discharged without any problems into the nearby lagoons for treatment of the local sewage water. At the time effluent has to be discharged the possibilities of this discharge should be discussed with the local sewage Authority.

4.6. Slaughterhouse Al Baida

This slaughterhouse is not yet in operation, but the slaughtering process will start here within a few months. There is hardly any land available here, so treatment in a series of lagoons and land treatment of effluent is not possible here. The daily load is estimated at 13 m^3 with a BOD_5-load of 15-30 kg/day. The local sewage water of Al Baida is treated in a series of lagoons, with an estimated daily load of 600 m^3 with 250 kg BOD_5. In view of the treatment process and the present underloading of the lagoons (see EUROCONSULT/DHV, 1988) it would not give any problem when the slaughterhouse waste water would be discharged into the sewage treatment system. Some pre-clarification with bar screens, Rotostrainer and a buffer tank for settlement of solids could be useful to get the waste water accepted by the local Sewage Authority. A buffer tank of 100 m^3 is already present at the slaughterhouse. In fact this tank will start to act as an anaerobic reactor (theoretically needed volume 80 m^3), which means that 75-85% of the BOD_5 will be removed here. One should try to keep the sludge in the tank by constructing the outlet some 25 cm below the water surface in the tank. Using this tank as an anaerobic reactor has of course the disadvantage that the tank can no longer be used as a buffer tank.

Based on the situation in Hodeidah the charge for treatment of the waste water in the local sewage treatment system may amount to roughly YR 175,000 per year. Therefore it might be a good solution to install a small treatment system at the slaughterhouse, e.g. an anaerobic pond or tank (80 m^3, 75-85% BOD_5-removal, in fact this is already present), an oxidation ditch (55 m^3, >90% BOD_5-removal) or a small activated sludge unit, which can be bought as a prefabricated unit. Especially in the latter two cases the effluent is clean enough to discharge without further treatment (perhaps in a nearby wadi of via a soakaway into the soil, since the water flow is very small, only 13 m^3/day). Otherwise the effluent has to be discharged into the local sewer system.

4.7. Slaughterhouse Ibb

This slaughterhouse has not been built yet. According to the plans the building activities will start in the course of 1989. It is a slightly sloping area and there is land available for treatment of waste water in a series of lagoons. The daily loading is expected to be about 27 m^3 with a BOD_5 of 50-100 kg/day. Based on tables 3 and 7, the waste water could be treated in an anaerobic lagoon of 270 m^3 plus a facultative lagoon of 1080 m^3 (with 3 compartments of each 360 m^3). In this case the effluent is supposed to be sufficiently clarified to discharge into a small wadi next to the site. It seems also possible to infiltrate the effluent by rapid infiltration on a piece of land of 1350 m^2. However, the slaughterhouse is located in the water catchment area for drinking water supply of Ibb. Although the effluent which will ultimately reach the groundwater will be of excellent quality thanks to purification processes in the soil, the local Authorities might not accept this situation.

Another possibility for discharge of treated effluent may be discharge via a pipeline into a wadi outside the catchment area (2-3 km away). If this will be considered then it is also possible to build the lagoons outside the catchment area near this wadi. Discharge of the effluent into the local sewage treatment system seems not possible, because this system is already overloaded.

5. POSSIBILITIES FOR REUSE OF SOLID STOMACH CONTENTS, MANURE AND SLUDGE

At the slaughterhouses a certain amount of solid waste comes available that probably could be reused as an organic fertilizer. The dry stomach and intestine contents have the same characteristics as organic manure, although the material is less fermented. The quantity of this material is calculated and presented in table 5 (chapter 2).

Furthermore, sludge is produced in the water treatment systems. Sludge production is relatively high in aerobic treatment systems. Normally, sludge production decreases when loading decreases and retention time increases, because then the system operates in the endogenous respiration phase of the bacterial growth cycle. The organisms are starved and forced to undergo partial oxidation.

The highest sludge production rate occurs in activated sludge systems such as at Sana'a slaughterhouse. Here the sludge production is estimated at 0.5 kg dry matter per kg BOD_5 removed. At 80% BOD_5-removal, this means an average sludge production of 3.4 kg per ton of LWK. In lower loaded systems, like an oxidation ditch or an extended aeration basis, the sludge production will be much lower, in the range of 0.2-0.3 kg dry matter per kg BOD_5 removed or at 90% removal, 1.4-2.0 kg per ton of LWK. In anaerobic systems, like the anaerobic lagoon, the sludge production will often be lower than 0.1 kg dry matter per kg BOD_5 removed, so at 80% removal less than 0.6 kg per ton of LWK. Excess sludge has to be removed from such lagoons once per 1-2 years. The sludge is removed from the water treatment system as a slurry and has to be dried on sludge drying beds before it can be reused. Sludge drying beds are only present at Sana'a slaughterhouse.

Direct use of stomach contents and sludge is not recommended because the material may not be free of pathogenic organisms. After drying and storage of the material (e.g. in large heaps) during some months the material can be used as an organic fertilizer on agricultural fields. The most important effects of this fertilizer are that the organic matter content of the soil is raised and that nutrients like nitrogen (N) and phosphate (P) are added to the soil. In order to get farmers interested some analyses of the material should become available (pH, N, P, K).

Except for Sana'a slaughterhouse, the quantity of stomach contents and sludge is small. In the first place, the material is a waste product that has to be disposed off. Therefore it is not of great importance to get a certain price when it should be used by farmers. When farmers can get it free of charge then they are perhaps willing to come to the slaughterhouse to get the material. In this way the slaughterhouses save the costs for transport to a local dumping place.

In table 8, the potential amounts of solid stomach contents and sludge expressed as dry matter are summarized. These are potential quantities, because in Taiz and Hodeidah the sludge is discharged with the effluent or waste water. Assuming that in agriculture perhaps 5-10 tons of this dry matter will be added per hectare, it is clear from table 8 that the amounts produced are very small, with the exception of Sana'a slaughterhouse. The material produced here could serve perhaps 15-20 ha of agricultural fields.

Table 8. Potential quantities of stomach and intestine contents and sludge at the slaughterhouses, expressed in dry matter.

Slaughterhouse	Stomach contents (tons/year)	Sludge (tons/year)	Total dry matter (tons/year)*
Sana'a	93	53	146
Taiz	20	5	25
Hodeidah	28	3	31
Dhamar	11	1	12
Al Baida	4	0.4	4
Ibb	15	1	16

* estimated content of nutrients : 2% N, 0.2% P
(C/N- ratio = 20)

At Sana'a slaughterhouse the solid stomach contents are now transported to a local dumping place. On the other hand the sludge is occasionally taken away by farmers after drying on the sludge beds. Because there are many sludge beds here that are not all necessary for sludge drying, it could be considered to dump the wet solid stomach contents also into these drying beds to let it take away by farmers after a certain period of drying. In the sludge beds the material is exposed to solar radiation. Together with a certain storage time in the beds this will kill the majority of pathogenic germs.

Except for the possible interest of farmers for this organic fertilizer, there is also interest to use this material for the production of potting compost (a mixture of soil, organic manure and fertilizer). One of the problems is how to get enough cow manure for the composting process. The price that has to be paid for this cow manure, is in the range of YR 500 per ton (mainly transport costs). Potting compost is used in various agricultural projects to grow trees and vegetables, e.g. in the Forestry Project Hassabah (Sana'a), the British Agricultural Project Risabah and the Marib Nursery. Contacts with the people of the Risabah Project showed that they are willing to do an experiment with the dry stomach contents. It is therefore recommended to bring there one truck of this material to let them do a composting experiment.

6. ENVIRONMENTAL ASPECTS AND DATA COLLECTION

6.1. Environmental aspects

When the treatment systems for waste water and solid waste are operated and maintained well, there will be hardly any problem with emission of bad odours. A more important aspect concerns the effect on the quality of scarce groundwater resources. Recharge of groundwater varies considerably per region as can be concluded from the rain fall distribution map in Yemen (fig 1). Also the quality of groundwater varies depending on the rate of infiltration of water. The electrical conductivity (EC) of the groundwater varies from about 500 μS/cm in areas with little irrigated agriculture up to 4000 μS/cm in areas with intensive irrigation from groundwater wells (information Water Resources Assessment Project, 1989). Especially in areas with intensive agriculture the leaching water contains a lot of salts because the salts of the irrigation water are concentrated in only 10-20% leaching water that is left after evapotranspiration. Therefore the salt content in the seepage water that reaches the groundwater may be 5 times higher than the irrigation water extracted from groundwater wells.

Infiltration of water into the soil and groundwater will take place at the slaughterhouses by seepage from lagoons, sludge drying beds and by land treatment of effluent. Thanks to the large depth of the groundwater (20-80 meter below soil surface) there are optimal conditions for purification of waste water and effluent in the soil. Even in the case of rapid infiltration on relatively small areas the retention time of the water before it reaches the groundwater will be in the range of 0.5-4 years depending on the depth of the groundwater level. This means that the biodegradable organics and pathogenic organisms will be completely removed at groundwater level. The salt content of the infiltrating water will, however, be higher than the water that was extracted from the pumping well, but it is certainly lower than the infiltrating water in areas with intensive agriculture. Because of the high nitrogen content of the waste water and the effluent it is likely that the groundwater will become polluted with nitrate. The European directive for nitrate in groundwater, that is used for drinking water, amounts to 50 mg NO_3/l.

On a regional scale the water use in slaughterhouses is relatively small compared for instance to the water use in agriculture. This means that infiltration of effluent near the slaughterhouses will have minor and only local effects on the quality of the groundwater. This also holds for seepage of waste water from lagoons. Moreover, the bottoms of lagoons will soon be clogged with organic material. It is however expected that the larger part of the infiltrating water is recycled by the well at the slaughterhouse site. Therefore it has to be expected that on the long run, the quality of the water extracted from the well at the slaughterhouse will be affected by the infiltration of effluent. This means that the content of inorganic compounds in the extracted water will gradually increase in time. As indicated before, there is little risk that the groundwater will become polluted with organic compounds and pathogenic bacteria, but there is a risk of nitrate pollution.

6.2. Data collection

At the moment, it is difficult to quantify the environmental aspects more specifically, because hardly any data on the quality of waste water and effluent are available. It is therefore recommended to take samples from the waste water to get a better idea of the BOD_5-loading and the BOD_5-removal in the water treatment systems. The waste water flow from the slaughterhouse can be sampled by taking samples every hour during the periods of discharge. From these samples, one mixed sample can be made. The samples have to be cooled to prevent biological degradation in the sampling bottles.

The most important analyses that have to be done for the waste water and the effluent are:

- acidity (pH);
- electrical conductivity (EC in μS/cm);
- total nitrogen (mg N/l);
- ammonium (mg NH4-N/l);
- nitrate (mg NO3-N/l);
- total phosphorus (mg P/l);
- coliform bacteria (MPN/100 ml).

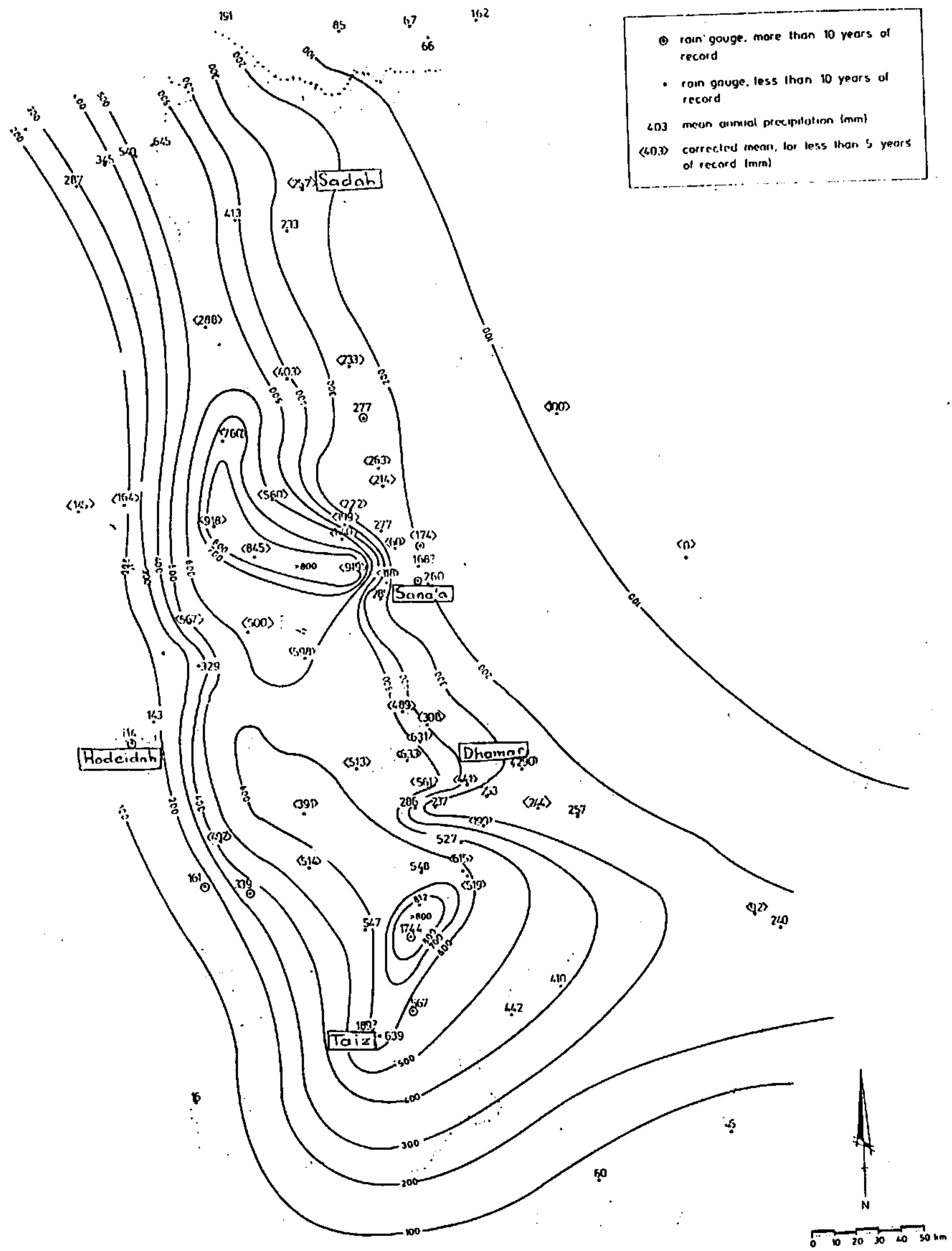
Perhaps these analyses could be made at local laboratories in Yemen. Otherwise some of the most simple analyses could perhaps be done at a small laboratory at the Sana'a slaughterhouse. An indication of the minimal outfit for such a small lab and the apparature needed is given in Annex 2.

The same applies for the quality of the solid material that could be used as an organic fertilizer. Some quality specifications of this material should be available to make potential clients interested. The most important qualifications are:

- acidity (pH) in a 1:5 water extract;
- electrical conductivity in a 1:5 water extract ($\mu S/cm$);
- total N-content (mg N per kg of dry matter);
- total P-content (mg P per kg of dry matter);
- organic matter content (mg C per kg of dry matter).

There are various possibilities to get samples analysed in Yemen. Especially for the production of potting compost several analyses have been done in the past both for constituents and final products. They have their own laboratories to do these analyses or know the laboratories where these analyses can be done.

Fig. 1. Mean annual precipitation in the Yemen Arab Republic (Y.A.R.)



7. CONCLUSIONS AND RECOMMENDATIONS

The conclusions and recommendations given in this report can be summarized as follows:

a. The problems with water treatment at Sana'a slaughterhouse could probably be reduced by constructing an anaerobic pond for first treatment and mixing of the waste water. The effluent of this pond could be brought into the existing water treatment plant and ultimately to the two lagoons from where it is brought onto the nearby field for rapid infiltration. There is little risk of groundwater pollution with degradable organics or pathogenic bacteria, only polltion with inorganic compounds will occur. The most problematic compound in this respect might be nitrate.

b. The treatment system at Dhamar and Taiz slaughterhouses are working satisfactorily. Discharge of effluent may give rise to some problems with Local Authorities and farmers. Further discussions and more data about effluent quality will be needed to get agreement on discharge of effluent.

c. Discharge of waste water from Hodeidah slaughterhouse into the local sewage treatment system appears to be quite expensive. From an economical point of view it could be a good solution to have some pre-clarification (e.g. with an anaerobic lagoon) to reduce the BOD load into the sewage treatment system by at least 50%, provided the charge calculated by the Sewage Authority is based on BOD-loadings. For a final decision, more information has to be collected about the calculation of the charge by the Sewage Authority.

d. At Al Baida slaughterhouse some pre-clarification and buffering is possible with an anaerobic pond or tank. The effluent could be discharged into the local sewage treatment system, since there is no land available for land treatment. The sewage treatment system in Al Baida seems to be underloaded, which means that discharge of effluent from the slaughterhouse into this system would not give any problem.

e. Near Ibb slaughterhouse, there is enough land available for the construction of anaerobic and facultative lagoons. The discharge of treated effluent might be problematic there because the slaughterhouse is situated in a water catchment area. Although the effluent will be of excellent quality after percolating through several meters of soil and in spite of the fact that also the municipal sewage water is treated in lagoons in the same catchment area, it might be necessary to transport the effluent with pipes into a wadi outside the catchment area.

f. The systems proposed in this report (lagoons, land treatment, oxidation ditch) are dimensioned on the present situation assuming that it will not always be possible to exclude blood from the waste water. Figures have been given per ton of live weight killed (LWK), which makes it possible to extrapolate when an increase in slaughtering activities should take place. Again it has been made clear in this report that separate collection and disposal of blood is of utmost importance.

g. Reuse of treated effluent and solid organic material as irrigation water and organic fertilizer is possible in view of the chemical composition, although more data will be needed. Reuse can only be realized when local farmers are willing to accept this material. Because the material is seen as a waste product, it is believed that hardly any financial compensation for reuse can be obtained. The only profit could be that transportation costs are saved. Moreover, the quantity of water and organic fertilizer is so low that possible financial returns would be negligible compared to the main activities of the slaughterhouse. The maximum possible return for water and organic fertilizer would be in the range of YR 10 per ton of LWK, based on YR 1.5-2.0 per m^3 of water, and YR 250-500* per ton of dry organic fertilizer. Or expressed in a different way: about YR 7 for the water and about YR 3 for the organic fertilizer per ton of LWK.

h. It is recommended to bring a truck of dried solid stomach contents to the people of the British Risabah Project for a composting experiment. They produce about 80 m^3 of potting compost per year in which about 35 m^3 of cow manure is mixed. Assuming that the stomach contents will be a good replacement for cow manure, this means that only about 25% of the organic material, which comes available at Sana'a slaughterhouse, can be used. Nevertheless, it is supposed that such an experiment is important for the acceptance of the material as an organic fertilizer.

i. More data about the water use, the quantity of waste water, effluent and solid organic material should become available. This means that flow measurements should be done and that samples have to be taken and sent to local laboratories for analyses. It could be considered to do the more simple analyses in a small laboratory at Sana'a slaughterhouse. For some analyses simple portable apparature is available. An indication for a minimal outfit and prices is given in Annex 2.

j. An important item for a follow-up program is the arrangement of meetings with the local Sewage Authorities in Hodeidah, Ibb and Al Baida to discuss the calculation of charges for disposal of waste water into the sewage system in relation with more or less pretreatment at the slaughterhouses. Other items are collection of data on water and waste quality and experiments with land treatment of clarified effluent. This can perhaps be done in the coming months by a Dutch student from the Agricultural Highschool in Deventer (NL). Suggestions for a follow-up program on data collection and experiments are given in Annex 3.

* including transport costs, i.e. the material has to be transported to the site where it is used. (price exclusive transport costs will perhaps be YR 100-125 per ton).

8. LITERATURE

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ANNEX 1. BRIEF DESCRIPTION OF MISSION PROGRAM (March 5th-24th, 1989)

<u>Date</u>	<u>Description of the program</u>
5	Flight Amsterdam - Sana'a (Y.A.R.). Picked up from airport by Mr.M.Gietzelt and Mr. F. de Wit.
6	Visit to the Sana'a slaughterhause to get a first impression of the waste water treatment (activated sludge system) and the handling of sludge and effluent. Discussions with Mr.M.Gietzelt, Mr.S.A.Holland and Mr.J.Harris about water treatment, slaughtering activities, reuse of sludge and effluent in agriculture.
7	Further explanations on slaughterhouse activities by Mr. Holland and Mr. Harris: solid waste production, treatment of hides and skins, production of cattle feed in rendering plant. Discussion with Mrs. Margret Verwijk on sale of cattle feed and effects on milk and meat production. Literature study on water use, waste water quality and waste water treatment.
8	Visit with Mr.M.Gietzelt to the Dhamar slaughterhouse, where the waste water is treated in lagoons. Effluent infiltrates into the soil by seepage from the lagoons. Study on waste water quantity and quality, estimates based on live weight killed, literature data and local experience.
9	Visit to Central Office in Sana'a for meeting with Mr.R.I.Schara, general director of the MMSMM-project (Management Municipal Slaughterhouses and Meat Markets), Mr.Holland and Mr.H.Vet to discuss the program for the mission. Contacts made with British Agricultural Project (potting compost), Water Resources Assessment Project (soil/geological data, groundwater data) and Poultry Veterinary Services (analysis of water samples). Discussion with Mr.Gietzelt (technical manager) and Mr. de Wit (building activities) on alternative waste water treatment systems, risks for groundwater pollution, and data about pumping wells at the slaughterhouses.
11	Visit to Mr.F.C.Dufour and Mr.W.M.J.Luxemburg (Water Resources Assessment Project) for information on geological data, groundwater data and rainfall data. An extensive data system is available

here. Discussion with Mr. Holland on land treatment and crop production.

12 Visit with Mr. Vet to British Agricultural Project Risabah to discuss possible use of stomach contents for production of potting compost (Mr.T.Portman).
Visit to Rada Water Supply and Sanitation Project in Rada for meeting with Mr.D. de Gier and Mr.E.H.Hofkes to discuss water treatment possibilities, e.g. with lagoons, oxidation ditch or prefab units.
Water samples were taken from the lagoons near the Dhamar slaughterhouse.

13 Visit to Poultry Veterinary Services (Mr.S. de Vries) to discuss possibilies for analysis of water samples. Dhamar samples were left here for analysis.

14 Visit with Mr. Holland to Ibb, where a new slaughterhouse will be built, and to the Taiz slaughterhouse to evaluate present water treatment system and alternative possibilities (lagoons, land treatment, discharge into local sewage treatment system, etc.). Flight back from Taiz to Sana'a.

15 Study at Central Office on data gathered, estimates of production of waste water and BOD-loadings, first start with mission report.

16 Study at Central Office, discussions on assumptions made and possible solutions.

18 Selection of waste treatment systems in view of costs, land availability, risks of groundwater pollution, etc.

19 Formulation of recommendations for waste water treatment at the slaughterhouses.

20 Study on possibilities for reuse of stomach contents as organic fertilizer, estimates on quantity and quality.

21 Visit with Mr. Vet to the slaughterhouse in Al Baida to explore possibilities for water treatment. Visit to nearby sewage water lagoons (2 anaerobic, 4 facultative lagoons), system works well and is perhaps underloaded (red algae).

22 Discussions with Mr.Schara, Mr.Vet, Mr.Holland and Mr. de Wit on first draft of report and recommendations made.

23 Discussion on recommendations, especially with respect to the situation in Hodeidah, Ibb and Al Baida. Further discussions will

be needed with local Sewage Authorities. In the report indications for a follow-up program will be given (data collection, experiments, further discussions with local authorities).

24 Flight Sana'a - Amsterdam.

ANNEX 2. APPARATURE FOR SMALL LABORATORY AT SANA'A SLAUGHTERHOUSE

The most important data for the characterization of waste water, effluent and solid waste are COD, BOD_5, Cl, Electrical Conductivity (EC), pH, Nitrogen (Kjeldahl-N, NH_4, NO_3) and Phosphorus (Total P, PO_4). Some of these analyses can also be done at local laboratories in Yemen. This applies in particular for the analyses with respect to nutrients in the water and solid material.

For a more intensive control of the efficiency of the water treatment systems at the slaughterhouses measurements of BOD_5, pH, EC and Suspended Solids could be done in a small lab at the Sana'a slaughterhouse. A prerequisite is, however, that the analyses can be done in a simple way and do not require a lot of chemical knowledge. A possible outfit for the analysis of the parameters mentioned could be (prices are given in Dfl.):

-Biochemical Oxygen Demand (BOD_5)	Dfl. 3,500.-
Needed: Oxygen meter (f. 2,000,-) with electrode (f. 1,000,-) BOD-flasks Small pump for aeration of samples	
-pH-meter	Dfl. 1,000.-
-Electrical Conductivity meter	Dfl. 1,000.-
-Suspended Solids	Dfl. 1,000.-
Needed: water bath for drying of samples balance	

ANNEX 3. SUGGESTIONS FOR A FOLLOW-UP PROGRAM

At the time of the mission hardly any data were available on quantity and quality of waste and waste water. The here presented report is largely based on estimated values derived from literature data and local experiences. Therefore it is recommended that data will be collected concerning the following aspects:

- pH, EC, Cl and BOD_5 of waste water and effluent from treatment systems;
- Nitrogen and phosphorus contents of waste water and effluent;
- Nitrogen, phosphorus and potassium contents of solid stomach contents;

Furthermore the following experiments could be done, perhaps with a Dutch student of an Agricultural Highschool, to get more information on possibilities for land treatment, possibly in combination with crop production (maize, alfalfa, Eucalyptus trees):

- a composting experiment with solid (dried?) stomach contents in cooperation with the people of the British Risabah Project. Special points of interest: decrease of number of pathogenic bacteria during composting on heaps, change in C/N ratio, emission of odours, final composition (moisture, organic matter, N, P);
- experiments with land treatment of clarified effluent on small fields, both by flooding and by ridge and furrow irrigation. Special points of interest: duration of flooding, frequency of water supply, capacity for infiltration with both systems, clogging of the soil surface, supply of nutrients with the water, growth of maize or trees, salt content of soil at start and end of the experiment;
- collection of data concerning the efficiency of water treatment systems at the slaughterhouses in Sana'a, Dhamar, and Taiz and the quality of incoming waste water and the treated effluent.

The analyses needed for these experiments can be done at the Poultry Veterinary Services and/or in consultation with the people of the British Risabah Project. Perhaps some of the analyses required for assessment of the efficiency of water treatment systems can be done at the slaughterhouse if it is decided to buy some appropiate apparature.

For the final decisions about the selection of water treatment systems at the slaughterhouses in Hodeidah, Ibb and Al Baida the local Sewage Authorities will have to be consulted. Of particular importance is the calculation of charges for discharge of waste water and the acceptability of discharge or infiltration of clarified effluent.