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Oxidation Ditch for Treating Hog Wastes

Purdue University Cooperative Extension Service

AGRICULTURAL ENGINEERS' DIGEST

Oxidation ditches are a low-odor refinement to liquid waste storage and disposal. They can greatly reduce offensive odors in a building with stored liquid wastes and during field disposal of those wastes.

The oxidation ditch is a continuous open channel which holds the liquid waste (Fig. 1). An aeration rotor churns the liquid wastes, mixing in air which supplies the necessary oxygen for the aerobic bacteria. The action of the rotor also keeps the wastes circulating so that the solids are kept in suspension. The rotor is normally operated continuously.

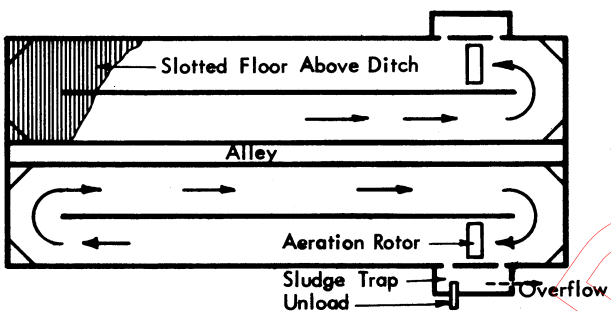


Figure 1. Schematic diagram of typical oxidation ditch installation.

Aerobic bacteria use the organic matter in the wastes as food, reducing the biologically degradable organic matter to stable minerals, with carbon dioxide and water as byproducts. In time, nondegradable organic solids and salts may build up in the ditch to the point where they will interfere with the biological process. Solids can be diluted by emptying part of the ditch and refilling with water, or the solids can be settled out in a settling tank and disposed of separately. The overflow from the ditch may flow into a lagoon or be spread on crop land; it is not treated adequately for discharge into a natural watercourse.

Advantages include:

- Objectionable odors will be reduced in the building and during transport and field spreading.
- Total waste volume to be hauled will be reduced through digestion and through evaporation in the building and from the surface of the lagoon.
- Rodent and insect pests will not infest the liquid.
- Minimum continuous winter ventilation rates may be reduced below those commonly recommended for odor control.
- Regular operation and maintenance of the ditch and equipment are fairly simple.

Disadvantages include:

- Cost of facilities and operation are higher than some other disposal systems.
- Extra attention is required after even a relatively short (1 day) period with the rotor not working (power or equipment failure or equipment maintenance).
- Foaming problems may be severe if there is a system failure or the building is overloaded with more animals than the system can service.
- Few buildings can be adapted to the system without major construction.

DESIGN

Shape

The most common shape of an oxidation ditch is a racetrack as shown. Other shapes could be used if a continuous loop is maintained and the curvature at the end of the ditch is not too sharp. Where sharp corners exist, install deflectors in the corners to help maintain uniform flow and reduce settling.

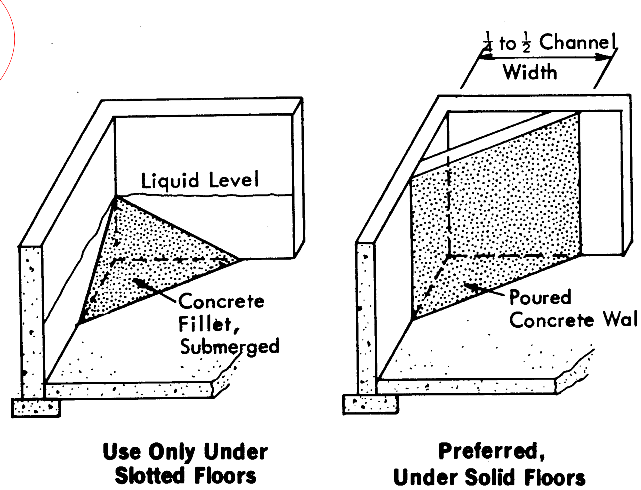


Figure 2. Corner deflector.

Ditch Capacity

Recommended capacity is specified in Table 1 and described in the example, page 4 . The recommendations allow for about 50 days of detention time. The ditch should be designed for the maximum pounds of pigs per building, and not just the average weight.

Experience has shown that a high percentage of slotted floor is needed, especially for finishing hogs, to get the required ditch volume and desirable shallow depth.

Developed from American Society of Agricultural Engineers' Paper 69-924 by D.L. Day et al, University of Illinois, and from AEng-878 by A.J. Muehling, University of Illinois.

Rotor Capacity

A major role of the aeration rotor is to mix air into the liquid wastes as a means of adding oxygen. The recommended oxygen that must be supplied equals 2 times the 5-day biological oxygen demand (BOD_5) of swine wastes, or about 0.6 lb of oxygen per 150 lb of liveweight (Table 1).

Rotors must be calibrated in water at the immersion depth at which they will operate to determine their oxygenation capacity. Capacities have been measured in clear water from 1.3 lb of oxygen per hour-foot of rotor at 6″ immersion and 100 rpm, to 5.65 lb of oxygen per hour-foot of rotor at 12″ immersion and 100 rpm. A general guide for good treatment is: one foot of rotor length for 40 to 45 150-lb hogs with a 6″ immersion and turning at 100 rpm.

Depth of Rotor Immersion and Liquid Depth

Increasing the depth of rotor immersion increases the rate of oxygenation, rate of liquid flow, size of motor required, and power consumption. Increasing the liquid depth in the channel increases detention time, depth of immersion, and the rate of rotor rotation needed to keep the solids in suspension. The simplest method of operation for a constant rotor immersion is to keep a constant liquid level in the ditch by using an overflow that discharges into a holding tank or lagoon. Slight variations in the liquid depth may be desirable to achieve the most efficient rotor immersion depth.

For finishing hogs, rotor immersion is equal to about one-third the liquid depth in the ditch to prevent settling of the solids. A 6″ immersion is about maximum to avoid rotor operation problems. Recommended liquid depth is, then, between 1′ and 2′. Greater depths at 6″ immersion may result in excess settling of solids. Provide a ditch 12″ or more deeper than the maximum liquid level to allow for some foaming without obstructing liquid circulation.

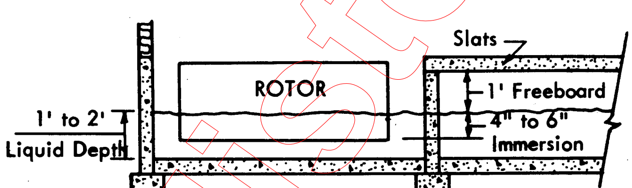


Figure 3. Typical cross section dimensions.

Rate of Liquid Flow

The aeration rotor must circulate the liquid wastes fast enough to keep the solid particles in suspension. Liquid transport can be the limiting factor in the design of a rotor even when adequate oxygen is being added. The liquid velocity required depends on the weight and size of waste particles in suspension circulating in the ditch. Normally, a minimum velocity of about 1.25 ft/sec of the liquid is recommended. At this velocity, the liquid should not travel over about 350′ without passing another rotor, since air should be added to the wastes about every 5 minutes for most efficient treatment.

OPERATION

Start-up

Fill the channel with water and start the rotor at the designed blade immersion. Start **before** adding manure to the ditch. Add wastes gradually at first to minimize foaming. A slight ammonia odor may be noticed during start-up. If initial foaming is a problem, it can be controlled with antifoam agents such as vegetable or fuel oil. Once an adequate microflora is established in the ditch, the start-up foaming should subside. This can take up to 3 weeks. The start-up period can be reduced by initially "seeding" the ditch with activated sludge from a satisfactorily operating ditch or from a municipal sewage plant. Don't drain the ditch completely unless absolutely necessary. Leave at least one-third the volume for enough sludge to provide a "seed" when the ditch is refilled with water.

Problems

The major operating problems have been foaming and incomplete treatment. If aerobic conditions are not maintained, anaerobic bacteria will predominate, causing odors and foam. There are other causes of foaming, including sudden temperature changes and sudden increases in waste quantities added to the ditch. The solution is more dissolved oxygen, reduced waste loading rate, or both. Temporary solutions include removing some wastes and refilling with water, or removing some livestock from the building. Increase rotor speed or depth of immersion for regular operation.

Symptoms of Inadequate Operation

Changes in appearance of the liquid or the foam may indicate imminent foaming problems. Clinging odors indicate an improperly operating ditch, while an earthy smell generally means a properly operating ditch. A greenish-black liquid color indicates anaerobic action and that more oxygen is needed, while a dark rich brown indicates a properly operating ditch.

The dissolved oxygen concentration indicates how the ditch is operating, but requires special equipment for measurements. A reading of 3 to 5 ppm of dissolved oxygen about 15′ downstream from the rotor is common. The oxygen level in the last one-fourth of the ditch normally falls below 0.5 ppm, showing that aerobic bacteria have been active.

CAUTION: Open up the house and turn on maximum ventilation before starting a rotor which has not been operating for over one day. Pigs have been killed by gases released when a rotor was started after having been turned off for some time, allowing the ditch contents to become septic. If the rotor has been off more than 2 or 3 days, drain part of the wastes and refill with tap water before restarting.

Regular maintenance is required. Rotor bearings must be lubricated regularly and occasionally replaced so they should be located for easy service and replacement. Belt drives seem to operate better than chain drives.

Sludge Removal

After a ditch has been in operation for several months, remove some sludge to reduce the amount of solids in the ditch. A properly operating ditch should stabilize the sludge so it can be handled without causing objectionable odors.

A sludge trap is not normally recommended, but if desired, one can be provided as in Fig. 1. Since the rotor creates an inch or so of hydraulic head, the inlet to the trap can be placed in the ditch just after the flow passes the rotor. If the outlet is placed just behind the rotor, flow will be opposite the direction of flow in the ditch (see Fig. 1). As the flow enters the tank, the velocity drops and solids are deposited in the trap. The sludge trap will need to be cleaned out periodically; pump onto drying beds or haul directly to the fields for fertilizer.

If no sludge trap is available, the solids content can be lowered occasionally by removing several inches of liquid from the ditch and diluting the remainder with tap water.

Final Disposal

The liquids from the oxidation ditch cannot be released into a natural watercourse. For operator convenience, allow overflow to discharge into a lagoon with a fluctuating depth. Irrigate from the lagoon if surplus water is a problem.

If it is not desirable or possible to have a lagoon, build a storage tank outside the building to store the overflow from the ditch. Empty the storage tank with a tank wagon for spreading on fields or distribute with an irrigation system.

Costs

The costs for an oxidation ditch will include first costs and operating costs. The cost of the rotor is about $300 per horsepower, so a 5 hp rotor costs about $1,500 including motor. Operating costs are estimated in Table 2. Additional costs will include maintenance, effluent disposal, and sludge removal.

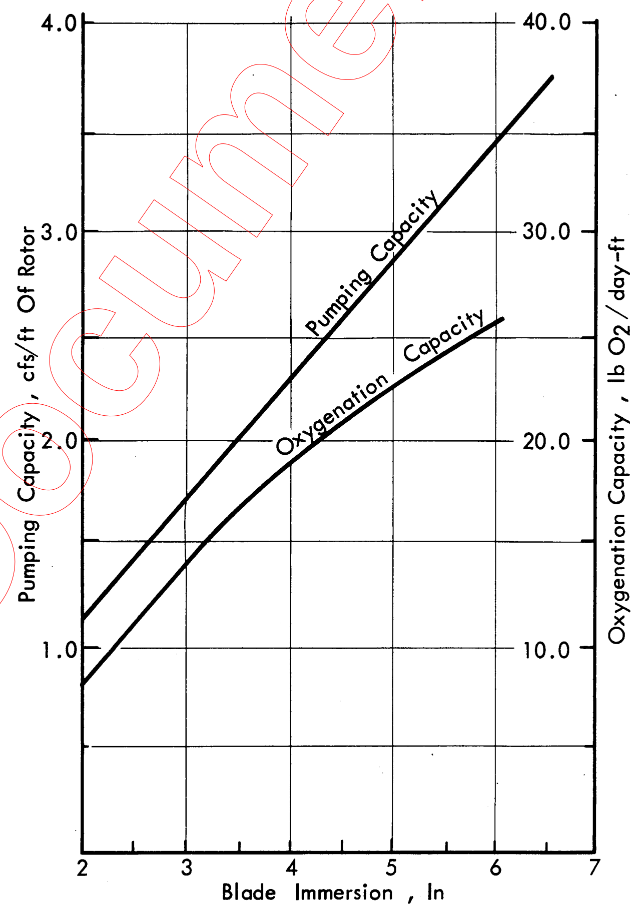


Figure 4. Performance data for a typical type of rotor.

Table 1. Design Recommendations for In-The-Building Oxidation Ditches.

Unit	Weight (lb/unit)	Ditch volume (cu ft/unit)1	Daily BOD_5 (lb/unit)	Daily required oxygenation cap. (lb/unit)2	Ditch area at 18" liq. depth, (sq ft/unit)
Boar	350 lb	12.0 cu ft	.40 lb	.80 lb	8.0 sq ft
Gestating sow	275	12.0	.40	.80	8.0
Sow with litter	375	22.5	.75	1.50	15.0
Nursery pig	35	2.1	.07	.14	1.4
Growing pig	65	3.9	.13	.26	2.6
Finishing pig	150	9.0	.30	.60	6.0

[1] Ditch volume based on approximately 30 cu ft/lb of daily BOD_3 produced.
[2] Oxygenation capacity to be supplied is twice the daily BOD_5 produced.

Table 2. Approximate Power Requirement and Daily Operating Cost of Oxidation Ditches.

Unit	Daily power requirement (KWH/unit)	Daily cost, ($/unit)1
Boar	.42 KWH	$ .84
Gestating sow	.42	.84
Sow with litter	.79	1.58
Nursery pig	.07	.14
Growing pig	.14	.28
Finishing pig	.32	.64

[1] Daily operating cost is based on 2¢/KWH.

EXAMPLE: OXIDATION DITCH FOR SWINE FINISHING UNIT.

(Note: refer to manufacturer for performance and specifications for the actual rotor to be installed.)

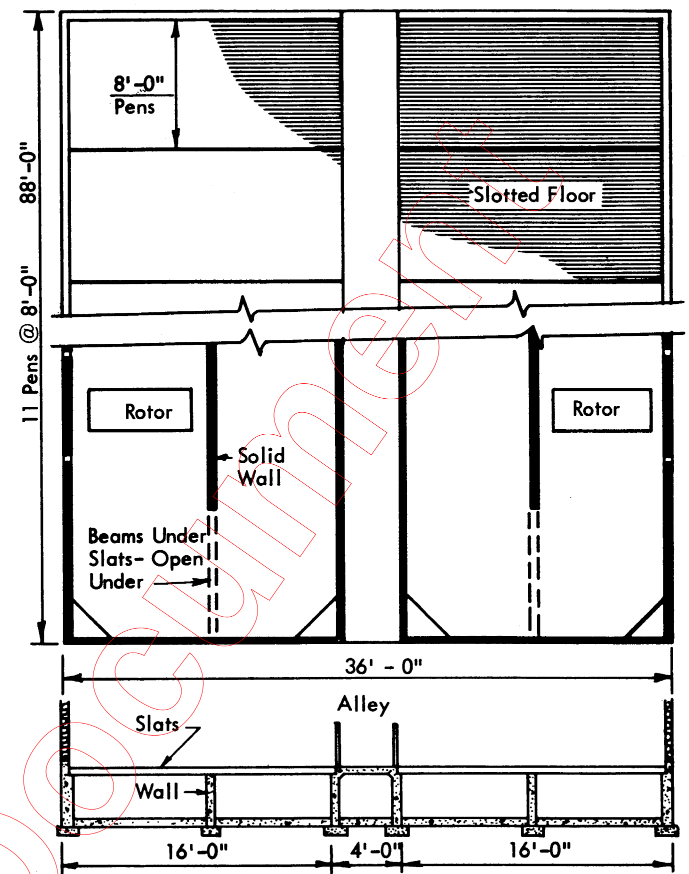
Given:

A building with slotted floors to house 500 finishing pigs with maximum average weight of 150 lb.

Specify an in-the-building oxidation ditch to treat the waste and eliminate objectionable odors. Assume the ditch is operated at a constant liquid depth by using an overflow.

Solution:

Use a floor area of 6 sq ft per finishing pig. A 36′ wide building with 22-8′x16′ pens in 2 rows will provide one extra pen: total building length is 88′.



Step 1. **Find the required ditch liquid volume.**

From Table 1, liquid volume = 9 cu ft per hog x 500 hogs = 4,500 cu ft.

Step 2. **Find the required ditch liquid depth.**

Assume two ditches, one on each side of the building. Total ditch length = 4 x 88′ = 352′. The surface area of the ditch circuit will be 352′x 7.5′ = 2,640 sq ft. The ditch depth = 4,500 cu ft/2,640 sq ft = 1.7′, or about 21″.

Step 3. **Find the oxygen capacity that must be supplied by the rotor.**

From Table 1, oxygen required = 0.6 lb O_2 hog-day x 500 hogs = 300 lb O_2/day.

Step 4. **Find the rotor depth required for oxygenation.**

Assume two rotors, each 7′ wide. Thus the oxygenation rate = (300 lb O_2/day) ÷ (2 x 7′ rotor) = 21.4 lb O_2 day per foot of rotor length. From Fig. 4 a rotor blade immersion of 4.8″ should be used for oxygenation. To keep solids completely in suspension, the ratio of liquid depth to rotor blade immersion depth should be no more than 4:1, preferably 3:1. Therefore, for 21″ ditch depth, immersion should be 5¼″-7″. Use 5½″.

The maximum distance between rotors should be about 350′—one rotor in each 176′ ditch is acceptable.

Step 5. **Check the rotor depth required for pumping capacity.**

The ditch liquid cross sectional area is 1.7′ x 7.5′ = 12.75 sq ft. A minimum flow rate of about 1.25 ft/sec should be maintained. Thus the rotor pumping rate = 1.25 ft/sec x 12.75 sq ft = 17 cu ft/sec. The required pumping capacity = 17 cu ft/sec ÷ 7 ft = 2.45 cu ft/sec per foot of rotor. From Fig. 4, a rotor depth of 4.2″ will give the required pumping capacity—therefore the 5½″ depth selected for oxygenation is adequate.

Step 6. **Check the rotor operating cost.**

From Table 2, the approximate operating power cost is 0.6¢/hog x 500 hogs = $3.00/day.

Step 7. **Select a method of ultimate disposal of the mixed liquor overflow.**

Assume the mixed liquor effluent will flow by gravity to a non-overflow, naturally aerobic lagoon. The daily BOD_5 loading of the lagoon may be assumed at 10% of the daily ditch loading, due to a typical 90% BOD_5 reduction in the ditch. A lagoon loading rate of 45 lb of daily BOD_5 per surface acre can be used in the central latitudes of the United States. The surface area required for a 4′ depth is (0.03 lb BOD_5/hog-day x 500 hogs) ÷ (45 lb daily BOD_5/acre) = 1/3 acre. The lagoon depth may fluctuate; remove surplus water and sludge as required.