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Beef cattle lagoon seepage

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BEEF CATTLE LAGOON SEEPAGE

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Summary

Most compacted soils can be used for lagoon liners to achieve seepage guidelines established by the Kansas Department of Health and Environment.

(Key Words: Lagoon Seepage, Permeability, Soil Lagoon Liner.)

Introduction

The protection of surface and groundwater and the utilization or disposal of animal waste are the primary functions of waste storage ponds and treatment lagoons. However, seepage from these structures creates risks of pollution to surface water and underground aquifers. The permeability of the soil in the boundaries of a constructed waste treatment lagoon or waste storage pond strongly affects the potential for downward or lateral seepage of the stored wastes.

Research has shown that many natural soils on the boundaries of waste treatment lagoons and waste storage ponds will seal at least partially as a result of physical, chemical, and biological processes. Suspended solids settle out of suspension and physically clog the pores of the soil mass. Anaerobic bacteria produce by-products that accumulate at the soil-water interface and reinforce the seal. Soil structure also can be altered as bacteria metabolize organic material. Chemicals in animal waste, such as salts, can disperse soil, which also may reduce seepage. Research has shown that soil permeability can be decreased by several orders of magnitude in a few weeks following contact with animal waste in a storage pond or treatment lagoon.

The physical clogging of the soil is considered to be a function of the type of waste; the percent total solids in the waste; and the permeability, size, and geometry of soil pores. Until recently, research has focused on total solids of the waste as the most important factor in the physical sealing process. However, research published in the late 1980's has shown convincingly that a soil's equivalent pore size computed as a function of particle size distribution and porosity is probably more important. Although research has shown that permeability in all soils will decrease from 1 to 3 orders of magnitude because of manure sealing, this sealing alone probably will not provide enough protection against excessive seepage and groundwater contamination for soils with a very high initial permeability. Other research has demonstrated that for soils with clay contents exceeding 5 percent for ruminant or 15 percent for monogastric animal manure, a final permeability of 10^{-6} to 10^{-7} cm/sec usually results from manure sealing. Clay content is defined as the percent by dry weight of a soil that is smaller than 2 microns (0.002 mm) and is roughly equivalent to the percentage of soil that will pass through a No. 200 seive.

Site Investigation

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An on-site investigation of a potential waste storage site should include: evaluating soils, bedrock, groundwater, climatic conditions, and local water uses, to provide insight into the potential impact of the site on groundwater resources. Data should include the presence of any water wells or any other water supply sources, depth to the seasonal high water table, general ground water gradient, general geology of the site, and depth to bedrock, if applicable.

Determining the intensity of any detailed site investigation is the joint responsibility of the designer and the person who has authority to approve the engineering job. The intensity of investigation required depends on past experience in a given area, the types of soils and variability of the soil deposits, the size of the structure, the environmental sensitivity, and an assessment of the associated risks involved. State and local laws should be followed in all cases.

The subsurface investigation can employ auger holes, dozer pits, or backhoe pits. The investigation should extend to at least 2 feet below the planned bottom of the excavation. A site investigation can include field permeability testing and taking samples for laboratory testing, or it can be limited to field classification of the soils. Information from the site investigation should be documented and included in the design documentation. When logging soils from auger holes, always consider that mixing will occur and can obscure the presence of cleaner sand or gravel lenses. Pits and trenches expose more of the foundation, which is helpful in detecting small, but important, lenses of permeable soil. Always use safety rules around trenches.

Soil Properties

Soil mechanics laboratories of the Natural Resources Conservation Service (NRCS) have a database of permeability tests performed on over 1,100 compacted soil samples. Experienced NRCS engineers have analyzed these data and correlated permeability rates with soil index properties and degree of compaction. Based on this analysis, Table 1 (from NRCS Technical Note 716) has been developed to provide general guidance on the probable permeability characteristics of soils. The grouping is based on the percent fines (percent by dry weight finer than the #200 sieve, roughly equivalent to percent clay) and a plasticity index. This index represents the range of moisture contents at which a soil remains cohesive.

Table 2 summarizes a total of 1,161 NRCS tests. Where tests are shown at 85 to 90% of maximum density, the vast majority of the tests were at 90%. Where 95% is shown, data include tests at both 95 and 100% degrees of compaction, with the majority of the tests performed at 95% of maximum density.

Table 2 gives a summary of the permeability test data. The first column indicates the general soil group described in Table 1. The second column indicates the degree of compaction of the soil. The higher the percent dry density, the greater the compaction. The four soil types each have been tested at two different compaction rates. The data indicate that additional compaction of the same soil reduces the permeability of the soils by a factor of 2 to 13. The average permeability values are listed in the fourth column. These values, when multiplied by the depth of a lagoon and divided by the thickness of the liner, predict the seepage rate. The last column of Table 2, shows the predicted seepage rate for a lagoon with an average depth of 4 feet and a liner thickness of 1 foot. Kansas Department of Health and Environment (KDHE) regulations require that initial seepage be less than .25 inches per day. These data show that almost all soils in groups II, III, and IV can be adequately sealed. The permeability values shown are median values, so some soils in all the groups may have excessive seepage. Testing of existing soils is recommended to assess local conditions.

Soil liners are relatively impervious barriers used to reduce seepage losses to an acceptable level. One method of providing a liner for a waste storage structure is to improve the soils at the excavated grade by disking, watering, and compacting them to a suitable thickness. Soils with suitable properties make excellent material for liners, but the liners must be designed and installed correctly. Soil has an added benefit of providing an attenuation medium for the pollutants.

Those on-site soils in Groups I considered to be unsuitable usually can be treated with bentonite to produce a satisfactory soil liner. Additives such as bentonite or soil dispersants should be added and mixed well into a soil prior to compaction. A soil liner may also can be constructed by compacting imported clay from a nearby borrow source onto the bottom and sides of the storage pond. This is often the most economical method of constructing a clay liner, if suitable soils are available nearby. Concrete or synthetic materials such as GCL's (geosynthetic clay liners) and geomembranes also can serve as liners. In all cases, liners should provide a reduction in seepage from the storage/treatment pond and diminish the potential for contamination of groundwater.

Table 1. Grouping of Foundation Soils According to Their Percent of Small Particles and Plasticity Index - From NRCS/SNTC Technical Note 716

Group	Description
I	Soils that have less than 20% passing a No. 200 sieve and have a plasticity index less than 5. Generally, these soils have the highest permeability and, in their natural state, could allow excessive seepage losses.
II	Soils that have 20 to 100% passing a No. 200 sieve and have a plasticity index less than or equal to 15. Also included in this group are soils with less than 20% passing the No. 200 sieve with fines having a plasticity index of 5 or greater.
III	Soils that have 20 to 100% passing a No. 200 sieve and have a plasticity Index of 16 to 30. These soils generally have a very low permeability, good structural features, and only low to moderate shrink-swell behavior.
IV	Soils that have 20 to 100% passing a No. 200 sieve and have a plasticity index of more than 30. Normally, these soils have a very low permeability. However, because of their sometimes blocky and fissured structure, they often can experience high seepage losses through cracks that can develop when the material is allowed to dry. They possess good attenuation properties, if the seepage does not move through the cracks.

Table 2. Summary of Permeability Test Data, NRCS Soil Mechanics Laboratories

Soil Group	Percent of ASTM D698 Dry Density	Number of Observations	Permeability Median K cm/sec	Seepage (12-inch-thick liner 4 ft. avg. liquid depth) inch/day
I	85-90	27	7.2×10^{-4}	120
I	95	16	3.5×10^{-4}	60
II	85-90	376	4.8×10^{-6}	.85
II	95	244	1.5×10^{-6}	.24
III	85-90	226	8.8×10^{-7}	.15
III	95	177	2.1×10^{-7}	.036
IV	85-90	41	4.9×10^{-7}	.084
IV	95	54	3.5×10^{-8}	.006