

## SEEPAGE CONTROL IN FARM-SIZED DUGOUTS

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### INTRODUCTION

The farm dugout offers the only means of water supply in many areas where groundwater is either unsuitable or non-existent. In some instances, particularly in areas where the soil tends to be calcareous, these earthen water impoundments are subject to excessive seepage losses. Many methods of seepage control have been suggested. They include the use of lining materials such as concrete, polymer films, butyl rubber and bentonite. Apart from certain problems associated with each of the four mentioned lining materials, they are considered to be generally expensive. Other methods that may be advantageous economically, but are not as well publicized include the use of chemical reagents and organic liners.

The chemical characteristics of the soil often have more influence on permeability than texture. Excessive concentrations of calcium cause clay particles in the soil to aggregate and to form a porous water stable structure with high permeability characteristics. This undesirable property can be rectified by replacing the calcium with sodium. Sodium ions cause aggregates to disperse, thereby reducing the permeability of clay.

Reginato et al. (1968) describe a method of using sodium carbonate to reduce water loss and give equations for determining the amount of chemical required based on the cation exchange capacity of the soil.

$$\text{Na}_2\text{CO}_3 = 0.0428 \text{ DA} (0.15 \text{ CEC} - \text{ES})$$

where  $\text{Na}_2\text{CO}_3$  = grams of sodium carbonate; D = depth of soil treated (cm); A = area to be treated ( $\text{m}^2$ ); CEC = cation exchange capacity (meq/100g); ES = exchangeable sodium (meq/100 g).

The above formula facilitates calculation of the quantity of sodium carbonate required to raise exchangeable sodium percentage from its original value to 15 (designated by the factor of 0.15) assuming complete replacement by sodium. Graveland (1973) has found in a laboratory study that increasing the application rate resulted in decreasing the hydraulic conductivity to a levelling point that coincided with actual exchangeable sodium percentage of 15. This point was achieved by using a coefficient of 0.25 in the application rate equation.

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Another chemical method of retarding seepage was by the use of a patented chemical, SS-13, manufactured by Laurantan of Anaheim, California. A report prepared by the manufacturer claims that application of the chemical will normally reduce seepage losses to a range of 0.05 to 0.30 cu. ft. of water/sq. ft. of wetted soil area per day which is equivalent to 0.06 to 0.38 cm/hr.

A new, innovative concept which appears to have distinct possibilities is the use of organic liners which was first reported by Mirtskhulava et al. (1972). They reported that activities of certain anaerobes cause a chemical reduction which results in accompanying increased dispersity, plasticity and a decrease in water permeability. Mirtskhulava, who has reported the U.S.S.R. patented process, does not describe the necessary details such as suitability of materials, rates of application, and associated experimental results.

This paper will report some of the results from laboratory and field studies on control of seepage by the use of sodium carbonate, patented chemical called SS-13 and organic liners.

#### MATERIALS AND METHODS

##### Laboratory Methods

The soils that were used for test purposes consisted of subsoils of the Wood Mountain loam and Hatton sandy loam series that are known to seep. Soils used for analyses and test purposes were air-dried and passed through a 2-mm sieve. Table 1 gives the soil textural characteristics.

Table 1. Soil Textural Characteristics

	% C	% S	% Si
Wood Mountain silty loam - top soil	18	31	50
Wood Mountain clay loam - subsoil	40	25	35
Hatton fine sandy loam	10	79	11

Hydraulic conductivity tests were conducted using 3.2-cm diameter plastic tubes, 30 cm long. The bottoms of the tubes were equipped with a fine metallic screen that was covered with a fine layer of sand, 2 cm thick (Fig. 1). A column of soil, 10 cm in depth, was packed uniformly to a density of 1.3 g/cm<sup>3</sup> with a mechanical packer (Jackson, 1962). A constant head of water of 15 cm was maintained using a Mariotte siphon.

All tests were replicated and are listed as follows:

<u>Test</u>	<u>Control Method</u>	<u>Treatment</u>
1	None	Comparison of replicated checks.
2	Sodium carbonate	(a) $\text{Na}_2\text{CO}_3$ mixed in soil as per equation. (b) $\frac{1}{2}$ amount of $\text{Na}_2\text{CO}_3$ as per equation. (c) $\frac{1}{4}$ amount of $\text{Na}_2\text{CO}_3$ as per equation. (d) Check
3	SS-13	(a) As per instruction (one part per thousand parts water). (b) Check
4	Straw lined	(a) Covered with top soil. (b) Covered with subsurface soil. (c) Check.
5	Lined with straw and decayed material	(a) Straw line covered with subsoil. (b) Decayed material covered with subsoil. (c) Check.
6	Lined with various types of straw	(a) $5 \text{ kg/m}^2$ wheat straw (b) $5 \text{ kg/m}^2$ oat straw (c) $5 \text{ kg/m}^2$ barley straw (d) No treatment.
7	Barley straw liner in soils of various textures	$5 \text{ kg/m}^2$ barley straw lined in soils of: (a) 10% C, 70% S, 20% Si (b) 14% C, 59% S, 27% Si (c) 18% C, 49% S, 33% Si (d) 21% C, 39% S, 21% Si
8	Straw incorporated at various rates	(a) $15 \text{ kg/m}^2$ wheat straw mixed with soil (b) $10 \text{ kg/m}^2$ wheat straw mixed with soil (c) $5 \text{ kg/m}^2$ wheat straw mixed with soil (d) Check
9	Incorporation with various types of straw	(a) $5 \text{ kg/m}^2$ wheat straw mixed with soil (b) $5 \text{ kg/m}^2$ oat straw mixed with soil (c) $5 \text{ kg/m}^2$ barley straw mixed with soil (d) Check
10	Combination of gleiza-tion and other methods	(a) $5 \text{ kg/m}^2$ wheat straw mixed with $\text{Na}_2\text{CO}_3$ and soil. (b) $5 \text{ kg/m}^2$ wheat straw covered with a mixture of soil and $\text{Na}_2\text{CO}_3$ . (c) $5 \text{ kg/m}^2$ wheat straw covered with soil and a layer of bentonite.

### Field Studies

Several dugouts and ponds treated with sodium carbonate and with straw liners were observed over a two- to three-year period. Observations consisted of observing the rate of drop of water surfaces for various treatment conditions. Prior to treatments, soils were sampled and analysed for texture and chemical parameters if the sodium carbonate method was used.

## RESULTS AND DISCUSSION

### Laboratory

An evaluation of the methodology by comparison of replicates is given in Fig. 2. It was found that the use of a soil packer built by Jackson (1962) resulted in reproducible results which was considered essential for the comparison of various methods of seepage control.

The sodium carbonate method was evaluated (Fig. 3) and the results were comparable with those of Graveland (1973). The equation for determining the amount of sodium carbonate was considered acceptable for controlled laboratory conditions.

The use of SS-13 as per label instructions did not prove to be satisfactory (Fig. 4). In repeated trials, seepage rate was lower than the check only during the initial stages of the test. For the Wood Mountain loam soil, the chemical did not prove satisfactory. Tests were not conducted on other types of textured soils.

The use of straw as a lining material was evaluated (Fig. 5) following the rate recommended by Mirtskhulava et al. (1972). A test was conducted to determine whether it was necessary to cover the straw liner with topsoil in order to enhance the gleization process. The test indicated that the use of topsoil did not either enhance gleization nor impede the microbial process when compared to straw covered with subsoil.

A test was conducted to determine whether decayed material such as straw or manure could be used as a lining material (Fig. 6). Results of the test indicated decayed material was equally acceptable as straw. The advantage of using decayed material as a liner was that the initial seepage rate was greatly reduced in comparison to that lined with straw. However, the time span for the decayed material to cause seepage reduction to an acceptable level was somewhat longer.

Comparative tests were made to evaluate various types of straw material that might be used as liners. Wheat and barley straw were found to be equally acceptable as a source of lining material. The oat straw reduced seepage a level somewhat higher than wheat and barley straw.

Mirtskhulava (1972) reported that anaerobes cause a chemical reduction of the clay particles in the soil. In a test to evaluate the lower limits of clay in which the process of gleization can be employed, it was found that gleization did occur in soils containing clay contents as low as 10%. Seepage in the soil containing a clay content of 10% was reduced to an acceptable level by the gleization method.

Since straw liners might prove to be costly and difficult to install, the concept of incorporating straw into the soil was considered. A test was designed in which rates of straw of 5 kg/m<sup>2</sup> to 15 kg/m<sup>2</sup> were mixed in with soil. Results of this test (Fig. 9) indicated that the seepage rate was reduced to a level of 1 cm/hr which is not considered to be acceptable for practical purposes. It is believed that a seepage of .1 cm/hr can be tolerated in field situations. It was found that as the rate of straw was increased, the seepage rate or hydraulic conductivity was reduced. Following the same concept, a test was also conducted in which 5 kg/m<sup>2</sup> of wheat straw, oat straw and barley straw was incorporated into the soil. Similarly, it was found (Fig. 10) that a variation in soil materials did not reduce the hydraulic conductivity to a level of .1 cm/hr which was considered necessary. However, it was observed that oat straw did not reduce the seepage rate to the same level as wheat or barley straw when incorporated into soils.

Because the gleization method of seepage control was very much a time-dependent process, a combination of gleization and use of sodium carbonate and use of bentonite was employed in a laboratory study (Fig. 11). In this manner, it was anticipated that bentonite or sodium carbonate would control seepage to an acceptable level until the process of gleization occurred within the soil. It was found that sodium carbonate incorporated with the soil which covered the straw layer or the use of bentonite over soil over straw was equally acceptable. A test conducted in which sodium carbonate was incorporated with straw and soil did not reduce the seepage rate to a level of 0.1 cm/hr that was deemed as a necessary minimum.

#### Field Studies

Field trials of the sodium carbonate method of seepage control have been conducted by a number of farmers in Southwestern Saskatchewan. Effective control was achieved only in 35% of the reservoirs treated. It would appear that the treatment procedure must be strictly adhered to in order to ensure success. Another factor that may have contributed to the failures was isolated pockets of sand in the reservoirs treated. However, reservoirs which did hold water after the first season of use, continued to hold water after four years without an increase in the seepage rate. Based on a large number of soil analyses, an empirical relationship was developed to determine the cation exchange capacity based on soil textural analyses for percent clay content. This equation, found to be generally applicable to a number of soils in Southwestern Saskatchewan is given as follows:

$$CEC = 1.59 + 0.63 C$$

where CEC = meq/100 g; and C = % clay content.

This empirical relationship should only be used if the chemical analyses of the soil to be treated with sodium carbonate are not readily available.

Only two reservoirs have been treated with organic liners -- one with straw and the second with decayed straw and barnyard manure. After two years, the seepage rate in these reservoirs had been reduced to an acceptable level. Field inspection has indicated that gleization had occurred. A layer of blue-gray material beneath the organic layer had extended to a depth of 6 to 12 inches after a period of two years. A number of reservoirs and an irrigation canal have been lined with organic liners in 1976. These installations will also be monitored in the future.

### CONCLUSIONS

The use of sodium carbonate as a method of seepage control is considered acceptable. Based on field experiences, it appears that the treatment procedures must be strictly adhered to in order to ensure success. If the waters contained in the reservoirs treated with sodium carbonate are high in calcium and magnesium, the effectiveness of the treatment is expected to decrease with time. If seepage reoccurs, additional sodium in the form of sodium carbonate or sodium chloride may be added to improve seepage control.

The microbiological gleization process of controlling seepage is considered to be most promising. Wheat straw, barley straw or decayed organic material is a preferred source of lining material. Rate of application of organic material of 4 kg/m<sup>2</sup> is considered to be satisfactory. Laboratory studies have shown that incorporation of the organic material within the soil does not reduce the seepage rate to an acceptable level.

A laboratory test with SS-13 as a method of controlling seepage has shown not to be effective on a Wood Mountain loam soil. Based on limited testing, it is believed that other methods such as the gleization method or sodium carbonate method are more acceptable.

### REFERENCES

- Graveland, B.N. and Olynyk, G. 1973. Laboratory tests on the use of sodium carbonate for reducing permeability in soil columns. CSAE 15(1): 12-14.
- Reginato, R.J., Meyers, L.E., and Nakayama, Francis S. 1968. Sodium carbonate for reducing seepage from ponds. W.C.L. Report #7, U.S. Water Conservation Laboratory, U.S. Department of Agriculture, Phoenix, Arizona 85040.
- Mirtskhulava, et al. 1972. Effect of microbiological process on percolation of water through soil. pp. 713-721 In Fundamentals of Transport Phenomena in Porous Media. I.A.H.R.S. - I.S.S.S. Symposium, University of Guelph.

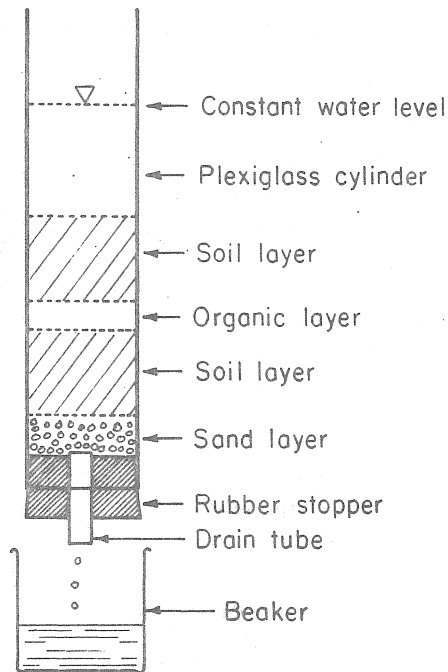


Fig. 1. Schematic of apparatus for seepage studies.

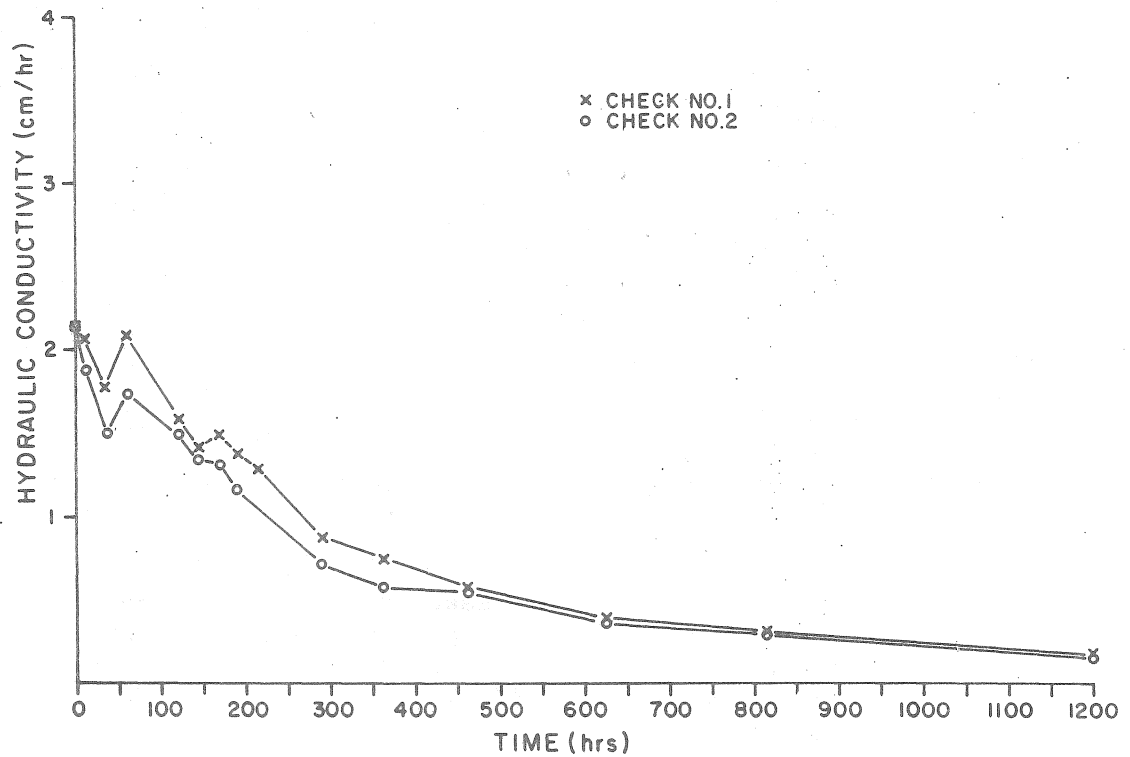


Fig. 2. Comparison of hydraulic conductivities of replicate check samples.

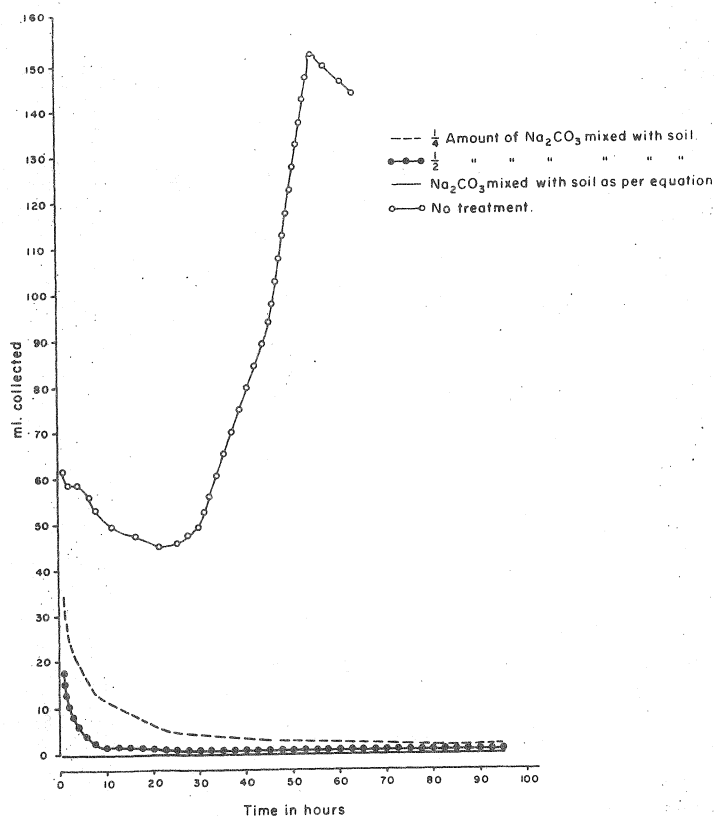


Fig. 3. Hydraulic conductivities for various rates of application of sodium carbonate.

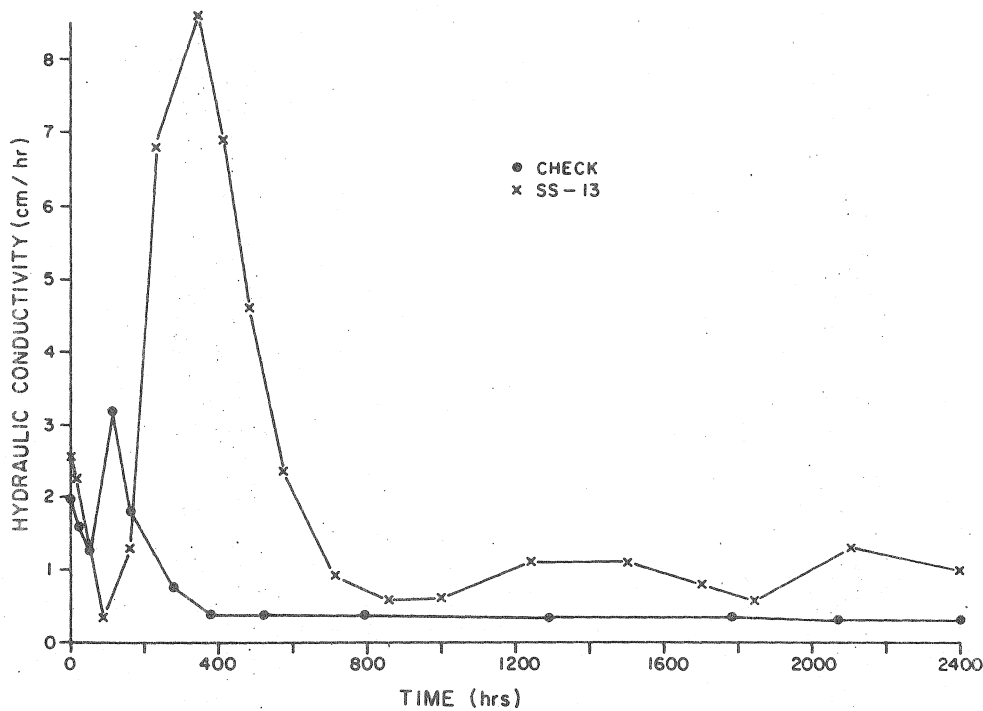


Fig. 4. Seepage rates using the SS-13 treatment.



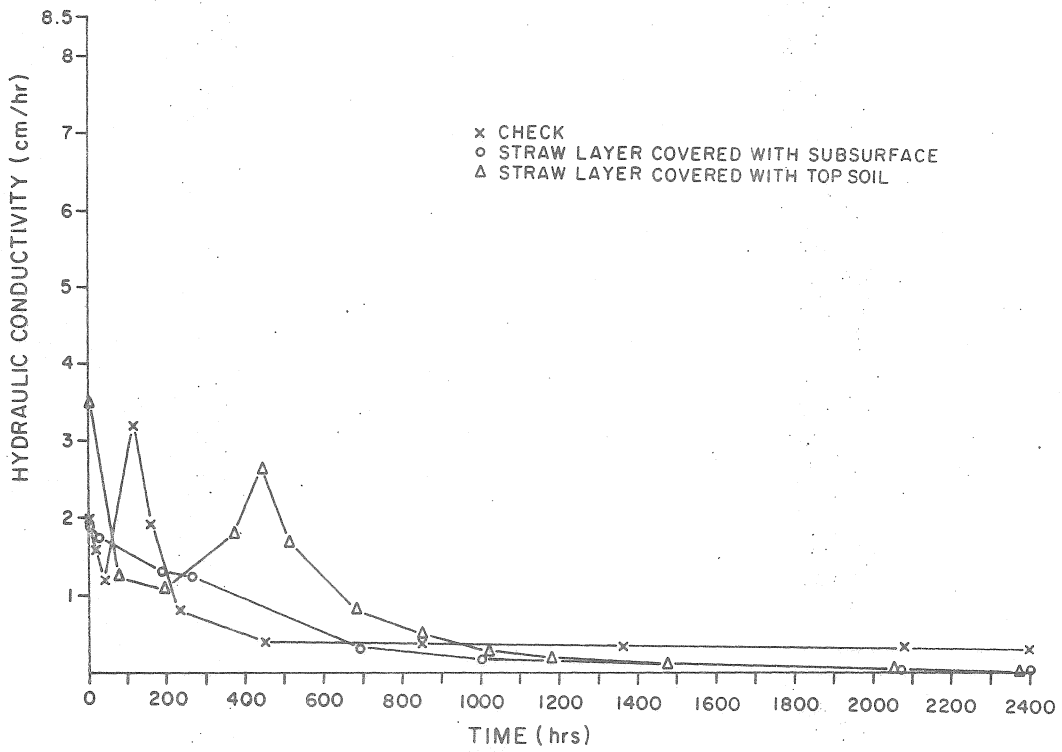


Fig. 5. Effect of topsoil on the gleization method of seepage control.

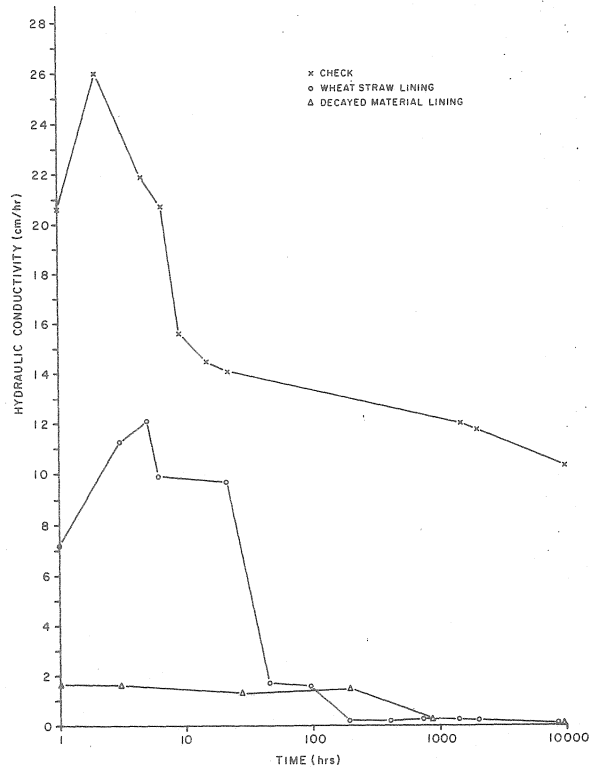


Fig. 6. Decayed material compared to straw as an organic liner for seepage control.

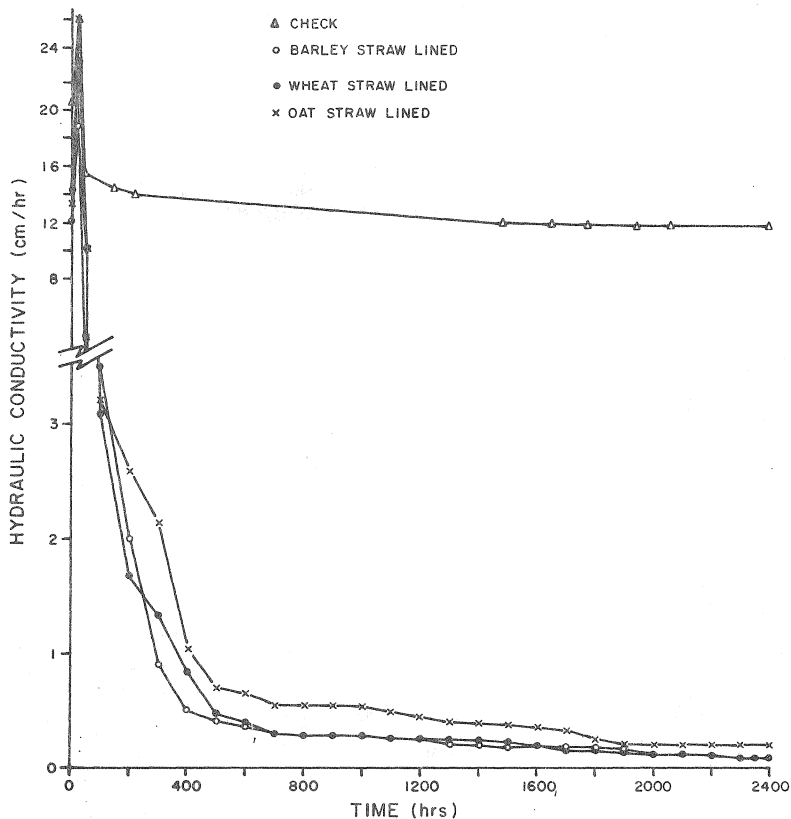


Fig. 7. Comparison of wheat, oat and barley straw as an organic liner for seepage control.

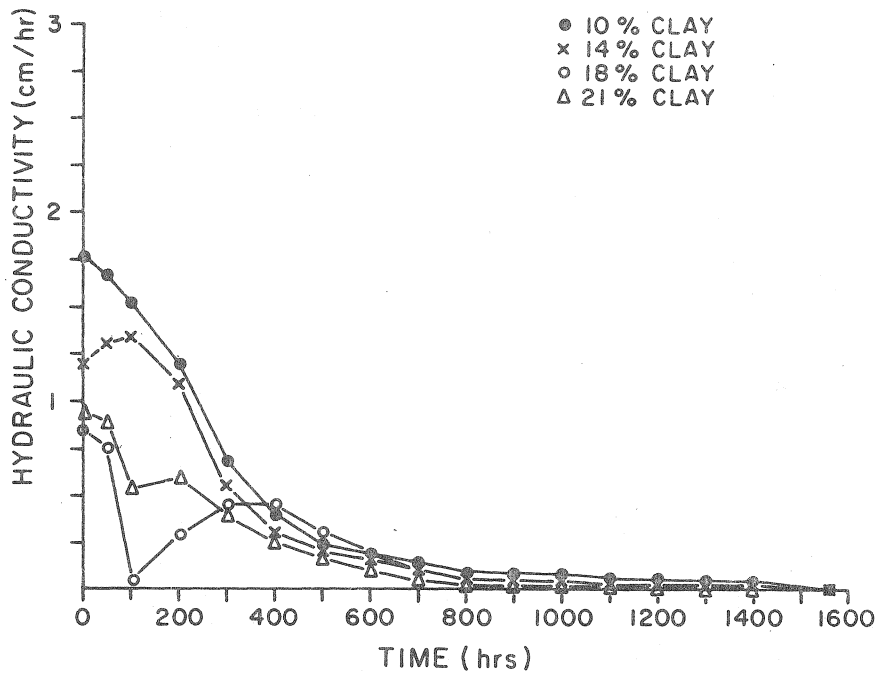


Fig. 8. Effect of clay composition on the gleization method of seepage control.

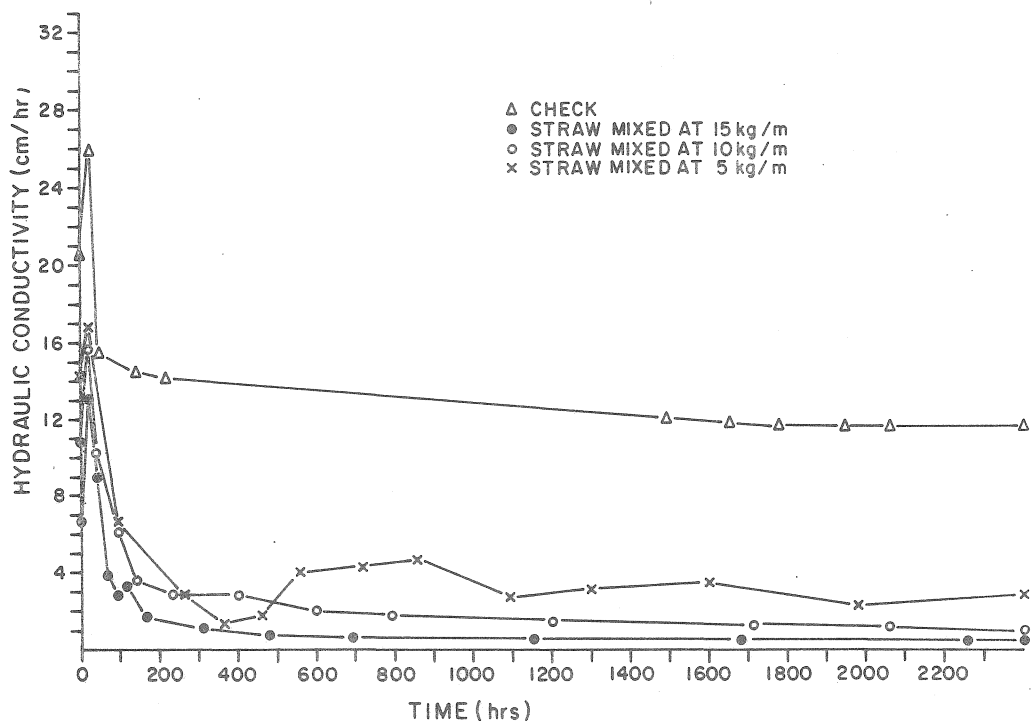


Fig. 9. Effect of rates of straw incorporated with soil on seepage control.

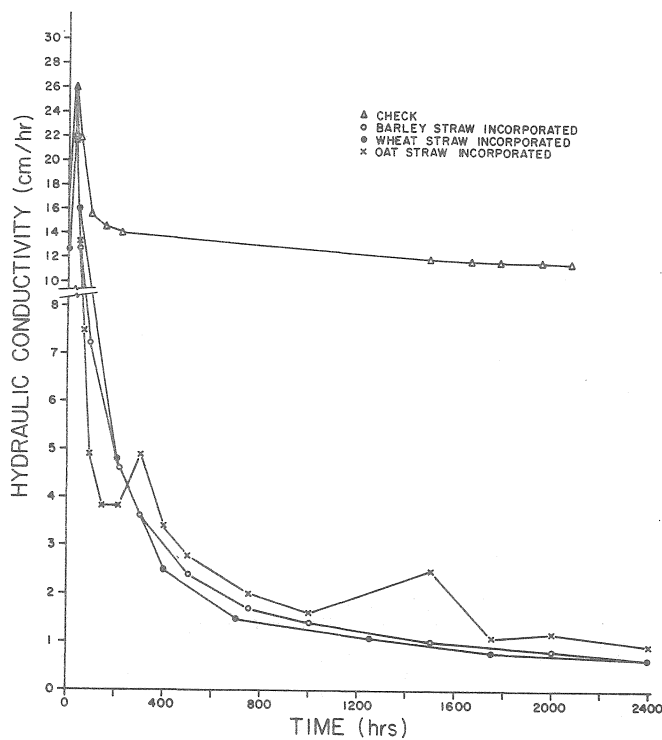


Fig. 10. Effect of wheat, oat and barley straw when mixed with soil on seepage control.

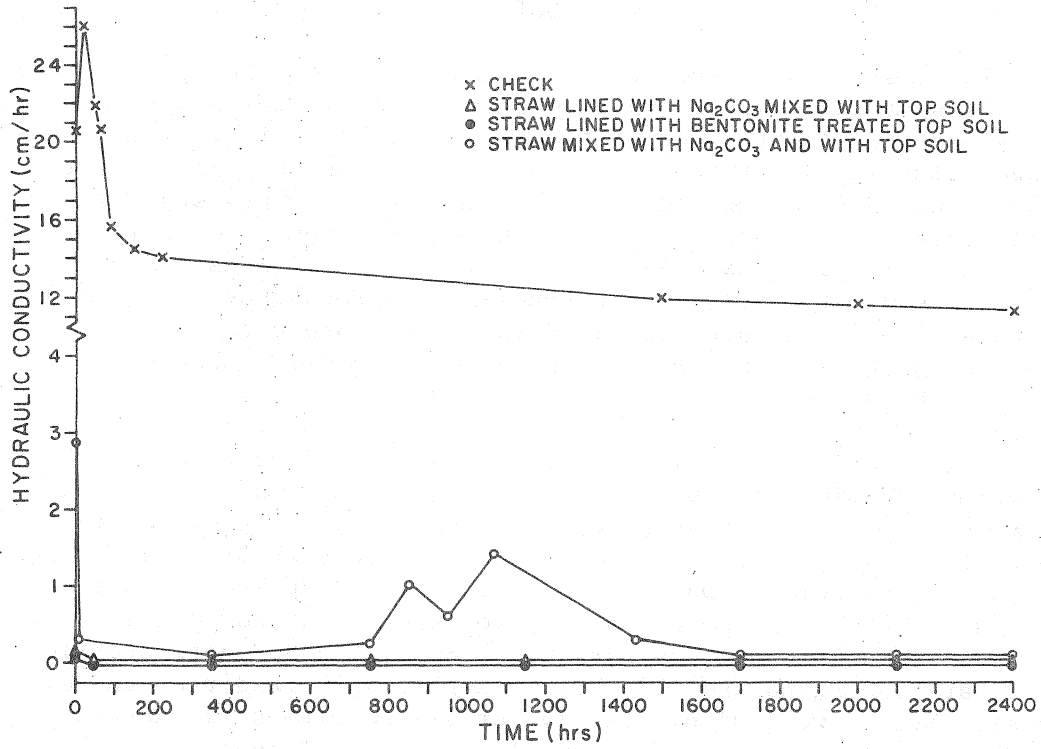


Fig. 11. Gleization method combined with sodium carbonate and bentonite method of seepage control.