The problems of equivalency of alternative barrier systems used as waste deposit liners

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ABSTRACT: The Hungarian regulation of waste disposal allows the use of alternative barrier systems instead of the standard, prescribed ones in case of proven equivalency. The authors developed the methodology and a numerical tool for equivalency calculations. The paper deals with the calculation method of equivalency and reports some problems of using alternative components (s.a. GCLs) in the barrier-system.

1 INTRODUCTION

The efficient isolation of waste bodies due to bottom lining systems became a standard in Hungary. Hungary has approximately 3200 municipal waste disposal facilities, which means that practically every settlement has its own landfill. Due to the large number of landfills they are small in size, out-of-date in performance, most of them have no technical lining system. Significant change occurred in the early 1990-es, when the concept of regional disposal facilities gained priority. From the waste management perspective it is reasonable to build approximately 60 regional landfills in Hungary, however based on the tendencies of the last years it is anticipated that 100-120 landfills will be built, from which 15 has been built yet.

The regional waste deposit sites constructed in the past few years has a bottom lining system according to the Hungarian regulation of waste disposal, which was descripted in several publications (Szabó & Kovács 2000). The Hungarian regulation is compatible to that of most of the European countries (ISSMFE TC5 1997) with exception of the possible use of alternative barriers. The only criterion of application is the alternative versus standard liner equivalency against the different transport processes (s.a. advection, dispersion, adsorption, etc.).

However, the investors lead by economic aspects try to find the cheapest solution for isolation, and that strengthened the intention of the use of geosynthetic clay liners (GCL) to substitute the standard compacted clay liners (CCL) in lack of suitable clay resources in the surrounding of the site. This fact take the problem of alternative barrier equivalency into the highlights, so numerical equivalency calculations based on series of laboratory investigation were performed.

2 THE USE AND BEHAVIOUR OF GEOSYNTHETIC CLAY LINERS

Geosynthetic clay liners appeared at the end of the 80's and since than they have increased the role among mineral liner systems. Several of their beneficial characteristics result in a wide scale of applicability in road-, and railway construction, hydraulic engineering, and in the field of environmental protection. Their application in landfill lining systems as substitute of the multiple layered clay lining is usually not adhered by the Hungarian regulative bodies. In case of Tatabánya landfill it was used though, but only as the mineral liners of the landfill sidewalls.

Two types of European commercial GCL-s available in Hungary were tested in laboratory. Since we would like to focus on their different behaviour, that is why their brand name is intentionally not mentioned (Let us say type A and B). The following sections show some examples of the above mentioned concerns.

2.1. Hydraulic behaviour of GCLs

The hydraulic conductivity of GCL-s is largely influenced by the hydration of its bentonite content. In real conditions it common that the GCL is exposed to rainfall or its hydration occurs before the waste load would be placed above it. Figure 1 shows the different behaviour of two saturated GCL-s (A and B) in a triaxial cell with 30kPa cell pressure. The hydraulic conductivity of the two bentonite GCL-s measured under same conditions after their saturation, resulted one order of magnitude difference. However, if the saturation of type A in the triaxial cell was conducted at σ_h=30kPa cell pressure and on a larger σ_n=80kPa normal pressure, the measured value of hydraulic conductivity was much favourable, it decreased with approximately one order of magnitude (Figure 2). GCL type A might be filled with bentonite granulate or powder. Figure 2 shows that the GCL with powder filling is more efficient.

Using GCLs at the sites there are overlapping parts at the edges. To investigate the isolation efficiency flexible wall permeability tests of the overlapping parts were performed using the two different GCL brands (Figure 3.).

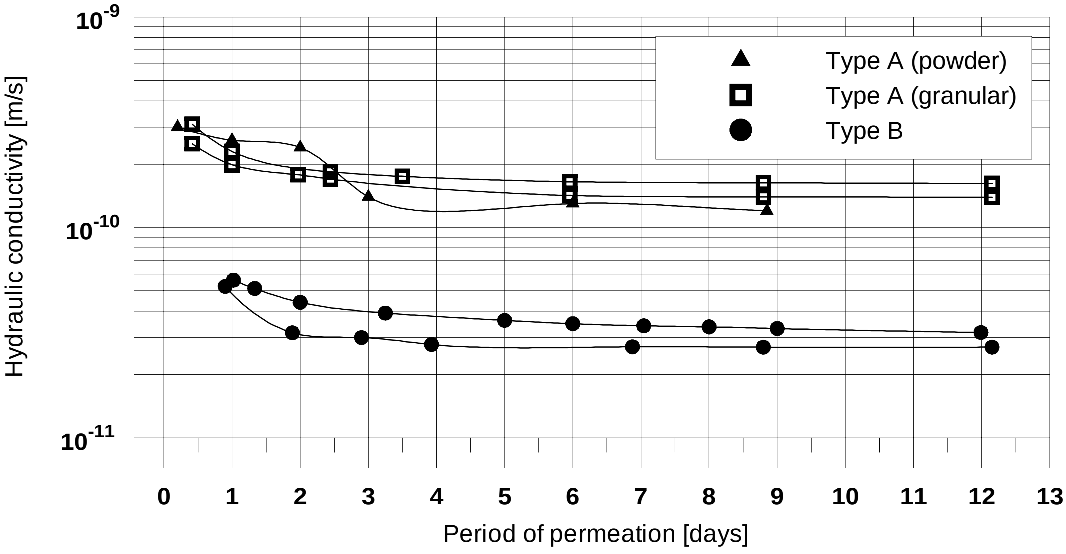


Figure 1. Measured hydraulic conductivity versus time

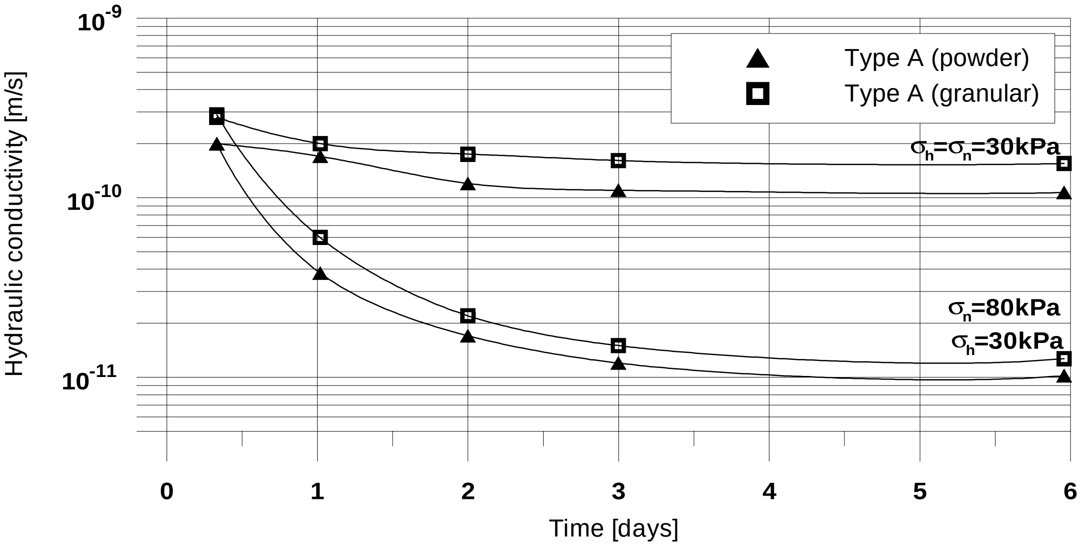


Figure 2. Effect of normal load on the hydraulic conductivity of GCL type A

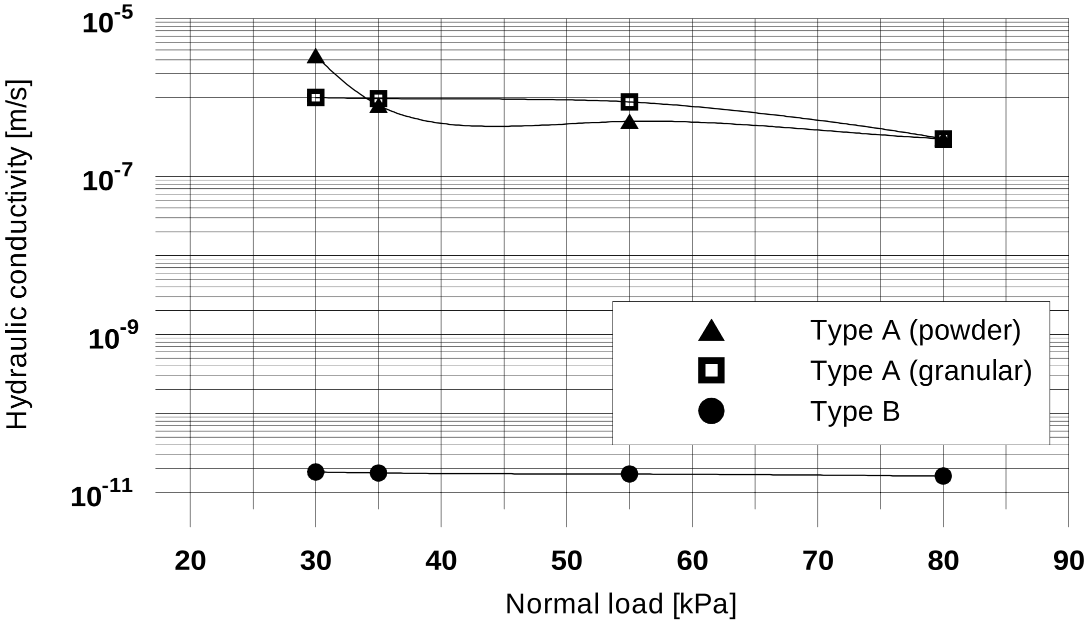


Figure3. Effect of normal load on the hydraulic conductivity of overlapped GCLs

Since the bottom lining system of the waste deposit is only partly covered by the waste in the first period after construction, the non-covered parts are heavily exposed to the varying meteorological circumstances. To test the effect of this phenomena number of freeze-thaw and wet-dry cycles were also completed (Figures 4. and 5.).

During all the tests there was a clear difference between the measured hydraulic conductivities: the isolation efficiency of type B GCL was much higher than that of type A. However, the root of the different behaviour of the tested GCLs is the mineralogical composition of the fill-material of the two products (Table 1.). It is apparent, that the mineral composition of type A is more favourable, with its higher ability to expand, and even in the lack of normal stress the desired density and impermeable structure is achievable. On the contrary, in case of type B the desired impermeability was achieved only, when the expansion was hindered or obstructed while saturation occurred.

2.2. Transport behaviour of GCLs

The migration of contaminants is due to four different processes: advection, dispersion, adsorption and degradation. The contaminant retention efficiency of GCLs is widely different regarding the mentioned processes, that is why different types of barrier equivalency is to be defined. (Czinkota et. al 1998)

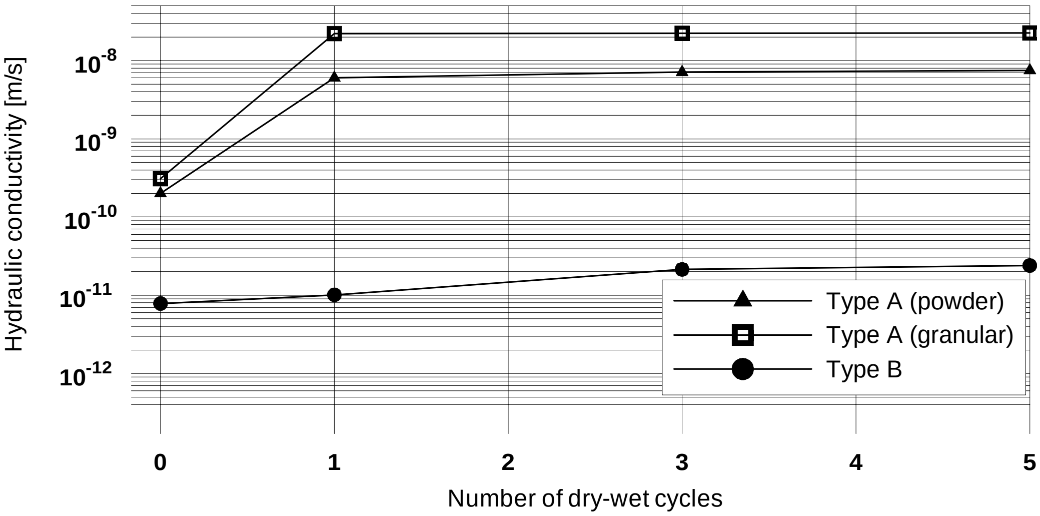


Figure 4. Effect of dry-wet cycles on the hydraulic conductivity of GCLs

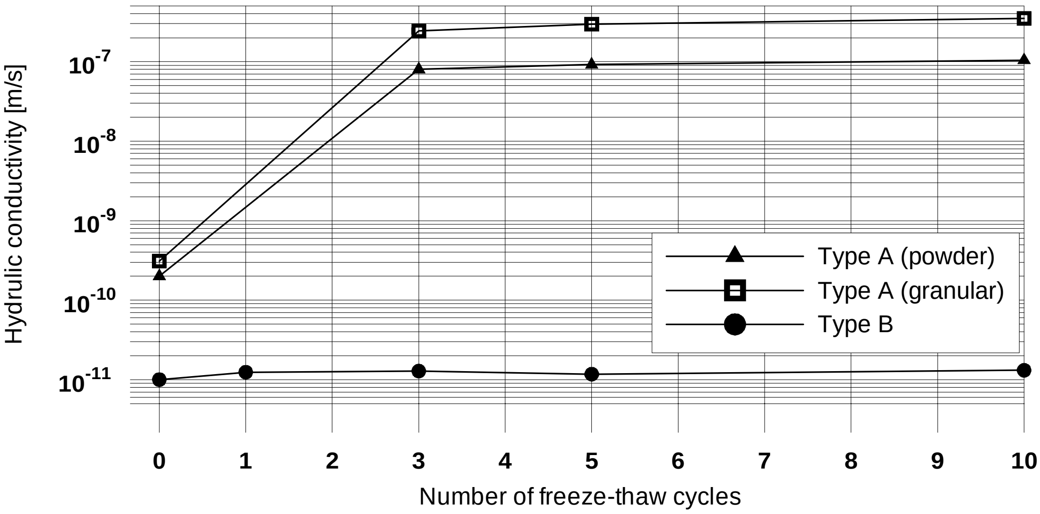


Figure 5. Effect of freeze-thaw cycles on the hydraulic conductivity of GCLs

Table 1. Mineralogical compound of the fill-material of the tested GCLs: Na-montmorillonite (Na-M), Cristoballite (Crist), Kaolinite (Kaol), Illite (Ill), Plagioclase (Plag), Quartz (Q), Amorphous components (Amorph), Gypsum (Gy)

Brand	Na-M	Crist	Kaol	Ill	Plag	Q	Amorph	Gy
Type A	59%	25%	3%	4%	2%	3%	5%	n.d.
Type B	81%	n.d.	n.d.	n.d.	3%	5%	5%	1%

Advective equivalency. Two barriers are equivalent against advection if the concentrations on the protected side - due to equal hydraulic and concentration gradient - are equal, taking only the advective transport process into consideration. Advective equivalency means the hydraulic equivalency as well.

Diffusive Equivalency. Two barrier-systems are equivalent against diffusion if the resulted fluxes due to diffusive mass transport are equal, considering a given concentration gradient. The definition of diffusive equivalency was given by Kohler and Heimerl (1995)

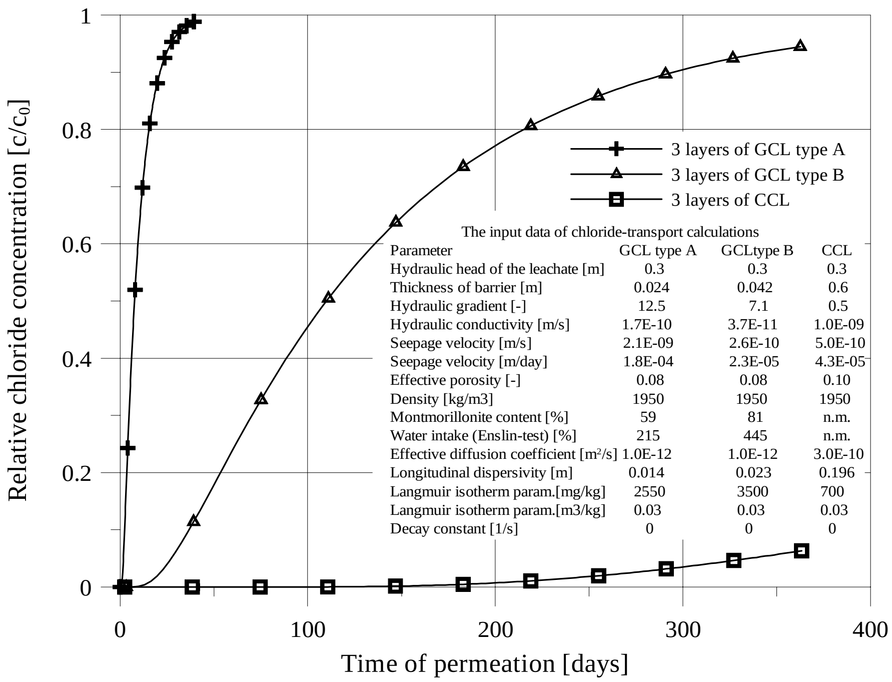
Advective-dispersive equivalency. A calculation method of advective-dispersive equivalency determination introduced by Shackelford in 1990. The dependence of the relative concentration versus time at different Peclet numbers was derived from the 1D solution of the transport equation for column-studies (Ogata 1960). Using that function, the time of reaching a given concentration on the protected side of the barrier might be calculated.

Complex (numerical) equivalency. To overcome the limitations of the above mentioned equivalency calculation methods the complex equivalency calculations were introduced, where all the relevant transport processes (advection, diffusion, dispersion, adsorption, precipitation, volatilisation, degradation etc.) might be taken into consideration both in saturated or unsaturated environment. The material properties and/or the leachate concentration may vary during the calculation. The calculation is completed using the 1D FDM solution of the transport equation. The modelled column is divided into cells, which are characterized by different material properties. As a result of the calculation, the time dependent concentrations at different cells of the column are gained.

Concerning the contaminant retention capacity of GCLs' it was proved, that

- a GCL layer is generally equivalent to a compacted clay liner (CCL) of 20 cm thickness in terms of advective transport fluxes. The condition of equivalency is the high smectite (montmorillonite) content, which causes a big swelling capacity and a hydraulic conductivity less than or equal to $5\text{-}8 \cdot 10^{-11}$ m/s.
- the GCL is generally not equivalent to the CCL concerning the diffusive contaminant transport. To fulfill the equivalency, the ratio of effective diffusion coefficient of the GCL should be 400 times less then that property of the clay liner, taking respectively 1 cm versus 20 cm thickness into consideration.
- since the seepage velocity is low through the barrier, the diffusion is dominant over the advection, so the complex equivalency of GCL to CCL during the transport process is not reached.
- the higher adsorption capacity of GCL is generally not enough to compensate the lack of diffusive equivalency.

Since the transport process is solute specific, the efficiency of the GCL barrier is p pollutant dependent. To demonstrate the above statements, calculations were completed concerning chloride transport through the investigated two GCL-s and a compacted clay liner. The calculations were completed with the code developed for complex equivalency calculations (Czinkota et.al., 1999). The material and transport-properties, the hydraulic conditions and the results are presented on Figure 6. The completion of the break-through took 41 days in case of the less effective GCL (type A), and 14 months even for the good quality GCL (type B), taking 0,3m hydraulic head of the leachate into consideration in both cases. In comparison with the compacted clay the relative concentration for the fast migrating chloride was about 6 %.



The input data of chloride-transport calculations

Parameter	GCL type A	GCLtype B	CCL
Hydraulic head of the leachate [m]	0.3	0.3	0.3
Thickness of barrier [m]	0.024	0.042	0.6
Hydraulic gradient [-]	12.5	7.1	0.5
Hydraulic conductivity [m/s]	1.7E-10	3.7E-11	1.0E-09
Seepage velocity [m/s]	2.1E-09	2.6E-10	5.0E-10
Seepage velocity [m/day]	1.8E-04	2.3E-05	4.3E-05
Effective porosity [-]	0.08	0.08	0.10
Density [kg/m3]	1950	1950	1950
Montmorillonite content [%]	59	81	n.m.
Water intake (Enslin-test) [%]	215	445	n.m.
Effective diffusion coefficient [m^2/s]	1.0E-12	1.0E-12	3.0E-10
Longitudinal dispersivity [m]	0.014	0.023	0.196
Langmuir isotherm param.[mg/kg]	2550	3500	700
Langmuir isotherm param.[m3/kg]	0.03	0.03	0.03
Decay constant [1/s]	0	0	0

Figure 6. The calculated break-through curves for the investigated GCL-s and a compacted clay liner

SUMMARY AND CONCLUSIONS

The hydraulic and transport behaviour of GCL vs. CCL was partly tested in laboratory, partly investigated using equivalency calculations. The results showed that there are big differences between the used GCLs, so both the hydraulic both the transport characteristics of each applied brand should be tested. It was also proved that GCLs are generally not equivalent to CCLs because their reduced thickness.

The statements above must draw our attention to an internationally accepted standardization of suitability testing, which must target the most accurate modelling of the in situ conditions.

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