Proceedings of the first Geologica Belgica International Meeting, Leuven, 11-15 September 2002
Aardk. Mededel., 2002, **12**, 261-264

The suitability of some Belgian Tertiary clays as construction material for landfill seals: interaction with domestic landfill leachates

R.M. Schmitz[1], A.S. Ourth[2], D. Dosquet[3], P. Illing[1], C. Schroeder[1], J.-C. Verbrugge[4], A. Bolle[1], R. Charlier[1] & J. Thorez[3]

1. GéomaC, Université de Liège, Chemin des Chevreuils 1 - Bât.B52/3, 4000 Liège, Belgium, RM.Schmitz@ulg.ac.be
2. LGE, Faculté Universitaire des Sciences Agronomiques de Gembloux, Passage des Déportés 2, 5030 Gembloux, Belgium
3. LGA, Université de Liège, Boulevard du Rectorat 17 - Bât. B18, 4000 Liège, Belgium
4. LJV, Université Libre de Bruxelles, Avenue F.D. Roosevelt 50 - Bât. C, 1050 Bruxelles, Belgium

ABSTRACT

Clays used as engineered barriers in landfills need to contain hazardous waste during hundreds of years. When clays are exposed to landfill leachates alteration processes occur. These alteration processes can affect the long-term behaviour of the clay, depending on the clay mineralogy and the composition of the landfill leachate. Geotechnical tests have been performed to analyse these changes. Changes in permeability have been observed concurrently with changes in clay mineral composition.

KEYWORDS

Clay-mineral-alteration, geotechnical-characteristics, landfill-barrier, landfill-leachate

Introduction

Huge amounts of waste are generated each day: The European Community produces each year around $2\cdot10^9$ tonnes of waste. This means that one kg of municipal solid waste is created each day by each European. Over the last six years, the amount of waste grew by 10% a year (EU focus on waste management 1999). This waste needs to be isolated, during long periods (several hundreds of years) from the biosphere in order to avoid contamination of ground water and surface water. Because of their specific properties, low permeability, high cation exchange capacity natural clay materials can be used as a seal to contain the waste. Clays are known to change their mechanical properties when they are exposed to aggressive leachates; however, little is known about the interaction of real clays and genuine landfill leachates. In this contribution, one focuses on the interaction of three Belgian Tertiary clays when in contact with domestic landfill leachates.

Materials

The materials that were used were natural Tertiary clays obtained from Soignies and Tournai (Ypresian) and from Kruibeke (Rupelian). The clays consisted of illite, an illite-montmorillonite (10-14m) and an illite-chlorite mixed layer (10-14c), chlorite and kaolinite. The leachates were obtained from three landfills in Wallonia of different ages (detailed description in Schmitz *et al.* 2001), reflecting the changing properties of ageing landfill leachate.

Geotechnical characteristics

Clays that are going to be used as landfill barrier need to have several special and contradicting characteristics:
1) permeability needs to be low
2) need a large cation exchange capacity
3) need to be flexible
4) need to be workable
5) be able to fulfil their function during the lifetime of the landfill

The workability of clays is given for example in the ManWal (2001) in terms of their Atterberg properties. The average Atterberg properties of the three tested clays (after gentle drying at 30°C and grinding) are given in table 1.

Table 1. Average Atterberg properties of the three clays.

Clay type	LL (%)	PI (%)
Kruibeke	61.2	33.0
Soignies	36.9	18.2
Tournai	114.5	79.3

If these values are compared to those still deemed workable by the ManWal (2001):
- Liquid limit: LL<80%
- Plastic limit: 10%<PL<40%

One is able to observe that e.g. the Soignies clay would be suitable but that the Tournai clay, is in terms of workability too plastic (Fig. 1). Even Kruibeke and Soignies samples subject to the influence of the leachates (clay stored during several months at 50°C and room temperature with different landfill leachates), all the data-points were within the limits. Leachate contact did not cause the Atterberg values of the Kruibeke and Soignies clays to change to such an extent that the boundary would be trespassed. The main factor to be taken into account is, however the permeability.

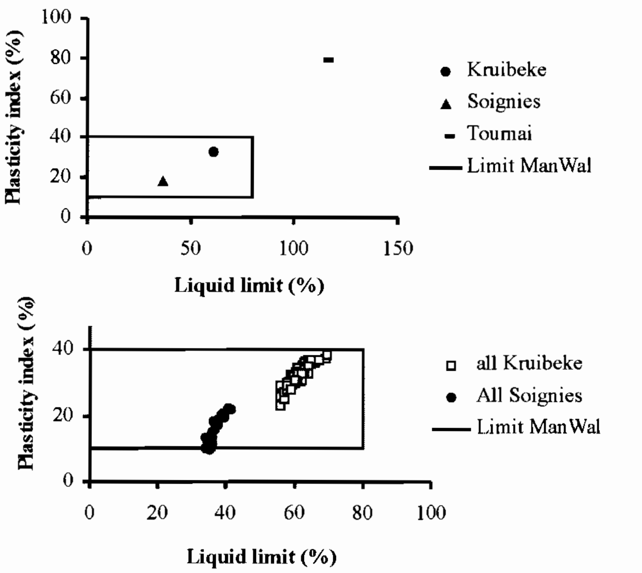

Fig. 1. The average Atterberg values of 100 batch tests and the workability boundaries.

Permeability

The permeability was measured in modified oedometers (falling head tests) and triaxial cells (constant head tests), the results are given below:

- Natural Tournai clay with tap water $0.3\text{-}0.5 \cdot 10^{-10}$m/s, with a relative young landfill leachate: $0.09\text{-}0.2 \cdot 10^{-10}$m/s
- Natural Soignies clay with tap water $7.3\text{-}67 \cdot 10^{-10}$m/s, with a relative young landfill leachate: $2 \cdot 10^{-10}$m/s
- Previously dried and ground Kruibeke clay stored and tested with demineralised water: $3.9\text{-}15 \cdot 10^{-10}$m/s, the same clay stored and tested with a young landfill leachate: $0.8\text{-}2.2 \cdot 10^{-10}$m/s. But if the same clay was stored with demineralised water and tested with a young landfill leachate one was not able to measure any change.

Natural samples were statically compacted with a compaction pressure 1.1-1.7MPa. Their dry density was higher than the proctor density and the confining pressure during the permeability tests in a triaxial cell was 4MPa.

Dried and ground clay was tested in a modified oedometer cell. The sample was compacted before the test up to 80% of the optimum proctor density.

All clays fulfilled the values given by the EU (European Union Directive 1999) and the ManWal (2001): $<1 \cdot 10^{-9}$m/s. But taken into account that the permeability measured in the laboratory is always more favourable (less permeable) than the overall permeability in the field e.g. given the reference by the TaSi, (a standard that gives guidelines for the permeability to be obtained in the laboratory to guarantee that the required permeability is obtained in the field): $5 \cdot 10^{-10}$m/s at i=30. One sees that although the workability of Soignies clay is quite good, the permeability is rather close to the limit. To test the influence of the leachate on the permeability the tests were repeated using a leachate. A change provoked by the leachates on the Kruibeke clay was a slowing down of the consolidation process, at several stress levels (50, 100, 200 400 and 800kPa) a decrease with a factor 1.7 to a value near $1 \cdot 10^{-8}$m^2/s. The values obtained by direct measurements of the permeability of samples contacted by leachates were:

- Natural Tournai clay permeability with a relative young landfill leachate: $0.09\text{-}0.2 \cdot 10^{-10}$m/s
- Natural Soignies clay permeability with a relative young landfill leachate: $2 \cdot 10^{-10}$m/s
- Previously dried and ground Kruibeke clay stored and tested with a young landfill leachate: $0.8\text{-}2.2 \cdot 10^{-10}$m/s. But if the same clay was stored with demineralised water and tested with a young landfill leachate, one was not able to measure any change with respect to the samples stored and tested with water.

For all the three clays measured with various methods, the effect of the leachate was a decrease of the permeability. In contrast to the permeability the parameters related to the structural strength remained unchanged. Tournai and Kruibeke clay tested with a young landfill leachate and water gave the same angle of internal friction (Tournai 27°, Kruibeke 32° scatter 29-34°) and the same order for the elasticity modulus (Tournai 36MPa) and the same consolidation coefficient (Kruibeke Cc=0.44 scatter 0.43-0.45). This clay material was stored longer than one month with leachate or water (ratio 8·LL for Kruibeke clay and 1·LL Tournai clay) then tested: oedometer test and CU-triaxial test preconsolidation stress 400kPa, OCR ratio 1.4 Tournai 2.3 Kruibeke clay.

By using X-ray diffraction analysis we tried to find out what mineralogical changes were developed when leachates were occurring.

Clay mineralogy

The mineralogy was determined using Liège Clay Laboratory sample preparation (ManWal 2001), analysing the total clay fraction and not only the fraction smaller than 2 microns, thus taking into account the total clay mineral fraction. The analysis revealed that the clays consisted of illlite, neoformed volcanogenic illite-montmorillonite (10-14m) mixed layers, illite-chlorite random mixed layers (10-14c), chlorite and kaolinite and in the Tournai clay additionally some natural pillared smectite, Al hydroxyls in the interlayers, (Sm_{Al}). The composition of the clay minerals in the natural materials is shown in Fig 2.

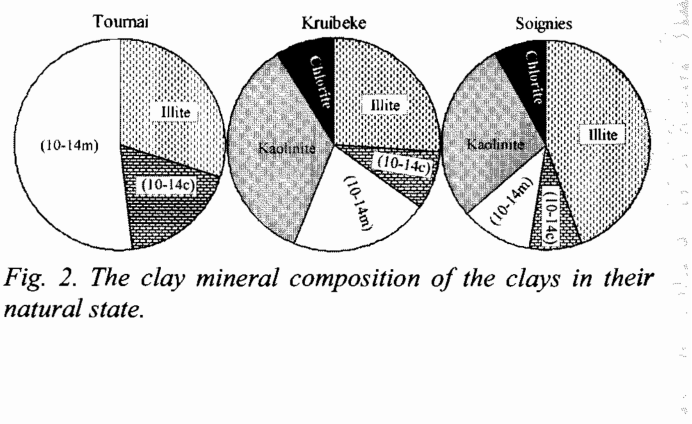

Fig. 2. The clay mineral composition of the clays in their natural state.

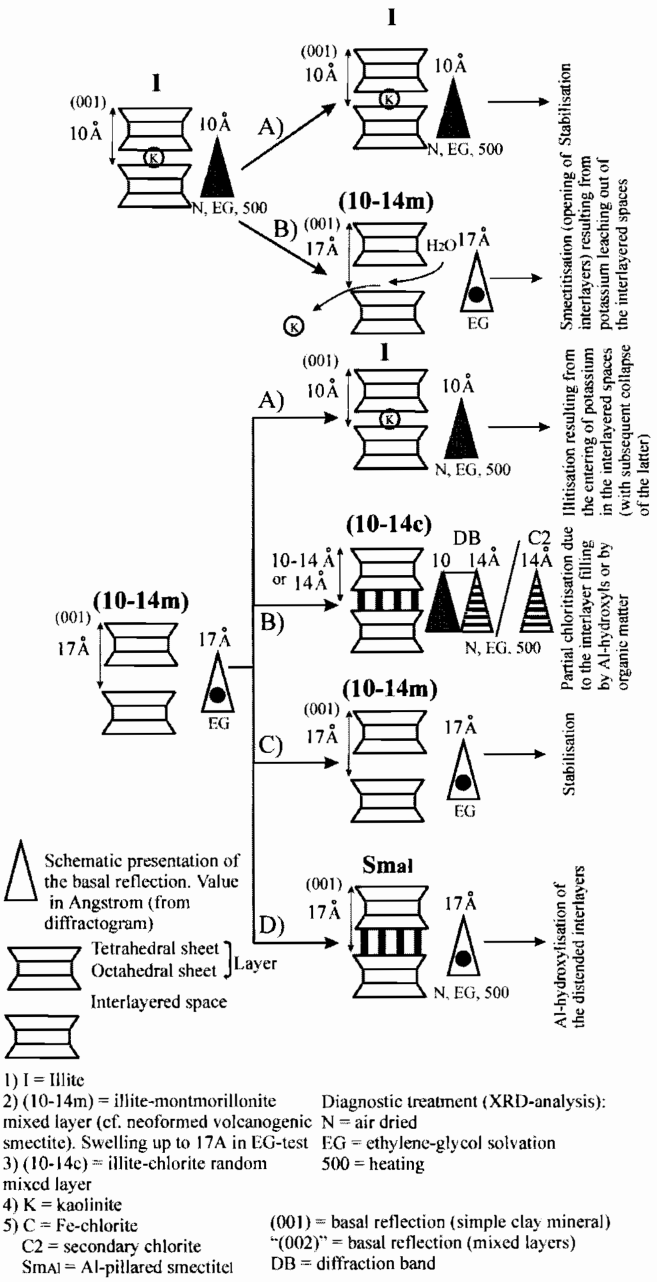

Fig. 3. A summary of the most dominant alteration processes.

We exposed the same clays to young and old domestic landfill leachates. The results showed that, although we did not observe any major shift in clay mineral compositions; we were dealing with the following processes (Fig. 3): smectitisation (left image), illitisation (pathway A, right image), secondary chloritisation (pathway B), Al-pillaring (pathway D) and kaolinisation. The most dominant processes in terms of magnitude were illitisation and smectitisation. Some of the changes measured during batch test, are shown in Fig. 4: leachate was added in different concentrations to the dried clay and stored up to six month at different temperatures.

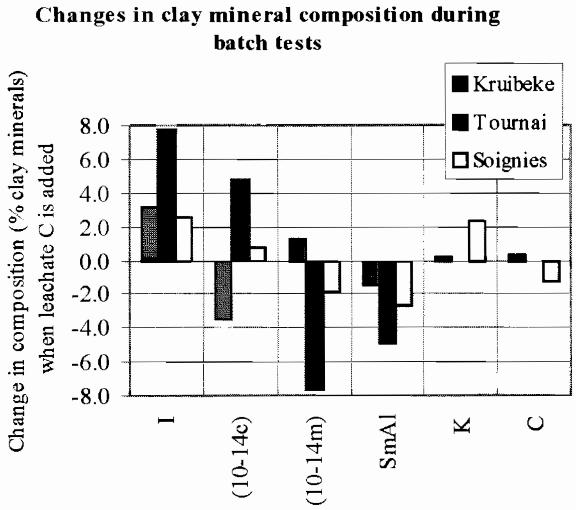

Fig. 4. Change in clay mineral composition when adding leachates.

A possible explanation for the decrease in permeability, the unaffected structural stability and the overall small changes in Atterberg properties and clay mineral content could be a partial smectitisation along preferential pathways in the remoulded natural clay (right hand side Fig. 5) or an overall slight modification of the clay mineral content affecting the permeability of the sample. This is only measurable after the storage (left hand side lower part) of the dried and ground clay with a leachate during a certain period of time (terms of months). It is not measurable when the clay was quickly permeated by the landfill leachate, without previous long-term storage

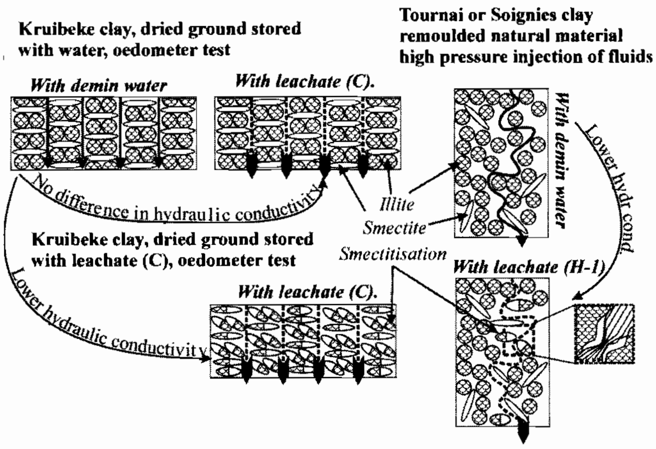

Fig. 5. Change in clay mineral composition when adding leachates.

Conclusions

In order to construct a landfill seal that must be able to contain the waste on the long term, it is important to take into account possible alteration processes of the clay. The short term effect (half a year) showed that the modifications were small (minor mineralogical changes) and in fact favourable because the leachates had the tendency to decrease the permeability. In the ideal case a multi mineral barrier should be used by combining the better workability and clay mineral stability of the low plastic clays with the high plastic clays which have a lower permeability and higher cation exchange capacity.

Acknowledgements
The research work described in this paper was supported by grants from the Belgian National Fund for Scientific research (FNRS). It was based on the 'Action de Recherche Concertée' of the 'Communauté Française de la Belgium', convention n° 99/04-243, entitled 'Confinement de centres d'enfouissement technique à l'aide de barrières argileuses. The support of the FNRS and that of the Communauté Française de la Belgium were gratefully acknowledged. The reference bentonite, product name: Colclay A-90, was donated by Ankerpoort N.V. Maastricht, The Netherlands.

REFERENCES

EUROPEAN UNION DIRECTIVE. 1999. Directive 1999/31/CE du Conseil du 26 avril 1999 concernant la mise en décharge des déchets. *OJ L series N° 182 16.7.1999*. Office for Official Publications of the European Communities, Luxemburg, 24 pp.

EU FOCUS ON WASTE MANAGEMENT. 1999. *EU focus on waste management.* Directorate-General Environment, Nuclear Safety and Civil Protection Luxembourg, Office for Official Publications of the European Communities, 18 pp.

MANWAL. 2001. *Manuel relatif aux matières naturelles pour barrières argileuses ouvragées pour C.E.T. (centres d'enfouissement technique) et réhabilitation de dépôtoirs en Région wallonne.* Ministère de la Région wallonne, Direction générale des Ressources naturelles et de l'Environnement, Office wallon des déchets, 79 pp.

SCHMITZ, R.M., DOSQUET, D., ILLING, P., RODRIGUEZ, C., OURTH, A-S, VERBRUGGE, J-C., HILLIGSMAN, S., SCHROEDER, C., BOLLE, A., THOREZ, J., CHARLIER, R. 2001. Clay – leachate interaction: a first insight. In: *6th KIWIR International Workshop on Key Issues in Waste Isolation Research.* Ecole Nationale des Ponts et Chaussèes. Paris, France, 28-30 November 2001, 245-269.

TA-SI. 1993. Technische Anleitung zur Verwertung, Behandlung und sonstigen Entsorgung von Siedlungsabfällen (Dritte Allgemeine Verwaltungs-vorschrift zum Abfallgesetz). Bundesminister für Umwelt, Naturschutz und Reaktorsicherheit. Bundesanzeiger Verlagsges.mbH, Köln. *Bundesanzeiger. Jhrg.* **45**, *99a.*