PROPERTIES OF BARRIER MATERIALS FOR LOW-LEVEL NUCLEAR WASTE DISPOSAL

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ABSTRACT

A database of the properties of materials which may be used in the construction of engineered barriers for the long-term containment of low-level nuclear waste (LLW) has been created at Brookhaven National Laboratory in Upton, New York. This paper describes what information is available through the database and how to access it. Properties of interest include hydraulic conductivity, sorbtive abilities, corrosion rates, diffusion coefficients, permeabilities, equilibrium distribution coefficients, structural integrity factors and strengths. Information contained in the database was gathered from a literature survey on the properties of potential engineered barrier materials.

INTRODUCTION

Disposal of low-level nuclear waste (LLW) can pose a threat to the health of current and future generations. Current disposal technology consists of shallow land burial, an approach similar to landfilling of municipal waste. To minimize potential danger, current research suggests that a multibarrier containment scheme for LLW is the best alternative for protecting the environment from the waste.

Low-level waste is disposed of in a form which acts to slow the release of radionuclides into the environment. One or more engineered barriers may provide secondary and subsequent levels of protection to the environment from dangerous materials in LLW. Finally, the geology of a disposal site provides a last measure of safety.

A database of the properties of materials, which may be used in the construction of engineered barriers, should assist in the design of low-level nuclear waste disposal facilities. Such a database has been created at Brookhaven National Laboratory in Upton, New York. This paper describes what information is available through the database and how to access it. Information contained in the database was gathered from a literature survey on the properties of potential engineered barrier materials.

LOGIC BEHIND SELECTION OF MULTIBARRIER SYSTEMS

Many LLW radioactive materials have relatively short half- lives, for example, on the order of thirty years. In three-hundred years a material with a thirty year half-life decays over 99.9%, resulting in extremely low-levels of radioactivity. However, some radionuclides have significantly longer half-lives and these materials will dominate the design of a disposal facility over its useful life. The Nuclear Regulatory Commission has promoted the idea of a design life of five hundred years for a low-level nuclear waste disposal facility.

Current research in the field of LLW management suggests the multibarrier strategy to prevent or reduce the transport of waste materials to the environment. The basic logic behind this approach is statistical. In general, multibarrier systems should provide significantly higher levels of protection than even a very good single barrier. As an illustrative example:

> Assume protective barriers 1, 2, 3, and 4 each provide a ninety percent chance of maintaining an acceptable level of LLW containment. If barrier 1 were improved 60% compared with the combination of barriers 2, 3, and 4, the multibarrier system would be a more effective alternative. The numbers are as follows:
>
> Probability of containment using improved barrier material 1 equals:
>
> (Current Technology Barrier 1 alone) plus (Improvement in Barrier 1 Technology) equals:
>
> 90% + (60%•(remaining 10%)) equals:
>
> 96% chance of containment using a single improved barrier.
>
> Employing Technologies 2, 3, and 4 simultaneously yields:
>
> (Chance of Technology Barrier 2 working) + (Chance that Technology Barrier 2 fails, but Technology Barrier 3 works) + (Chance that Technology Barriers 2 and 3 both fail, but Technology Barrier 4 works) equals:
>
> (90%) + (10%•90%) + (10%•10%•90%) = (90%) + (9%) + (0.9%) equals:
>
> 99.9% chance of containment using a multibarrier system

As illustrated in this example, use of a multibarrier system generally provides a greater level of safety than a single barrier system.

DESCRIPTION OF DATABASE

Categories of properties described in the database include: mechanical strengths, material modification parameters, composite material compositions, permeabilities, sorbent abilities, and experimental conditions.

Materials must have sufficient mechanical strengths so that the barrier systems will maintain a required level of structural integrity over time. Composite materials often can take advantage of beneficial properties of more than one material simultaneously. For example, a polymer impregnated concrete might benefit from the low permeability properties of the polymer material and the strength and low cost of concrete.

Permeabilities and sorbent abilities are of special interest in the containment of low-level waste because water may enter a facility, and if allowed to escape containing radionuclides, a pathway to the environment could be created. Low permeabilities help keep water out. High sorbent abilities of some barrier materials can help strip out dangerous materials from groundwater that does manage to leach out waste materials and pass through the facility.

Table I summarizes field headings currently in the database. Table II lists the materials currently in the database. Analysis of the validity of the data collected from literary sources is beyond the scope of this paper.

The literature search was conducted using the resources at Brookhaven National Laboratory and the DIALOGUE on-line computerized database network. A limited amount of data is available in the field of low-level nuclear waste containment. Further research and development in the field is anticipated to expand available data in the future. The seventy-nine references which appeared most pertinent to properties of

TABLE I

Summary of Material Headings In Database

Material Name	Orientation of Specimen
Identification Number	Organic Carbon Content
Cement	Permeability to
Admixture	Gas
Compressive Strength	Water
7 day	Poisson Ratio
28 day	Pore Volume
After Additional Time	Radiation
Entrained Air Percent	Radionuclide Sorbed
Manner of Curing	Rd Values** with
Type	Demineralized Water
Composition of Composite Materials	Saturated $Ca(OH)_2$ Solution
Corrosion	Static Fracture Toughness
Aerobic Conditions	Storage Conditions
Anaerobic Conditions	Strength
Calculated	Impact Resistance
Measured	Tensile
Cost	Dynamic Yield
Density	Static Yield
Diffusion Coefficient to	Temperature
Water	Test Period Time
Gas	Total Dose of Gamma
Elongation	Radiation and
Experimental Conditions	Energy Absorbed
Fracture Mode	Water Solubility
Hydraulic Conductivity	Water to Cement Ratio
Kd Values*	
Modulus of Elasticity	

*Kd values -- Kd is the equilibrium distribution coefficient, defined as the ratio of the amount of a chemical species sorbed on the buffer material (moles/kilogram) to the concentration of the chemical species in the groundwater solution in contact with the buffer (moles/cubic meter)

**Rd values -- Rd is similar to Kd, but the supposition of equilibrium is not made.

TABLE II

Materials Currently in the Database

A-51 Zeolite	Ionsiv IE-95
Activated Charcoal	Ionsiv A-51
Al_2O_3 (99%)	Kaolinite
Al_2O_3 (99.8%)	Limonite
Alumina	Marcor 9658
Amberlite (IRC-718)	Metal Filled Epoxy
Attaflow-350	Mineral Colloid BP
Attasorb-LVM	Montmorillonite
Avonseal (Na-Bentonite)	Mullite
Ball-Milled Incinerator Ash	Oak Ridge Soil
Basalt	Poly ethylene
$BaTiO_3$	-tetrafluoroethylene
Bauxite	Polyethersulfone
$BaZrO_3$	Polyfurfuryl Alcohol
Bitumen	Polymethyl Pentene
$CaTiO_3$	Polymide
$CaTiSiO_5$	Polyphenylene Oxide
$CaZrO_3$	Polyphenylene Sulfone
Cement (Numerous types	Polysulfone
and mix compositions)	Pyroceram 9617
Charcoal	Red Clay
Clinolite-12	Sealbond (Illite-Rich Shale)
Clinolite-20	Silica
Clinoptilolite-3	Titanate
Coal Fly Ash	Sodium Titanate
Concrete (Numerous Types)	Various Sorbent Barrier
Dowex XFS Resin	Formulations
Dowex 21-K	Steel
EPDM Rubber	Thixojel
Filtaclay 75 (Ca-Bentonite)	TiO_2
Glauconite	Titanium Grade 2
Graphite	Titanium Grade 12
Greensand	Vermiculite
Hanford Soil	Vitreous Silica
High Alumina Cement	Volcanic Ash
IE-96 Zeolite	Volclay (Na-Bentonite)
IE-95 Zeolite	X-61 Zeolite
Illite	$Zr0_2$
Illitic Slate	$ZrSiO_4$

materials useful in the construction of engineered barriers were reviewed. The result of the collection and organization of available data attained through this in-depth literature search is presented. Each material in the database is assigned a reference "Identification Number." The number is four digits long. The first two digits refer to the reference material from which the information was obtained. The second two digits differentiate the particular material. For example: Identification number 1107 would refer to the seventh material obtained from reference 11. For further details on the materials, the original references may be consulted.

DIRECTIONS TO USE DATABASE

Use of the database is straightforward. A working knowledge of the Q&A (Questions and Answers) software package published by Symantec Corporation, 10201 Torre Avenue, Cupertino, California 95014 Telephone: 408-253-9600, is required, however. Enough knowledge of the software package to use the database can be gained in about half an hour. The database was prepared using Q&A Version 3.0.

Materials may be selected by use of the Q&A search features. The reference identification number may be used, if known. If the reference identification number is not known searches may be performed by the name of the material, the type of material, by any known property value of the material, or by simply browsing.To search by identification number, name, property value or to browse, the Q&A standard commands are used. To search by material type, as many letters of the material type as are known are specified. The Q&A software package will find all materials in the database which match the specifications. The double period command in Q&A can be used as a wildcard value. For example: "Cem.." will find all material types which begin with "Cem" such as "Cement." Matches will be generated whether the uppercase letters match the lowercase letters specified or not.

CONCLUSION

The design of low-level nuclear waste repositories is not a well understood technology, and data is limited. Current disposal methods have significant room for improvement, and multibarrier engineered systems should be employed.

Databases, such as the one discussed in this paper, can be of assistance in the repository design process. Nonetheless, further research is needed to augment an understanding of low-level waste disposal technology and add to the body of available information. To get a copy of the database discussed in this paper please send a blank 720 kilobyte or 1.44 megabyte three and one-half inch floppy disk formatted for use on an IBM personal computer to:

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