United States
Environmental Protection
Agency

Municipal Environmental Research
Laboratory
Cincinnati OH 45268

Research and Development

EPA-600/S2-81-122 July 1981

EPA

Project Summary

Liners of Natural Porous Materials to Minimize Pollutant Migration

Wallace H. Fuller

This study concerned the relative effectiveness of natural low-cost liners—(a) crushed limestone, (b) clayey soil, (c) hydrous oxides of iron, and (d) crushed pecan hulls—to minimize the migration of beryllium, cadmium, chromium, iron, nickel, zinc, and total organic carbon constituents of municipal solid waste landfill leachates. Several leachate variables such as aqueous dilution, aeration, pH, and flux were also studied for their effect on movement of metals through 11 representative U.S. soils. The research was conducted on a laboratory scale with the use of soil columns as a first step in screening for potential liners and leachate manipulation practices.

This Project Summary was developed by EPA's Municipal Environmental Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

When landfills are not completely impermeable then underlying groundwater may be contaminated by leachate constituents if these are not adequately retained by soils between the landfill and groundwater. Research on industrial waste disposal has centered on use of manufactured products such as plastics and cementing roadbed materials (such as asphalt and concrete) to alleviate the leaching problem by completely preventing liquid movement out of the landfill. Little attention has been given to use of natural low-cost materials as barriers for minimizing pollution migration by retaining contaminants from liquids as they pass out of the landfills.

The objectives of the project were to

1 Identify further those parameters in *soil* and municipal solid waste landfill leachate that influence movement of contaminants through soils.

2. Evaluate crushed limestone as a liner to limit metal movement from landfills.

3. Evaluate hydrous oxides of iron, natural clays, and pecan hulls as liners to limit metal and organic constituent movement from landfills.

4. Study the use of control of flux (flow rate) to limit migration of metals and organic carbon constituents through soils.

The elements that were considered include: arsenic (As), beryllium (Be), cadmium (Cd), chromium (Cr), iron (Fe), nickel (Ni), selenium (Se), vanadium (V), and zinc (Zn) as well as total organic carbon (TOC).

Materials and Methods

Table 1 presents the properties of some of the soils used in the study. Leachate was generated in two 4000-L tanks that had been packed with typical municipal solid waste (MSW). The soils were uniformly packed into PVC cylinders. MSW leachate was perfused through soil using a peristaltic pump regulated to deliver fixed fluxes ranging from 1.2 to 17.1 cm/day. The effluents were collected and analyzed each hour by use of a fraction collector. Where necessary, leachates were enriched to a concentration of 100 mg/L for the element in question to ensure that metal migration would occur through the soil columns. The following barrier materials were considered:

Limestone

Unsieved, commercial-grade limestone (98% $CaCO_3$) from Cedar Bluff, Kentucky, was used. The limestone, developed for commercial agricultural soil application, has a particle density of 2.72 g/cm³ and a fairly broad range of size distribution. When used as a leachate barrier, the Cedar Bluff limestone was compacted to an average density of 1.67 g/cm³.

Pecan Hulls

Pecan hull waste from a local commercial pecan production enterprise was further crushed by hand in a ceramic mortar to pass a 2-mm sieve. In this form, it was layered over soil in a column.

Hydrous Oxides of Iron

Iron rust was scraped from a gas boiler, ground in a steel mortar to pass a 0.5-mm sieve, and used without further alteration. No carbon was identified as a contaminant. Also, waste ferrous sulfate was sprinkled on some columns and allowed to oxidize.

Results

Layers of crushed limestone retarded movement of contaminants through soil. Concentrations of contaminants increased more rapidly in effluents from untreated soil columns than they did in effluents from limestone-treated columns. See Figure 1 for an example of the effect of movement on Fe. The retardation of Cr movement by limestone and soil combined was greater than the sum of the effects of each acting alone (Table 2).

Iron hydrous oxide applied as iron rust was an effective barrier, retarding movement of contaminants so that they appeared much later in effluents from treated columns than in effluents from untreated columns. Figure 2 shows an example of this effect on two soils for Cr and Ni. Waste ferrous sulfate treated soils likewise retained metals from leachate, but increased levels of iron were noted in column effluents. Because of this leaking effect, ferrous sulfate waste is not recommended as a liner. No iron leakage was noted from the iron rust treated columns.

Conclusions

- The composition of MSW leachate (particularly with reference to TOC content, total ion concentration, and pH) exercises a profound influence on retention of the metals As, Be, Cd, Cr, Fe, Ni, Se, V, Zn, and the more common elements Ca, K, Na, and Mg.
- An abundance of electron donors (TOC and Fe^{+2}) in leachates combined with acidity reduction, either naturally by aging or by inserting a limestone barrier, encourages chromium retention by soil through the mechanism of valency change of CrVI to CrIII. CrIII, a cation, is less mobile than CrVI, an anionic form.
- When placed in layers over soil, crushed agricultural limestone;
  —significantly slows the rate of movement of As, Be, Cd, CrIII,

Table 1. General Characteristics of Some of the Soils

Soil Series	Soil Paste, pH	Cation Exchange Capacity meg/100g	Elec. Cond. of Extract, µmhos/cm	Column Bulk Density, g/cc	Silt, %	Clay, %	Soil Surface Area, m^2/g	Predominant Clay Minerals*
Davidson	6.4	9	169	1.40	20	52	51.3	Kaolinite
Mohave (Ca)	7.8	12	510	1.54	28	40	127.5	Mica, montmorillonite
Ava	4.5	19	157	1.45	60	31	61.5	Vermiculite, kaolinite
Anthony	7.8	6	328	2.07	14	15	49.8	Montmorillonite, mica
Mohave	7.3	10	615	1.78	37	11	38.3	Mica, kaolinite
Kalkaska	4.7	10	237	1.53	4	5	8.9	Chlorite, kaolinite
Wagram	4.2	2	225	1.89	8	4	8.0	Kaolinite, chlorite

*Listed in order of dominance.

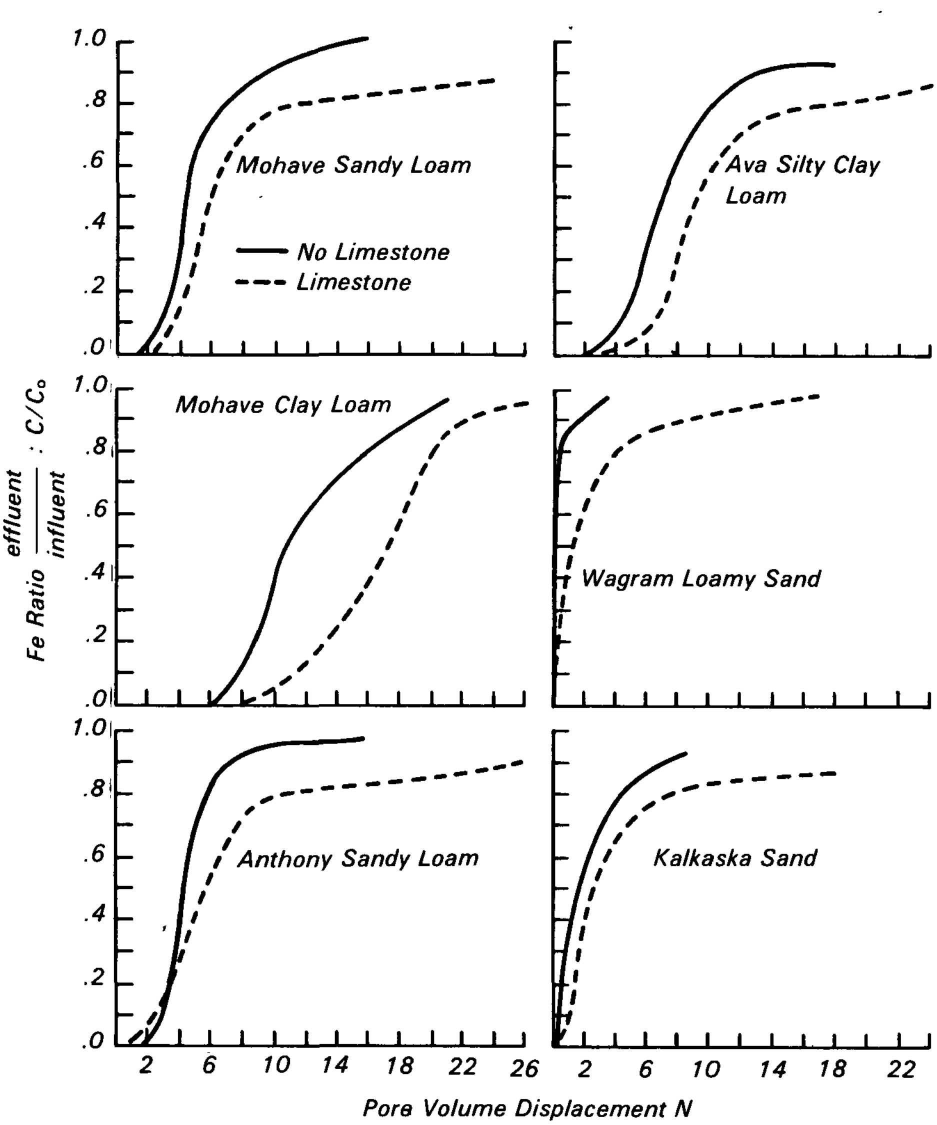

Figure 1. *Effect of crushed limestone layered (2 cm) over six soils on the retention of Fe from MSW landfill Leachate II.*

Fe, Ni, Se, V, and Zn through soil,
—affects metal retention in the following order of decreasing values:
CrIII>Se>As>V>Be>Zn>Ni>Fe>Cd>CrVI>TOC
—exhibits metal retention effects several times greater than when limestone or soil alone is used (a synergic effect),
—is poorly effective for TOC attenuation in MSW leachate, and
—does not effectively attenuate the TOC in MSW leachate.

Thick layers of crushed limestone (5, 10, 15 cm) provide a more effective barrier than thin layers (2 cm) for MSW leachate metal migration through soils.

- Leachate flux through soil columns has a significant influence on attenuation of certain metal ions in MSW leachates when flow rates are between 2 and 12 cm/day. The effect of other leachate variables such as pH or concentration of TOC or inorganic salts so overshadows the flux effect that it is difficult to separate flux effects on metal attenuation from the effects of other variables.

- Hydrous oxides of iron, either formed by spraying soils or sands with ferrous sulfate or iron rust placed as a 1-mm layer over soil, delay migration of soluble Fe and Cd.

- Other studies indicate that natural clay soils (20%<2μ clay), compacted to known homogeneous densities with sufficient sodium salts (Na_2CO_3, NaCl) to provide greater than 20% of cation-exchange capacity saturation, may be so manipulated as to prevent downward movement of MSW leachate, solution, and all pollutants nearly completely.

- The data reported here (except the item above) are the result of laboratory studies only and are intended as a first step in screening potential liners. They do not form a sufficient basis for exact liner design. The complex nature of the interactions of soil, leachate, and pollutants require field testing before final applications can be recommended.

Recommendations

- Because soils are highly stratified under natural conditions, soils underlying the disposal site must be made as homogeneous as practical by mixing and compacting to ensure minimum migration of pollutants from solid waste landfills.

- The use of crushed limestone should be considered for minimizing movement of potentially hazardous pollutants such as As, Be, Cd, Cr, Fe, Ni, Se, V, and Zn.

- Layering limestone over soil as a barrier between MSW landfill leachates and geological materials underlying the landfill is recommended over mixing limestone and soil together or mixing limestone with solid waste.

- A layer of crushed limestone about 15 cm (6 in.) thick is suggested as minimum at most disposal sites, but specific wastes and soils should be tested before a precise thickness is finally selected for a given site.

- The particle sizes of crushed agricultural limestone that are generally commercially available appear to be suitable for use, but field verification studies are suggested. The most desirable particle sizes range from coarse gravel to medium sand (5 to 0.05 mm), with most of the material in the middle group.

- High-quality limestone is recommended because polluting metals may otherwise be present and because, when compared with lime ($CaCO_3$), dolomite ($MgCO_3$) is highly insoluble and quite unreactive at field temperatures.

- Field studies should be conducted to verify the usefulness of crushed agricultural limestone and should include evaluation of (1) particle size distribution, (2) optimum thickness, (3) cementation characteristics, (4) channeling, and (5) mechanics of placement.

The full report was submitted in fulfillment of Grant No. R 803988 by the University of Arizona, Tucson, AR 85721, under the sponsorship of the U.S. Environmental Protection Agency.

Table 2. *Effect of Limestone Alone and Limestone Layered Over Soils on the Attenuation of Cr in MSW Landfill Leachate II**

Soil			Ratio of Cr in Influent and Effluent, C/C_o	#Pvd[+] Number When Cr Concentration in Effluent is at C/C_o Given in Col. 4		
Series	Clay, %	pH		Limestone Alone	Soil Alone	Soil and Limestone
Davidson c	52	6.2	0.13	2	2	28
Ava sicl	31	4.5	0.38	5	21	49
Anthony sl	15	7.8	1.00	57	39	125
Mohave sl	11	7.3	0.76	46	25	144
Kalkaska s	5	4.7	1.00	57	17	111
Wagram s	4	4.2	1.00	57	15	109

**Leachate II had a pH value of 4.0, TOC of >3000, and Fe of 300 ppm.*
[+]Pvd, Pore volume displacement number, is the number of pore volumes of leachate that have passed through the column.

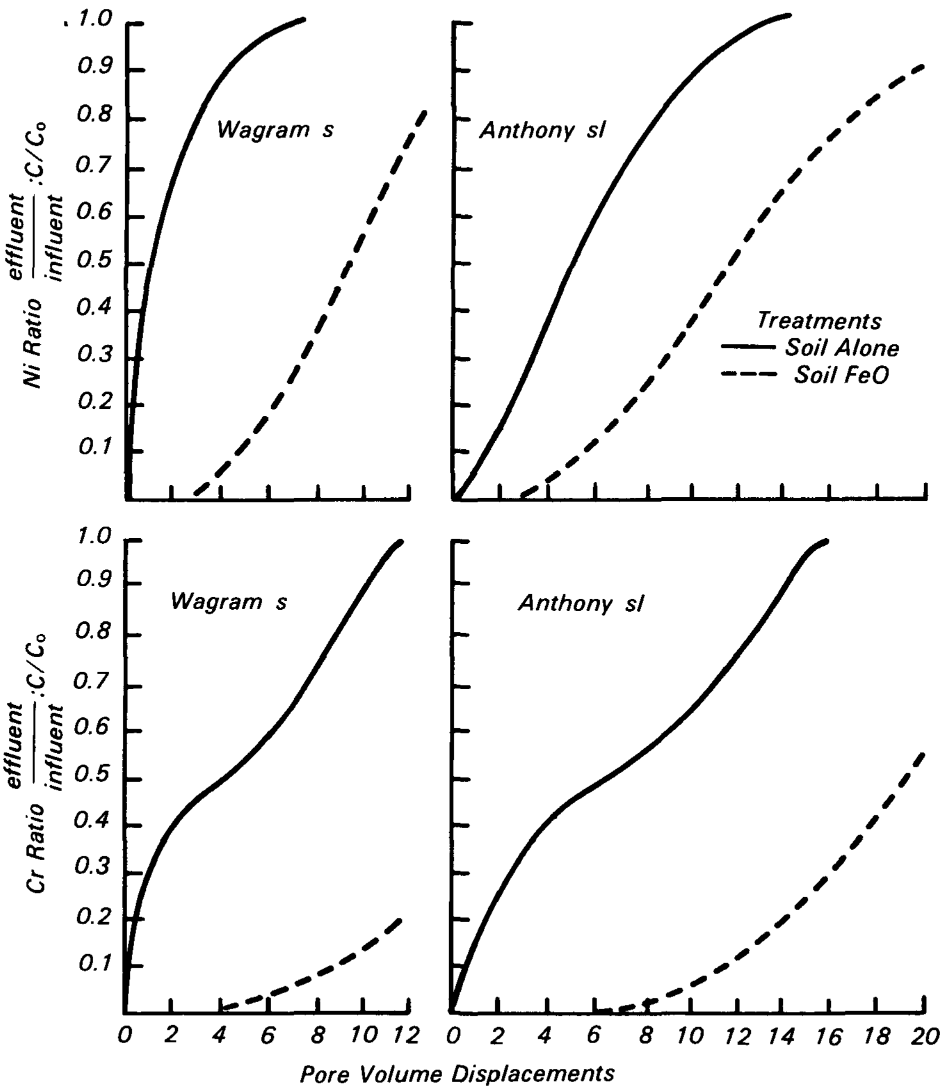

Figure 2. *Effect of the hydrous oxides of iron precipitated on Anthony sl and Wagram s on attenuation of CrVI and attenuation of CrVI and Ni of MSW Leachate I.*

Wallace H. Fuller is with the Arizona Agricultural Experiment Station, The University of Arizona, Tucson, AZ 85721.

***Mike H. Roulier** is the EPA Project Officer (see below).*

The complete report, entitled "Liners of Natural Porous Materials to Minimize Pollutant Migration," (Order No. PB 81-221 863; Cost: $9.50, subject to change) will be available only from:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650

The EPA Project Officer can be contacted at:

Municipal Environmental Research Laboratory
U.S. Environmental Protection Agency
Cincinnati, OH 45268

☆ U.S. GOVERNMENT PRINTING OFFICE: 1981 -757-012/7236

United States
Environmental Protection
Agency

Center for Environmental Research
Information
Cincinnati OH 45268

Postage and
Fees Paid
Environmental
Protection
Agency
EPA 335

PS 0000523
U S ENVIR PROTECTION AGENCY
REGIONAL SERVICES STAFF
26 WEST ST CLAIR STREET
CINCINNATI OH 45268