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Leachates from Excavations and Fills: Summation

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There are extensive data available on leachate quality and quantity, but the environmental effects and leachate control methods have not been investigated as thoroughly as might be expected. Test methods are primarily centered in the laboratory; there is a need to establish field evalaution methods.

The purpose of this paper is to summarize the five papers presented at the Symposium on Leachates from Highway Fills and Cuts organized by the Committee on Physicochemical Phenomena in Soils (A2L03). It describes the state of the art by identifying areas where information on the role of leachates is available as well as topics that require study or further investigation.

Among the various environmental concerns that have surfaced during the past decade or so, the problem of leachates from fills and excavations has been rather sporadically studied. On the one hand, pollutants and their sources have been rather well identified; on the other hand, field and laboratory testing, which enable the determination of leachate quality and quantity, has not reached the point of established meaningful criteria. It appears, then, that the problem has not been approached with a well-designed overall research plan and balanced emphasis.

GROUPING OF REPORTS

The five papers reviewed herein, as given in Table 1, differ in scope and methodology. Another possible way to categorize these papers is to group them according to the following dimensions of leachates:

1. Source characterization,

Table 1. Classification of reports based on scope and methodology.

Author	Title	Scope	Methodology
Wright and Iyengar	Survey of Techniques Used for Predicting Leachate Quality	To compare and evaluate techniques for predicting potential leachate quality	Assessment of test methods Important parameters in each test Advantages and disadvantages of tests Experiments with slag and ash by using American Society of Testing and Materials (ASTM) 1:4 extraction and U.S. Environmental Protection Agency (EPA) toxicity tests. Some tests are qualitative, but leach tests are quantitative and predict contaminants Batch tests rapid; column tests more dependable but time consuming
Wagner, Fanning, and Foss	Identification of Source Materials for Acid Leachates in Maryland Coastal Plain	To identify sulfidic strata in soils subject to highway construction activities	Seven soils characterized Minerals with high potential in pollution identified in nonoxidized and oxidized form The worst source for pollution is in jarosite, which results from the oxidation of pyrite in acidic environments
Van Zyl, Shepherd, and Smith	Quality of Seepage and Leachate from Mine and Mill Wastes and Control of its Effects	To classify these wastes and identify problems and methods for control purposes	Classification of mine waste Potential to produce acid waste Extraction (metallurgical processes) Problems of impact Acid-generation reactions Time lag in observing pollution impact Extraction Cyanide Low pH; bacterial action Treatment before, during, and after placement; detergents
Jones, Bell, and Hansen	Induced Polarization Survey of Sulfide-Bearing Rocks in Eastern Tennessee and Western North Carolina	To discuss the induced polarization process to detect sulfide deposits and identify environmental problems in disturbing such deposits	Acid drainage from low concentrate sulfide (pyrite) Damages observed Techniques and equipment in induced polarization process, and reconnaissance survey
Lee and Jones	Evaluation of Potential Water Quality Problems in Highway Excavation and Fill	To review EPA regulations on fill materials and evaluate them	Physical and chemical impacts on water quality Water leachate test Deficiency of water quality standards Dredged materials Four-tiered hazard assessment Proposal to modify EPA methods

Table 2. Grouping of reports based on leachate parameters.

Author	Source Characterization	Leachate Testing	Environmental Effects	Evaluation of Environmental Effects	Control
Wright and Iyengar		X			
Wagner, Fanning, and Foss	X				
Van Zyl, Shepherd, and Smith	X		X		X
Jones, Bell, and Hansen	X		X		X
Lee and Jones	X	X	X	X	

2. Leachate testing both in quality and in quantity and rate-determining factors,
3. Environmental transport,
4. Environmental effects and evaluation thereof, and
5. Control and abatement of leachates.

Table 2 presents the results of this grouping method.

SYNOPSIS OF REPORTS

The main theme in Wright and Iyengar's paper is the prediction tests of leachate quality. They present very useful tables on the advantages and disadvantages of various tests. The data relate to slag, bottom ash, and fly ash. They advance the thesis that criteria such as reaction pH, buffer pH, and total sulfur provide minimal information, and between the leach test method and the batch method the latter is preferable because it is rapid. Also, they point out that column tests, while time consuming, are more dependable in studying long-term effects.

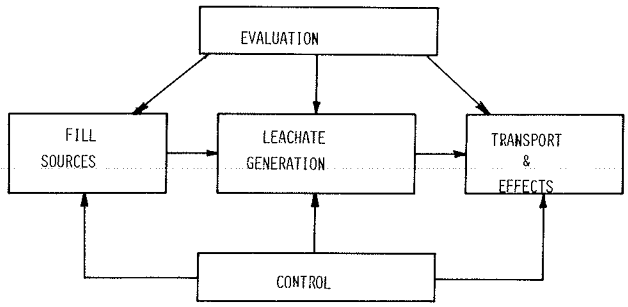
Wagner, Fanning, and Foss deal with the identification of sulfidic strata and describe how pyrite converts from a sulfide to a sulfate form, namely jarosite. The source of the deleterious effects of acid-producing materials is reported to be created when the sulfidic sediments are exposed to an oxidizing environment. This condition follows from excavation activities or from using such sediments as borrow materials for fills.

Van Zyl, Shepherd, and Smith report on leachates from mine and mill wastes. They classify these wastes as "unacceptable" and "acceptable" based on the degree of pollution produced or the extent of curtailing (reducing) the performance of engineering structures such as drains. A very interesting feature of this paper is the treatment on the techniques to control leachate quality. They classify these techniques as (a) treatment before placement, (b) treatment at or after placement, and (c) treatment of the effluent. Needless to say, they prefer the first two approaches as being more effective. For treatments washing, calcining, encapsulation, injection of detergents, and lime are suggested.

The paper by Jones, Bell, and Hansen discusses in detail the technique of the induced polarization survey used in detecting sulfide mineral deposits. Thus, again the problem associated with pyrite comes to the forefront. This technique appears to be very promising as a tool in the planning, location, and design of a highway.

Finally, Lee and Jones review the current evaluation methods used on fill material insofar as its environmental impact is concerned, and they recom-

Figure 1. Component phases of leachates.



mend a four-tiered hazard-assessment approach for contaminants associated with fill materials. The report raises the very legitimate question of the definition of quality in water.

These papers provide a wealth of references that constitute a very impressive codification of the topic on leachates.

CONCEPTUAL FRAMEWORK FOR ANALYSIS

Figure 1 provides a basis for additional discussion of the five papers presented as well as a framework for relating their substantive aspects. It is important to identify the sources of fill material, the potential for leachates being generated from the materials, and the environmental transport and resultant effects from the generated leachate. Evaluation of fill material sources, leachate generation, and transport and effects includes both in situ analysis as well as laboratory evaluation and interpretation. Control measures to minimize the undesirable consequences of leachates from highway fills and cuts include material selection as well as approaches to minimize leachate generation and control environmental transport. The purpose of this section of the paper is to discuss the state of the art of information related to each of the five components within Figure 1.

Fill Sources

Fill sources include natural materials such as soil, rock, and sand as well as man-altered waste materials such as municipal solid waste, incinerator residue, coal ash, and mine tailings. Extensive work has been done on the water pollution characteristics of both natural and waste materials (1). Bhutani and others (2) described some of the general water pollution problems related to the use of natural materials for highway fills and other types of projects. Table 3 summarizes two pertinent types of pollutants and the associated concerns.

Municipal solid wastes may be used as a highway fill material. The impacts of this fill material are difficult to characterize due to the nonhomogeneity of municipal solid waste. Both the physical and chemical composition depend on factors such as geographic location, economic standards of the generating community, and seasonal variations. Numerous studies have been conducted on the characteristics of leachate waters; most focus on chemical constituents (1). Incinerator residue has also been used as a highway fill material. Schoenberger and Fungaroli (3) investigated an incinerator residue disposal site. Their work included an analysis of the chemical composition of solid waste from the City of Philadelphia, the incinerator residue prior to landfilling, and the incinerator residue two years after landfilling. The nutrient content of the leachate was rather high, with the total nitrogen content being about 125 mg/L. The total dissolved solids content was almost 8000 mg/L, and the chemical oxygen demand (COD) was about 1300 mg/L. The biological oxygen demand (BOD) was much lower than the COD, primarily because of the large concentration of heavy metals in the leachate. The principle metals were iron (Fe), zinc (Zn), lead (Pb), copper (Cu), and chromium (Cr).

Coal ash residue consists of bottom ash collected from utility boilers and fly ash collected by air pollution control equipment. Fly ash consists of many small (0.01-100 micron diameter), amorphous, glasslike particles of a generally spherical character. Coal ash has been primarily used as a mineral filler material for concrete highways and other construction projects. A considerable amount of information exists on the composition of coal ash material (4,5). Theis and others (6) pointed out that, while it is important to know the total metal content of fly ash materials, it is perhaps even more important to determine the fraction of these metals actually available to the environment. The potential chemical and biological impacts from the use of coal ash as fill material are related to depletion of dissolved oxygen, changes in pH, and release of trace metals. Depletion of oxygen would have an adverse effect on fish and zooplankton in general and on the species composition of bacteria and other microorganisms in particular; the population of anaerobic microorganisms would probably be enhanced. The pH changes could cause elimination of certain species of fish, with some effects on the species composition of macroinvertebrates, phytoplankton, vascular plants, and benthic organisms. The release of several trace metals, including cadmium (Cd), Cr, cobalt (Co), Cu, Fe, Pb, nickel (Ni), Zn, and perhaps mercury (Hg), may occur. Any or all of these may be toxic to certain species in the environment and could undergo bioaccumulation and biomagnification in the ecosystem.

The papers in this symposium that relate to fill sources include the one by Wagner, Fanning, and Foss on the identification of potential acid leaching from sulfide-bearing sediments, and the one by Jones, Bell, and Hansen on a polarization technique for identification of the location of sulfide-bearing sediments. In summary, relative to fill sources, there is extensive information on the water pollution characteristics of various types of materials used for highway fills (1) and a growing amount of information relating to the potential leachates from highway cut areas, particularly as related to sulfide-bearing sediments.

Leachate Generation

Although both natural as well as waste materials used for highway fill areas may contain constituents that represent potential water pollutants, generation or release of these constituents from the fill area and their transport to the water environment represent the key issues that relate to leachate effects. Extensive work has been done within the past decade on leachate generation from various types of materials, including municipal solid waste and dredged materials (1). In this symposium, the paper by Wright and Iyengar provides a good summary of a variety of laboratory techniques for estimating leachate quality and, depending on the test and the procedures used, information that can be used for estimation of leachate quantity. In addition, the paper by Lee and Jones describes the advantages and limitations of certain leachate testing methods.

The confusing issue that relates to leachate testing is associated with the myriad of potential

Table 3. Water pollution from construction activities—cause and effect matrix.

Class	Pollutant Material	Source Activity/ Occurrence	Effect	
			Beneficial	Adverse
Physical: Sediment	Inert and organic particles; colloids; microorganisms (note, during transport, the sediment load comprises the suspended load plus the bed load)	Land-disturbing operations: surface clearing, grading, excavating, trenching, and stockpiling (note, subsoils often have different erodibility characteristics than surface soils)	May provide material to maintain a receptor stream channel in equilibrium, i.e., provide adequate suspended sediment to prohibit erosive degradation of a fluvial channel, in-stream sediment required in formation of silt-laden farmlands along flood plains and near river mouths; fine-grain sediment helps in removal of ions that adhere to and are transported by particulates, which settle to the bottom; dredged material disposal may also create new land areas (for building sites, beach restoration, waterfowl habitats) and decrease vectors in marshfilling	May exceed equilibrium suspended load of receptor stream, thereby altering many physical and biological characteristics of the channel; these include channel aggredation, silting of reservoirs, undesirable effects on marine life such as blanketing and smothering of benthic flora and fauna, altering the flora and fauna as a result of changes in light transmission and abrasion, destroying or altering the species of fish due to changes in light transmission and abrasion, destroying or altering the species of fish due to changes in flora and fauna on which fish depend, or obstruction of their gill function; also a need may arise for excessive treatment (sedimentation, clarification) prior to consumptive use for municipal, industrial, or irrigation purposes; channel siltation can adversely affect its capacity to carry floor flows or support navigation and recreation; dredged material disposal may destroy land areas (salt marshes, wildlife refuse, vegeted coverage), block flow circulation, or increase vectors in the disposal area
Chemical: Nutrients	Ammonia, orthophosphates, polyphosphates, organic N, organic P	Fertilization of reestablished vegetal cover	Stimulates growth of plants and grasses on areas denuded by construction (especially on slopes), thereby reducing soil loss in rain storms	Nutrients, especially from excessive application of soluble fertilizers, will be transported from new growth surfaces at construction sites in the runoff of precipitation; by then stimulating growth of algae and marine plants, nutrients can have adverse effects on chemical exchange processes, which lead to eutrophication and lowered oxygen levels; in addition to the biostimulation impacts, a large concentration of unoxidized nitrogen (organic nitrogen and ammonia) could represent a significant oxygen demand in the receiving waters.

fill materials as well as numerous test conditions, each of which can yield different results in terms of leachate quality and quantity. Test procedures that focus on worst-case conditions would be desirable in terms of evaluation of potential leachates from various fill materials. Despite extensive work relating to leachate testing, very little systematic study has been made of the rate-determining factors in leachate generation, particularly as related to the environmental conditions within which the fill material will be used. Leachate test procedures typically focus on the qualitative identification of the water pollution constituents in the leachate. Additional testing and/or calculations are needed to enable the highway engineer to effectively estimate both quality and quantity of leachate materials over time. Essentially no information is available on the time variation of the pollution characteristics of fill material leachates.

An additional area of need in conjunction with leachate generation is associated with field verification of laboratory test procedures. As noted in the paper by Wright and Iyengar, the results of leachate testing vary depending on the test procedure used. The relation between these laboratory-based results and what would actually be anticipated under field conditions needs to be established. Accordingly, field studies in selected areas would be desirable to determine quantity and quality of leachates, and then compare those results with laboratory results. Leachate testing is typically conducted on materials prior to their placement and compaction within the fill area. Work is also needed to determine the influence of compaction procedures on leachate quality and quantity.

Transport and Effects

Critical environmental concerns that relate to leachates from highway fills and cuts are associated with the transport of leachates into either the surface or subsurface environment and the resultant undesirable effects that might occur on water quantity and quality as well as the aquatic ecosystem. In addition, effects on engineering structures could occur as a result of their exposure to leachate waters. There is an extensive body of literature associated with quantitative aspects of drainage from highway fill and cut areas (7). This type of information, when coupled with information on leachate quality, could be used to estimate leachate impacts on the receiving water environment.

A growing area of concern within the United States is associated with groundwater quality and the pollutional effects of a variety of man-made sources. It is estimated that more than one-half the population of the United States is dependent on groundwater in meeting their water supply needs. The subsurface transport of leachate materials into underlying aquifers, and the potential contamination of these aquifers or associated interconnected surface streams, are areas that need additional research. Minimal information is available on the subsurface movement of leachates from highway fill areas.

There has been extensive work done on the effects of various leachate constituents found in both surface water and groundwater as well as the aquatic ecosystem. In other words, if metals are anticipated from the potential fill material, then a review of the literature would reveal extensive information available on the water quality and biotic effects of metals (1). The paper by Lee and Jones summarizes some of the types of water quality concerns, while the paper by van Zyl, Shepherd, and Smith describes some of the biotic effects of leachates from mine and mill wastes.

An issue related to the effects of leachates from highway fills and cuts that has not received much attention is associated with potential impacts on engineering structures. The paper by van Zyl, Shepherd, and Smith addresses the potential impacts of acid drainage on engineering structures; the primary areas of concern relate to low pH and resultant corrosion of metals, high sulfate concentrations, and degradation of concrete.

In general, relative to transport and effects, greater attention needs to be given to subsurface movement of leachate materials as well as the potential effects associated with exposure of engineering structures to leachates.

Evaluation

Evaluation encompasses source characterization of the fill material as well as testing for leachates and resultant environmental effects. Several of the papers presented in this symposium relate to evaluation. Source characterization is presented in the papers by Wagner, Fanning, and Foss; van Zyl, Shepherd, and Smith; Jones, Bell, and Hansen; and Lee and Jones. Leachate testing is addressed in the papers by Wright and Iyengar, and Lee and Jones. Environmental effects are addressed by van Zyl, Shepherd and Smith; Jones, Bell, and Hansen; and Lee and Jones. The specific research needs within each of the areas have been discussed in conjunction with fill sources, leachate generation, and transport and effects.

Control

As additional information becomes available on the effects of leachates from highway fills and cuts, more systematic approaches can be taken to control or abate the undesirable effects. Control measures may include selection of fill material characterized by minimal leachate quantity and constituents that cause undesirable water pollution effects, the application of measures to minimize leachate generation or transport, and actual treatment of the environment to clean up resultant undesirable effects. The paper by Jones, Bell, and Hansen relates to the use of induced polarization for identification of sulfide-bearing sediments in a given geographical location. Application of this technique would enable the selection of fill materials that would have a minimized potential for leachate generation. In addition, general knowledge about the water pollution constituents that might be present in leachates from a variety of materials could be used in fill material selection.

The paper by van Zyl, Shepherd, and Smith provides examples of control measures for minimizing leachate generation and environmental transport, as well as approaches that can be used for treatment of undesirable environmental conditions. Extensive literature is available on abatement or control measures for certain types of fill materials and the resultant types of leachates that would be generated. Specifically, an extensive amount of research has been done on the subject of acid mine drainage and control (8).

The general area of need is for systematic, engineering-oriented studies to identify and evaluate potential control measures for minimizing the undesirable effects of leachates from highway fills and cuts. Currently available information is generally oriented to certain types of materials but without extensive field application and evaluation. Although extensive research has been conducted on the control of acid mine drainage, the applicability of these research results to highway fills and cuts is somewhat questionable.

RESEARCH NEEDS

In summary, and based on the discussion associated with Figure 1, several general areas of needed research in this substantive field can be identified. These are as follows:

1. Fill characterization: Although extensive information is available on the water pollution constituents that might be found in certain types of potential fill materials, the development of systematic laboratory procedures for the evaluation of leachate quality and quantity, as well as the rate-determining factors, have not been achieved. In addition, research is needed to verify the results of laboratory testing in the actual field conditions in which fill material is used.
2. Leachate control: The emphasis given in this symposium to source characterization as well as identification of undesirable effects of leachates is indicative of the general minimal emphasis given to leachate control. Only two out of five papers provide information on control, and neither treats the issue in a comprehensive fashion. Research is needed on field-oriented methods that can be used to minimize leachate generation and transport. This type of research can be best accomplished by using an interdisciplinary approach that involves both chemical experimentation as well as engineering and geological inputs.
3. Subsurface movement: The majority of attention given to leachates from highway fill materials is associated with potential undesirable effects on surface watercourses. Leachates can also move through the subsurface environment and reach underlying aquifers. Information is needed on the rate-determining factors in subsurface movement as well as measures to minimize or control leachate penetration to underlying groundwater resources.
4. Groundwater effects: There is minimal information available on the groundwater quality effects that result from leachates from highway fills and cuts. No discussion of this subject was provided in any of the five papers presented in the symposium. Leachates could be anticipated to cause effects on physical, chemical, and biological characteristics of groundwater. In addition, informa-

tion is needed on the removal mechanisms that might occur in both the unsaturated and saturated zones of the subsurface environment.

CONCLUSIONS

This paper attempts to summarize the most significant conclusions presented by the authors of the five papers. The pertinent points made by the authors may be summarized as follows:

1. The preponderance of available data indicates that leachate quality and quantity is a problem of great concern.
2. Although the undesirable effects of leachates on surface watercourses have been studied adequately, the data on groundwater quality are minimal.
3. Sources of leachates have been well identified and there is continuing, if not increasing, interest in this area. However, leachate control data lag very much behind source data. Field-oriented studies on a broad scale should be initiated to identify leachate control methods.
4. In general, the studies on rate-determining factors for nearly all phases of leachate effects appear to have not reached a level that offer dependable design values.

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