Evaluation of Potential Water Quality Problems Associated with Highway Excavation and Fill

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The excavation and disposal of materials and the use of fill materials in highway construction are potential threats to water quality. Although most highway construction does not result in substantial water quality deterioration, there are some situations in which significant problems can develop, especially when excavation and/or filling occurs within or near watercourses. To provide guidance for the detection of potential problems from this source, the U.S. Environmental Protection Agency (EPA) published its Guidelines for Specification of Disposal Sites for Dredged and Fill Material in the Federal Register (December 24, 1980). They specify that a water leachate test be used for evaluating the potential impact of contaminants associated with fill material on water quality at or near the filling site. No information is provided, however, on the characteristics of this test. Current guidelines also specify that applicable state water quality standards be used to interpret the results of the leaching test, without any mixing zone allowance. The recommended approach of EPA has several technical deficiencies. This paper discusses the approaches that have been recommended for use in evaluating fill material for environmental impact and also the approaches that should be followed for making such evaluations. Outlined is a water quality hazard assessment approach for evaluating the potential significance of contaminants associated with fill material derived from highway excavation and filling, which will promote technically valid, cost-effective, yet environmentally protective evaluation and control of excavation and fill materials associated with highway construction.

The excavation and fill activities associated with highway development have the potential to impair beneficial uses of waters receiving area drainage. Although federal regulations for dredge and fill operations (P.L. 92-500, Section 404) have existed since the early 1970s, it appears that the portions dealing with fill materials have been largely ignored by the regulatory agencies. Interest in this area was prompted several years ago, however, when highway construction in the eastern Tennessee-western North Carolina Smokey Mountain region resulted in large-scale fish die-offs in area waters. It appears that sulfide minerals in the fill material used in that project were oxidized to sulfate on contact with air. Hydrogen ions were released, leading to the formation of sulfuric acid, which is alleged to have caused the fish kills in streams that received drainage from the highway area.

On December 24, 1980, the U.S. Environmental Protection Agency (EPA) published its proposed revised guidelines for implementing Section 404 of P.L. 92-500 (1). There are, however, a number of potentially significant technical problems with the approaches advocated in the guidelines for fill material proposed by EPA. If implemented into public policy, these guidelines could readily result in the taxpayers' spending large amounts of additional money for highway construction with little, if any, improvement in environmental quality. There remains a need for technically valid, cost-effective testing procedures that can detect potential environmental problems associated with highway construction, such as the generation of sulfuric acid from sulfide-bearing fill materials, without placing an unnecessary economic burden on the public for highway construction, most of which, in general, would not have a significant detrimental impact on the water quality of the surface and groundwaters of the region.

It is important to point out that, in both the classical and legal senses, "water quality" must be viewed and evaluated in terms of the desired beneficial uses of waters potentially affected, which are designated by the public. While possible desired beneficial uses for a particular water are often many, those generally considered are recreation-aesthetics, sports fisheries, and water supply. An activity that alters a physical, chemical, or biological characteristic of a water does not necessarily alter water quality unless the change adversely impacts a desired beneficial use of the water.

This paper reviews EPA's proposed regulations governing fill materials associated with highway construction, discusses potential problems with the implementation of the regulations into public policy, and recommends approaches that should be used to develop regulations that are more technically valid, cost-effective, yet at least equally and in some cases more environmentally protective than those proposed by EPA in December 1980.

REVIEW OF POTENTIAL SIGNIFICANCE OF HIGHWAY FILL MATERIAL ON WATER QUALITY

There are principally two areas of potential water quality concern associated with highway filling operations. One is the physical impact of solid material transported to watercourses from highway construction sites; the other is the impact of chemical contaminants in the fill material.

Potential Physical Impacts

During highway construction, there may be sufficient amounts of suspended particles transported from the area in runoff to cause waters of the region receiving the runoff to become highly turbid. In waters with low background turbidity, the suspended solids derived from highway construction and/or erosion could be judged to be adverse to water quality based on their impact on the aesthetic quality of the water. In general, the public does not like to see "muddy"-turbid water, especially if the waters were normally clear. If erosion were particularly severe, then several other potential problems would have to be considered. Large amounts of suspended solids can have direct effects on aquatic organisms by burying them or clogging their gills. Altered erosion can also have indirect impacts; it could cause changes in substrate particle size, which could have a significant adverse effect on aquatic organism habitat. While expected to be a rare occurrence, it is possible that sufficient erosion could take place to alter normal flow patterns of the waterbody, which in turn could have a significant impact on the aquatic environment. Normally, however, the placement of a highway in a region will have such a dramatic impact on the runoff pattern of the area that any erosional materials added because of erosion of the fill material after highway construction has been completed would be inconsequential as far as affecting aquatic habitat. Further, in general, except for very sloppy construction and/or poor design, it would be rare that the physical aspects of erosional materials derived from highway construction would have any impact other than temporarily causing the water to be somewhat cloudy. Eventually, even this would be mitigated as the fill material became stabilized with terrestrial vegetation.

Potential Chemical Impacts

The area of greatest potential concern with respect to fill materials is the potential release of contaminants from the fill material either while in place or during and after being transported to a watercourse with runoff-erosion. All fill materials contain contaminants that are potentially hazardous to aquatic life. Fortunately, most of the contaminants are sufficiently firmly attached to the soil particles so that they are not available to affect water quality.

The EPA in the Federal Register (December 24, 1980) (1) attempted to address the problem of contaminant release from fill material in several ways. First, it proposed that if the fill material were "clean," i.e., if there were no"... contaminants in the fill material above background levels ...", the filling may take place without further testing. There are several significant technical deficiencies in this approach. First, simply because all contaminants are present at background levels or less does not ensure that no adverse impact on water quality will occur. An example of this is the instance previously mentioned in which the area material used for highway fill contained sufficient sulfides to ultimately result in a fish kill in waters receiving area drainage.

Second, while we support EPA's approach of preliminary screening for fill material, its foundation on contaminant levels in the background and fill materials is technically invalid. It is well-known that the concentration of a contaminant in solid materials, such as soils or sediments, is not a reliable index to the potential for release of the contaminant to water or its potential impact on beneficial uses of the receiving waters. This has been repeatedly demonstrated by us in studies of contaminant release from dredged sediment, as discussed in a subsequent section. The fact that two sediments contain equal amounts of a contaminant does not indicate that both will release the same amounts. The basic issue that must be addressed is not the concentrations of the contaminants in the fill material but rather the potential mobility of these contaminants under the conditions that will exist at the filling site, and en route to and in the waters of concern. Mobility is governed by a variety of factors, the most important of which are the chemical forms of the contaminants in the system of interest.

Another significant problem with the use of background concentrations as a screen for potential water quality problems is in the definition of the background concentration for the region. Usually, considerable expense would be associated with properly establishing the normal background concentrations for the wide variety of contaminants for which EPA has developed water quality criteria. It is important to avoid the recurrence of problems encountered several years ago in the Great Lakes region when an EPA Region V staff member somewhat arbitrarily established "background levels" for certain contaminants in Great Lakes' sediments. Examination of these levels showed that for some contaminants, the "background" concentrations were less than the normal crustal abundance for these elements. Further, it is important that the highway construction field not adopt the mechanical approach that is being used in many areas of the water pollution control field today, of automatically requiring the analysis of the composition of the material, in this case fill, just to have numeric values to put in a report or impact statement. Substantial amounts of public funds are being wasted by using this approach. In order to properly implement this screening portion of EPA's proposed regulations, a large number of chemical analyses would be required to establish the background contaminant levels for a region and the character of the fill material. Since this would provide little if any insight into potential environmental problems and would only tend to confuse the technical issues, it would seem more appropriate for regulatory agencies to screen for potential water quality-related problems associated with the use of fill material based on the origin of and activities within the region from which the fill material was derived. Most importantly, this approach will save the taxpayers substantial amounts of money in useless testing and provide an approach that is at least as reliable, if not more reliable, than the one that is currently advocated by EPA. Under no circumstances should a regulatory agency establish a concentration of a contaminant in fill material to act as a signal to conduct further testing or to alter construction practice.

The EPA also specifies that there is no need for further testing of contaminated fill material if this material can be "... adequately contained to prevent leaching and/or erosion" (1). Ordinarily, while emphasis is given to contamination of surface waters by fill material, it is possibly more important to consider the potential for groundwater contamination from contaminated fill material. It is possible that certain types of contaminants in fill material that would be adequately contained with respect to surface water contamination could result in groundwater contamination. As a result of the implementation of the Resource Conservation and Recovery Act (RCRA), it is unlikely that highly hazardous industrial waste would be used for highway construction, but it is possible that certain types of mining wastes might be used. Before these types of wastes or other highly contaminated solid wastes or materials are used for this purpose, they should be reviewed in the same manner as they would be under the provisions of RCRA.

Water Leachate Test

The EPA has specified that when a material does not pass the screening test, a water leachate test shall be used to evaluate the potential release of contaminants from fill material. No information was provided, however, in the Federal Register, or by reference therein, to the nature of this test. It appears that neither EPA nor the U.S. Army Corps of Engineers have formulated the details of this test; it does not appear that this test is even under development at this time. Based on our discussions with staff members of the agencies responsible, the agencies seem to be inclined to recommend some type of column leaching test in which water would be percolated through the fill material for the purpose of attempting to simulate what might happen when the fill is in place. While this type of test might be suitable for certain types of filling operations and for more advanced-level tiers of testing if groundwater contamination is of concern, it is not recommended as a screening test. These types of tests are generally expensive and time-consuming, and their results are not interpretable in terms of contaminant release in runoff. When such tests are used for groundwater contamination evaluation, their designs must in general be site-specific; even for this application, their results are often difficult to interpret.

The elutriate test, a sediment leaching procedure developed by the Corps of Engineers and EPA for assessing potential contaminant release from hydraulically dredged sediments during open water disposal, provides a better starting point for the development of a screening test for highway fill material. It is simple, less expensive and time-consuming, and has been demonstrated to predict contaminant release potential for somewhat similar applications. Lee and others (2) and Jones and Lee (3) present a detailed discussion of the development and laboratory and field evaluation of the elutriate test for dredged sediment. Basically this test involves mixing one volume of sediment with four volumes of water for 30 min under oxic conditions. The mixture is allowed to settle for 1 h. The supernatent is filtered and the "soluble" contaminants of interest are measured. Jones and Lee (3) found that this test in general provided a fairly reliable estimate of the direction and amount of contaminant release that occurs during open water disposal of hydraulically dredged sediment. A test of this type would be appropriate for fill material that would become slurried in the water column, or as discussed below, as a screening test for the release of contaminants from fill material. A situation in which this type of elutriate testing would be most directly applicable to fill material would be a filling operation in water, such as construction of a causeway. Under these conditions appreciable amounts of solids could be suspended in the water column.

In the use of a leaching test similar to the dredged sediment elutriate test for fill material screening, some of the test specifications that can impact contaminant release should be altered to take into account the differences in the systems. For example, one of the factors that can significantly influence the results of elutriate tests is the liquid to solid ratio. It would be rare that the erosion from highway fill would result in a liquid-solid ratio of 4:1 in the runoff; usually the fraction of solid would be much less. It is suggested, however, that the 4:1 liquid:solid ratio be used in the screening test to represent a "worst case." If potentially excessive concentrations of contaminants are found to be released, then a series of additional elutriate tests should be run incorporating 20:1 and 100:1 liquid:solid volume ratios to determine the dependence of the amount of contaminant release per volume solid on the liquid:solid ratio.

Another factor that should be considered is the sediment/water contact time used in the leaching test. The dredged sediment elutriate test employs an approximately 1.5-h contact time. This was specified because it approximates the typical contact time found in many hydraulic dredging-open water disposal operations. Further, for most aquatic sediments most of the contaminant release occurs within an hour or so of contact. For fill material, however, since one cannot be certain that similar contaminant release patterns would be found, it is suggested that both 1.5-h and 24-h contact periods be used for the leaching test. If significant differences are found in the two test results, then an additional leaching period of one week should be used. It should be noted that certain potential problems such as sulfuric acid production from pyritic ores may not be detected even with several weeks of incubation. The formation of sulfuric acid under these conditions is similar to the formation of acid in acid mine drainage; the reaction appears to be catalyzed by bacteria that may take a number of weeks to become sufficiently active to be readily detectable. While this type of reaction is of importance where it occurs, it is doubtful, in our opinion, that it is worthwhile to try to screen for it through a leaching test unless the fill material is shown to have high concentrations of sulfides.

The waters used in the screening fill material leaching tests should be typical of the region in which the filling will take place. If the only water that will be in contact with the fill is slightly contaminated rainwater, then a distilled-water leaching test should be used. Ordinarily, however, almost instantaneously on contact, the distilled water or rainwater would assume a character dominated by the fill material as a result of the release of more readily soluble, dominant cations and anions such as Na^+, Ca^{++}, Mg^{++}, Cl^-, $SO_4^=$, and HCO_3^-. Obviously, if the water in contact with the fill is marine or estuarine, then waters of the same pH and salinity should be used.

As discussed by Jones and Lee (3), care must be taken in interpreting the results of sediment leaching tests. The results should not be mechanically compared with water quality criteria or standards for the purpose of judging potential water quality impact. Rather, a tiered hazard assessment approach, such as that described by Lee and Jones (3-5) and subsequently in this paper, should be used in which factors such as the rate and amount of contaminant release and the characteristics of the receiving waters are considered in determining and evaluating the potential impact of the contaminants released on water quality. For further details on the hazard assessment general approach, consult Lee and Jones (4,6) and Lee and others (7).

APPLICATION OF WATER QUALITY CRITERIA AND WATER QUALITY STANDARDS TO FILL OPERATIONS

The EPA states, "... the permitting authority shall determine whether the concentration of each contaminant identified during the 230.61 evaluation [leaching test] is substantially greater than the appropriate existing federal or state water quality standard" (1). This section of the proposed regulations is the one that would cause the greatest problem in implementing fill material environmental regulations in such a way so as to ensure that funds spent for contaminant control are used in a technically valid, cost-effective and environmentally protective manner. First of all, it should be noted that contrary to the Federal Register wording, there are no federal water quality standards; EPA has developed water quality criteria (8,9) that, while having no regulatory authority, are, according to P.L. 92-500, to serve as a basis for state standards that do have a regulatory function. The basic technical problem with this section is that as they exist today, the federal criteria and state water quality standards against which the concentrations of contaminants released in the water leachate test are proposed to be judged are in general inappropriate for this application.

The first set of EPA water quality criteria (Red Book criteria) was released in July 1976 (8); a second set of criteria for 64 of the 65 "Consent Decree" "toxic chemicals" was released in November 1980 (9). The parameters included in the November 1980 criteria, many of which are "exotic" chemicals, were established out of a lawsuit [Natural Resources Defense Fund et al. v. Train (EPA)] and did not receive appropriate peer review. Some of the chemicals on this list have not been found to be significant water pollutants. A number of the parameters in the July 1976 criteria were revised in the November 1980 criteria. Many of the remaining July 1976 criteria will be revised in December-January of 1981-1982. The EPA criteria are essentially equivalent to chronic exposure safe concentrations of the available forms of the chemicals, designed to protect essentially all forms of aquatic life. They assume that the organisms in contact with the contaminants will receive a chronic, usually life-time, exposure. Further, they assume that all forms of the contaminants in contact with the organisms are 100 percent available to the organisms. They are primarily directed toward regulating contaminants derived from municipal and industrial wastes. This per se is not a problem; however, EPA administration policy, until recently, has been that if a state adopts a numeric water quality standard, it must be at least as stringent as the EPA criterion for that parameter, or acceptable justification for a more lenient standard must be provided. Further, these state standards have in general been applied to the total concentrations of contaminants rather than the available forms of the contaminants.

In the late 1960s and early 1970s, it was decided that numeric water quality criteria and standards represented the most politically expedient and bureaucratically simple approach for developing water pollution control regulations in the United States. The basic premise of this approach was that if a single value, numeric standard can be established for a contaminant, all that the pollution control agency personnel would have to do would be to take a sample outside of the mixing zone or from the contaminant source. If the concentrations of contaminants in the sample were to exceed the numeric standard, then there would be a violation of the state water quality regulations that would require some type of corrective action. At the time that this approach was first adopted, little was known about how contaminants impair beneficial uses of water and, in particular, those promoting this approach did not have a very good understanding of the great importance of the aqueous environmental chemistry of many contaminants in affecting how a contaminant impairs beneficial uses of water.

It would be very rare that all of the contaminants associated with highway fill material would be in available forms; a substantial part of such contaminants would be associated with particulate matter, most of which would not likely become available to affect water quality. Therefore, if the water leachate test included the measurement of particulate contaminant forms, it could grossly overestimate the amounts of contaminants potentially available to affect water quality. Even if the contaminants in the leachate were soluble, and therefore likely to be available at the point of leaving the filled area, there would likely be sufficient amounts of suspended solids from erosion in the area runoff to convert many soluble contaminants to particulate forms within fairly short distances from the fill area, and thereby mitigate and sometimes completely eliminate, any water quality problem associated with contaminant release from the fill material.

Another significant deficiency with trying to use EPA water quality criteria, or state standards numerically equal to them, directly for judging the potential environmental significance of contaminants associated with fill material is the fact that, typically, fill material contaminants would leave the area of filling during relatively short periods of time associated with rainfall-precipitation-runoff events. If contaminants derived from these areas were to reach a watercourse, they would enter in pulses; the duration of elevated concentrations in the waterbody would be expected to be short compared with the chronic--life-time duration that was used to establish the criteria--standards. It would indeed be very rare that EPA criteria of the type released in July 1976 or November 1980 would be directly appropriate to judge the potential environmental impact of contaminants released from fill material in a water leachate test.

The Federal Register announcement of toxic contaminant criteria (9) contains two important new provisions that could significantly change the approach used to judge the significance of contaminants associated with fill material. Until this date, if a state adopted a numeric water quality standard, it had to be as stringent as the EPA criterion for that contaminant. As of that date, EPA dropped its "presumptive applicability" policy for its criteria and began to allow states to adopt site-specific standards. While Lee (10) pointed out many years ago that there were significant differences between the chemical environments of the bioassay test used to develop the criteria and real-world waters, it is only now that EPA is beginning to focus on providing guidance on the development of site-specific standards, adapting criteria to natural waters. With the significant cutbacks in federal funding, however, it is doubtful that funds will be available to address the development of site-specific numeric standards that would be applicable to the typical situation associated with contaminants derived from highway fill material in a meaningful way. It is recommended that no attempt be made to develop single value, numeric standards to be applied to all situations. This approach, while politically expedient and bureaucratically simple, will be unnecessarily strict in some instances and too lenient for environmental protection in others. Instead, the hazard assessment approach of the type described subsequently and by Lee and others (4-7) should be used to evaluate the potential impact of fill material-associated contaminants on a site-specific basis.

The Federal Register (9) contains another important provision that could significantly affect the evaluation of the significance of contaminants derived from fill material. While EPA has rescinded its presumptive applicability policy, it has required that states adopt water quality standards for all parameters for which it has developed criteria. Until this announcement, if a state did not want to adopt the EPA criterion value for a particular parameter, it could do so simply by not adopting any standard for that parameter. If fully implemented, this new policy will mean that the water leachate from the fill material testing will have to be analyzed for many more parameters (many of which are likely to be irrelevant) than have been required in the past. It is doubtful at this time, however, even if EPA should attempt to enforce this requirement, that this approach will be followed for any significant period of time. As discussed above, there are several of the criteria released by EPA in November 1980 for which states should not, in our opinion, develop standards.

For most discharges, water quality standards are to be applied to waters outside of a zone of mixing of the discharge with a receiving water. The EPA (1), however, specified that no mixing zone shall be used to interpret the potential significance of contaminants released in the fill material water leaching test. No rationale is given for this approach, nor do we see any logic to it. A mixing zone or "limited use zone" might be a way of allowing development of site-specific standards without having to designate specific numeric values. Lee and Jones (11) have recently discussed the use of the hazard assessment approach for the development of mixing zones for point source discharges of contaminants. This discussion should be consulted for additional information on this topic. It is hoped that EPA will not carry through on its proposed regulations on mixing zones as they apply to fill material. Rather than arbitrarily ruling out any mixing zones, EPA should allow the development of site-specific, appropriately sized mixing zones that would protect the publicly designated beneficial uses of the receiving waters, i.e., the swimmable-fishable character. This is in the best interest of the public in terms of highway development, other aspects of filling operations, and environmental protection.

APPLICATION OF DREDGED MATERIAL RESEARCH PROGRAM RESULTS TO FILL MATERIAL

A lack of validity of using bulk sediment criteria as a basis for judging the potential environmental significance of contaminants associated with dredged sediment resulted in the Congress' establishing a $30 million, five-year Dredged Material Research Program (DMRP) through the U.S Army Corps of Engineers and devoted to various environmental aspects of dredged sediment disposal. While the program was supposed to cover both dredged and fill material, those responsible for administration of this program within the Corps of Engineers gave only limited attention to the environmental aspects of fill material compared with that devoted to dredged sediment disposal. This was understandable from several points of view. First and foremost, the Corps has been given substantial Congressional authority to maintain U.S. waterways by dredging. They have limited activity and authority in the area of fill material. Second, it was the potential problems of contaminants in dredged sediment that stimulated the funding. Actually, to our knowledge, except for the situation mentioned above of sulfuric acid formation from pyrite-containing fill material, there has not been a single documented case within the United States of an open water-dredged material disposal or a filling operation's having caused a detrimental impact on water quality because of solids-associated contaminants.

A series of intensive studies was conducted by the Corps of Engineers as part of the DMRP, which was designed to detect potential, significant environmental quality problems. No problems were detected at any of the intensive site studies or at any of the other sites investigated that would justify using alternate, more expensive methods of dredged sediment disposal.

Another reason why the DMRP did not focus on fill material is that filling operations are a highly heterogeneous group of operations that cover a very wide variety of activities, each with its own somewhat peculiar characteristics. On the other hand, dredging and dredged-material disposal activities fall into a limited number of categories, many of which are readily amenable to study in a generalized way.

Although the Corps' DMRP did not specifically address fill material impacts to any significant extent, it did provide considerable information that can be used to guide investigations of the environmental quality aspects of a particular filling operation. First, it is clear that every filling operation must be treated on an individual basis. Attempts to generalize will either be under- or over-protective of the public's interest. It also clearly established, reinforcing what was already known, that bulk contaminant concentrations in solids cannot be used to estimate potential water quality problems.

One of the most significant results of the Corps of Engineers' DMRP that is pertinent to some, if not most, filling operations is the clear demonstration that the concentration of available forms-duration of exposure relationships that are found during open water dredged sediment disposal are such that EPA's water quality criteria (and hence standards equivalent to them) have limited direct applicability for judging the potential impact that a particular disposal operation may have on water quality. Further, out of the DMRP came the development of bioassay procedures and leaching tests that can be used to indicate if a particular sediment may release potentially significant amounts of contaminants that could cause water quality problems if disposed of in a particular location. The EPA and the Corps of Engineers developed a rather elaborate set of bioassay procedures designed to detect potential water quality problems that may be caused by contaminants in dredged sediment. Unfortunately, these procedures are not being widely used primarily because of their complexity and cost, as pointed out by Jones and Lee (3) and Lee and others (12). Essentially the same amount of useful information for management decisionmaking purposes can be gained from a single simple bioassay procedure as from the multiplicity of tests developed by EPA and the Corps of Engineers. For further information on dredged sediment bioassays, consult Jones and Lee (3) and Lee and others (12).

HAZARD ASSESSMENT APPROACH FOR FILL OPERATIONS

While it appears that the excavation and fill associated with highway construction would rarely have significant adverse impacts on aquatic systems beyond those that would occur because of the placement of the highway in the area, it is important to screen fill material used in highway construction for potential adverse impacts. This screening should be done in a tiered hazard assessment such as is discussed by Lee and others (7) and Lee and Jones (5). The EPA has recently proposed a similar approach for use in connection with the permitting of hazardous waste disposal sites (13). Basically, this approach involves an assessment of what may migrate from the deposition area to the surrounding area. Depending on results of screening tests, estimates would be made of the rate of migration, expected rate of dilution, and any attenuation or transformation that might occur between the site of placement of the solids and a point of concern for surface and groundwater quality.

In the first tier of testing, the source and general character of the proposed fill material should be reviewed as well as the probability for substantial amounts of erosion occurring. The sediments should also be evaluated for sulfides. If there are questions regarding the potential for contaminant release or leaching to groundwaters, or if there is likelihood of potentially significant amounts of solids being transported from the fill area, tier 2 testing should be undertaken.

Tier 2 testing should include worst-case screening tests for contaminant leaching similar to the elutriate test described previously. It is important to emphasize that the results of such tests should only be used in the context of the hazard assessment and not as a direct indicator that the fill material is unsuitable, etc. Consideration should be given to the mode and amount of potential transport to a watercourse of importance and to the environmental chemistry-fate of the contaminants in question. Where it appears that contaminant leaching may be significant to the quality-beneficial uses of the surface and/or groundwaters receiving runoff from the fill area based on interpretation guidance provided by Jones and Lee (3), tier 3 testing should be undertaken.

In tier 3, a series of chemical leaching tests should be conducted that bracket the conditions expected at a particular filling site with respect to water contact with the fill. Interpretation of the results of these tests should involve consideration of how the leachate from the fill containing the contaminants of concern would interact with the aquatic organisms of concern in the waters of the region. For these tests, EPA water quality criteria will likely be useful to flag those contaminants and fill materials that may have an adverse impact on water quality. If concentrations in tests designed to imitate real-world conditions are in excess of the chronic safe concentrations, tier 4 testing should be conducted.

Tier 4 tests should be designed to determine whether or not the "excessive" concentrations would cause a potentially significant impairment of the beneficial uses of the water of the area and justify alternate methods of construction and maintenance. These tests involve consideration, on a site-specific basis, of the amount and forms of contaminants that would be released from the fill material that would reach the watercourse of concern and the concentration of available forms-duration of exposure relationships that would exist in the waters of concern. In the Federal Register (1) EPA indicates that additional testing may be used if there are questions about the potential significance of contaminants released from fill material in impairing beneficial uses of the waters of the region. It is likely that tier 4 testing may include aquatic organism bioassays such as those developed by Lee and others (2,12). It is very important that this tier 4 assessment be based on the potential for actual impairment of beneficial uses. If the results of the tier 4 hazard assessment show that there is a significant potential hazard associated with the use of a particular fill, then, and only then, should alternate, more expensive sources of fill or fill containment be sought and evaluated as described herein.

Where groundwater contamination may be of concern, we recommend that EPA's announcement in the Federal Register (February 5, 1981) (13) as well as Lee and Jones (14) be used as a guide for examining the potential for groundwater contamination associated with filling operations. This is especially true for situations in which an attempt is made to "contain" hazardous fill material as mentioned in the Federal Register (1).

There are several significant advantages of using a sequential, tiered evaluation process such as outlined above. First, it provides rational, technically valid guidance for collecting information pertinent to the problem at hand, rather than having random pieces of information collected with the hope of being able to evaluate potential impacts. At the same time, because of the sequence proceeding from simple, inexpensive, but gross testing to sophisticated, more refined but more expensive testing, the hazard assessment scheme is highly cost-effective. Testing may be stopped at any tier once the reliability of the potential impact has been determined with sufficient reliability for the particular situation.

It is recommended that EPA modify its December 24, 1980, proposed methods for assessment of the environmental significance of contaminants in fill material to permit the use of a hazard assessment approach of the type described in this paper. The adoption of this approach ensures that funds spent for alternate, more expensive methods of highway construction and maintenance will result in a cost-effective expenditure of funds for environmental quality control.

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Quality of Seepage and Leachate from Mine and Mill Wastes and Control of Its Effects

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Mine and mill wastes, such as waste rock and tailings, are possible sources of road construction material. However, although such materials may be suitable from geotechnical considerations, they may prove to be problematic as they may produce contaminated seepage and leachate. A classification is presented of the types of mine and mill waste. Three important considerations in the use of these mine wastes are (a) the origin and characteristics of the waste rock; (b) the influence of mineral extraction process on leachate quality from tailings (typical problems associated with the various waste types are highlighted); and (c) changes in soil structure due to leachate, e.g., the Na ion, which can accelerate weathering or lead to changes due to ion exchange. Leachate from mine waste can have detrimental effects on the environment due to effluent quality. It can also influence the integrity of engineering structures through chemical attack in many forms. The detrimental effects of leachate from mine waste can be controlled by treatment before placement, treatment during placement, treatment of effluent, and other methods, e.g., the use of detergents to inhibit bacterial activity in the formation of acid drainage.

Mine and mill wastes, such as waste rock and tailings, are possible sources of road construction material. Such materials are available often in abundance and usually exhibit excellent geotechnical characteristics. Furthermore, because these materials are waste products, they are usually economically attractive. However, it is important that the potential chemical problems associated with mine wastes be investigated prior to their use as road building materials. Such problems can usually be solved in time, if they are recognized.

Although many chemical leachate problems can be associated with mine and mill waste, as will be discussed later, acid drainage is by far the most common and potentially serious. Acid drainage is the result of the oxidation of sulfur-rich minerals, most commonly pyrite. Bacteria act as important catalysts in the oxidation process and the development of acid drainage problems.

The purpose of this paper is to present an overview of seepage and leachate problems associated with mine waste and possible ways of limiting their impact. The information is based on our experience and some of the latest literature sources.

EVALUATING MINE WASTE

Classification of Mine Waste

Mine waste is defined here as all solid wastes associated with mining activities and smelters as well as the chemical industries where a mineral is used in the manufacturing of chemicals, such as the fertilizer industry.

Mine waste will be classified for this discussion as follows:

1. Overburden material resulting from stripping operations for strip or open pit mining;
2. Waste rock, including rock that contains subeconomic ore grades as well as "country rock" or rock that is not ore-bearing;
3. Tailings, the fine material remaining after crushing, milling, and processing of an ore;
4. Slag, the waste from smelting operations and usually disposed of as a high-temperature-melted material (the resulting waste is therefore very hard and massive unless recrushed); and
5. Other materials, such as calcine from pyrite roasting for the production of sulfuric acid (1) and gypsum tailings resulting from the production of phosphoric acid (2), fall in this category.

Although it is useful to classify mine waste, as done above, it must be emphasized that no unique leachate problems are associated with any type, e.g., all the types of mine waste can produce acid drainage. The usefulness in the classification is to identify the sources of waste and disposal methods, as each type of waste is usually disposed of separately during mining operations, e.g., overburden and waste rock dumps are separated from tailings impoundments and slagheaps.

Leachate-Producing Capacity of Wastes

There are two major considerations in evaluating the capacity of mine and mill waste to generate contaminated leachates: (a) the origin and characteristics of the waste rock, and (b) the influence of mineral extraction processes, especially the influence of chemicals added.

Origin and Characteristics of Waste Rock

The origin and characteristics of ore or waste rock determine the sulfide and carbonate contents of the waste and its potential for acid generation; hazardous chemical and radiochemical constituents present in the waste, such as heavy metals; and the potential for mobilization and release of these hazardous materials by way of expected interaction with the environment that will be developed by the use of the waste.

Caruccio and others (3) state: "In terms of a sample's potential to produce acidity (all other parameters being equal) the samples with a predominance of fine grained (framboidal) pyrite generate orders of magnitude more acid than samples having coarse grained pyrite".

An important consideration in the acid-producing capacity of a material is the relative percentage of