Evaluation of the Water Quality Significance of Eroded Suspended Sediment-Associated Constituents[1]

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Introduction

The control of erosion is often justified from several perspectives, including controlling the water quality impacts of the erosional materials in the receiving waters for the runoff carrying the eroded materials. In addition to problems of turbidity - water discoloration, siltation that adversely affects aquatic life habitat, and the physical filling of the waterbody with accumulated sediments, eroded materials often transport various types of chemical constituents such as pesticides, heavy metals, nutrients, and various types of organics that at some locations in some waterbodies cause water pollution - impair the designated beneficial uses of the water. While these "pollutants" may not be associated with the eroded sediment at the location where erosion takes place, many eroded sediments have appreciable capacity to sorb - take up dissolved constituents from the water, causing them to be transported with the particulate matter. For many types of potential pollutants, the primary mode of transport in water courses is associated with particulate matter, including eroded sediments.

Frequently, the control of erosion is justified primarily on controlling water "pollution" due to the particulate forms of chemical constituents associated with the eroded particles. However, the regulatory approaches towards the management of sediment-associated constituents in erosional materials are changing significantly. No longer is there technical justification for the control of particulate forms of heavy metals in erosional materials. It is now becoming more widely understood that particulate-associated chemical constituents, such as heavy metals, many types of organics, etc., are in non-toxic, non-available forms and can for all practical purposes be considered inert in the carriage waters for the erosional materials as well as the ultimate receiving waters for the eroded materials. This paper reviews some of the key issues associated with evaluating and regulating the water quality significance of chemical constituents associated with eroded materials.

Regulatory Approaches

The regulatory approaches that have been used for the last 20 years for regulating the concentrations of heavy metals have been intimately tied to the water quality significance of particulate forms of metals. Many heavy metals tend to exist in aquatic systems in particulate forms as precipitates as well as attached to the surfaces of organic and inorganic suspended sediments through sorption reactions. Such reactions occur through bonding between the heavy metal and the particulate matter surface. Such bonds can be quite strong and can, in fact, render the heavy metals inert with respect to their impacts on aquatic life.

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[1] Lee, G. F. and Jones-Lee, A., "Evaluation of the Water Quality Significance of Eroded Suspended Sediment-Associated Constituents," Land and Water, 40:19-23 (1996)

In the early 1970's, the National Academies of Science and Engineering appointed an advisory panel to develop a set of water quality criteria. These criteria were designed to represent the maximum concentration of chemical constituents that could be present in a water without adversely impacting a beneficial use, such as the propagation of fish and aquatic life. It was well-known at that time that particulate forms of heavy metals and for that matter other potential pollutants were non-toxic and therefore not available to aquatic life to a sufficient extent to be adverse to their numbers, types and characteristics in a waterbody. The NAS/NAE developed the "blue book" of Water Quality Criteria - 1972 (NAS/NAE, 1973).

After extensive review, the NAS/NAE committees determined that it was not possible to regulate heavy metals based on the total content in a wastewater discharge. The primary problem is that often significant parts of the heavy metals are in particulate, non-toxic forms. Further, it was found that even some of the dissolved forms are non-toxic due to complexation, colloid formation, etc. They recommended that heavy metals be regulated based on toxicity testing. The US EPA, as part of developing their "red book" of Water Quality Criteria in 1976, adopted the NAS/NAE recommended approach for regulating heavy metals.

In the early 1980's, however, the US EPA abandoned that approach in favor of total heavy metal content. This change in approach did not represent any new information that showed that the particulate fractions of heavy metals were toxic. The Agency adopted this approach for administrative reasons in order to simplify the regulation of heavy metals. In the Agency's 1986 "gold book" of Water Quality Criteria, mention is made for the heavy metals that implementation of the criteria based on total recoverable heavy metals likely overestimated the impacts of the heavy metals on water quality.

As part of implementing the National Toxics Rule, the Agency announced in 1993 that it recommended that ambient water heavy metals (arsenic, cadmium, chromium, copper, lead, nickel, silver and zinc) be regulated based on dissolved forms rather than total recoverable. This was made official policy by the Agency in May 1995 (US EPA, 1995) where it formally adopted dissolved metals as the regulatory approach that would be used by the Agency in those states where the Agency issues the NPDES permits. In those states where the authority for issuing NPDES permits has been delegated to the state, the state can if it wishes implement their water quality standards based on total recoverable rather than the recommended dissolved.

While the US EPA has not yet addressed similar issues for other types of constituents such as the organics, the same situation should apply. It is now well-known through the Agency's and others' work in sediment quality criteria development that only the dissolved form of the organic constituent is available - toxic to aquatic life. The particulate forms are non-toxic. Eventually, the Agency should adopt a similar approach for regulating other potentially toxic constituents as they have done for the heavy metals. This is the technically valid approach that should be used.

Water Pollution Control for Erosional Materials

The US EPA's recent adoption of ambient water dissolved metals as the regulatory approach for limiting the heavy metal content of point and non-point source discharges should significantly change the approach that is used to control water pollution associated with heavy metal inputs.

Where in the past stormwater runoff from urban areas, highways and rural areas has been "treated" for heavy metal removal through the use of detention basins and/or various types of filters, in the future the real efficacy of such approaches in controlling water pollution - use impairment has to be questioned. Such systems typically only remove the larger-sized particles. The potential pollutants associated with these particles, however, are now acknowledged to be non-pollutants. Therefore, in the future the justification for the construction of detention basins, filters, etc. for water pollution control should focus on the control of the erosional materials in order to eliminate any physical impacts that they may have on the beneficial uses of the receiving waters for the runoff.

Such physical impacts as

- turbidity - discoloration and reduced light penetration, which may affect photosynthesis;
- siltation, resulting in sediment accumulation that is adverse to aquatic habitats such as fish spawning areas and in tropical waters coral reefs;
- accumulation of sediment that reduces the depth of the waterbody to impair navigation, promote excessive weed growth, impair contact recreation, etc.
- should be the focal point of determining whether there is need to control the input of erosional materials beyond that possible by control at the source. The actual chemical make-up of the particulates, such as heavy metals, should not be an issue.

In evaluating the potential physical impacts of erosional materials - suspended solids in runoff on receiving water water quality, it is important not overestimate these impacts. While it is often assumed that small amounts of turbidity which may cause appreciable water discoloration especially in waterbodies that have exceptionally clear water, such turbidity does not necessarily significantly adversely impact the planktonic algae in the waterbody and therefore the trophic food web. As a result of the authors' studies on lakes and reservoirs located in many parts of the world, it has been found that light penetration as measured by a Secchi depth must be reduced to about one foot before sufficient turbidity exists to adversely impact the algal biomass that develops in the waterbody.

Similarly, it is often stated that inorganic turbidity - suspended solids is significantly adverse to aquatic life through abrasion of gills, etc. However, it has been found that suspended solids concentrations of hundreds of milligrams per liter or more are needed to be adverse to aquatic life. Most aquatic life have developed in situations that routinely experience significantly elevated turbidity - suspended solids associated with storms - runoff events, wind-induced mixing of shallow waters, etc. The settling of suspended solids can be a significant factor in adversely impacting spawning areas, and coral reefs are particularly sensitive to accumulation of sediment.

Protection Against Adverse Impacts of Particulate Chemical Constituents on Sediment Quality

It is sometimes advocated that there is justification to control particulate forms of heavy metals and other potential pollutants based on the accumulation of these materials in the receiving water sediments that would be adverse to aquatic life that live in and upon the sediments. It is inappropriate to try to regulate sediment quality issues by requiring that the input of particulate forms of heavy metals be controlled by treatment of the runoff waters through the use of

detention basins, filters, etc. It is not appropriate to assume that particulate heavy metals and, for that matter, other constituents in runoff waters will result in the development of deposited sediments in the receiving waters that will be adverse to aquatic life-related beneficial uses of the waterbody. The ability to reliably predict the fate and effects of particulate forms of heavy metals and other constituents in runoff waters is limited due to the inability to reliably determine where suspended solids in runoff waters will be deposited in the receiving waters and the chemical transformations that will occur in the deposited sediments that will cause the release of constituents that have been transported to the sediments on the surfaces of particulates. However, there is sufficient understanding of these issues to conclude that there will be few instances where a particulate heavy metal, such as lead, associated with runoff from a highway would lead to lead accumulation in the receiving water sediments that would be significantly adverse to the aquatic life populations in these waters.

The approach that should be followed in evaluating whether there is need to control particulate forms of heavy metals and other constituents is through site-specific investigations of the characteristics of the receiving water sediments. The US EPA and the US Army Corps of Engineers have many years of experience in evaluating the potential for open water disposal of contaminated dredged sediments to be adverse to the beneficial uses of the receiving waters in which the dredged waterway sediments are to be deposited outside of the navigation channels. These agencies have developed guidance manuals for evaluation of both freshwater and marine impacts (US EPA/COE, 1991, 1994). Lee and Jones (1992) and Lee and Jones-Lee (1994) have provided reviews on the water quality impacts of dredged sediment disposal that have relevance to evaluating the impact of erosional materials on receiving water water quality. Further, Lee and Jones-Lee (1993) have discussed the approaches that should be used to evaluate the water quality significance of chemical constituents in aquatic sediments.

There is considerable concern today about regulating chemical constituents in urban area, street and highway runoff. Part of this concern is focused on the need to regulate the particulate forms of heavy metals and other constituents in this runoff. While in the past, detention basins and/or filters have been constructed for the purpose of controlling particulate forms of heavy metals, etc., such practices are technically invalid and can be highly wasteful of public and private funds. As with erosion from other sources, the development of detention basins and/or filters for the control of particulate forms of constituents associated with highway, street and urban area runoff that occurs after the construction activities have been completed should only be done where it can be shown that the physical impacts of the particulates are significantly adverse to the beneficial uses of the receiving waters for the runoff. Lee and Jones (1991) and Lee and Jones-Lee (1995a,b,c) have provided further information on these issues.

Summary

There is significant justification for controlling the erosion of areas based on preventing the loss of topsoil and scarring of an area. Further, eroded soils can have significant physical impacts on water quality in the receiving waters for the erosional materials through turbidity and siltation. Generally, relatively high levels of suspended solids are needed to be adverse to aquatic life, however. There should be appropriate concern as to whether the deposition of the erosional

materials in the receiving waters adversely affects aquatic life habitat such as fish spawning areas as well as impairing the use of the waters through sediment accumulation.

While it is often advocated that the treatment of runoff waters containing erosional materials and suspended solids is justified from a chemical "pollutant" perspective, such justification is technically invalid. The US EPA's adoption of ambient water dissolved forms of heavy metals in May 1995 as the regulatory approach that the Agency will use to regulate certain heavy metals finally puts into practice what has been known for over 20 years--that heavy metals and, for that matter, other constituents associated with particulates in runoff waters are, in general, in non-toxic, non-available forms.

The approach of constructing detention basins and/or filters to remove particulates from runoff waters because of their potential chemical "pollutant" content is technically invalid. Detention basins and filters should be used where it is not possible to control the erosion at the source in order to prevent adverse physical impacts of suspended solids on the beneficial uses of the receiving waters for the waters carrying the suspended solids. Site-specific investigations utilizing biological effects-based testing procedures such as aquatic life toxicity should be used to determine whether particulate forms of heavy metals and other constituents are potentially adversely impacting the beneficial uses of a waterbody.

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