Application of the equilibrium partitioning method to derive copper and zinc quality criteria for water and sediment: A South African perspective

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Abstract

This paper presents the use of an equilibrium partitioning (EP) method to derive generic quality criteria. Quality criteria for dissolved concentrations in water, total water concentrations and total sediment concentrations were derived from direct-effect data (aquatic toxicity data) and product standard data (human consumption standards). Both sets of data were obtained from physico-chemical and bioaccumulation field measurements in the Olifants and Selati Rivers, South African water quality guidelines and South African product standards. Emphasis is laid on the relation between effect and local physico-chemical data. Examples have been given for copper and zinc. Even with the acknowledged shortcomings of the EP methods the derived quality criteria for water and sediments were comparable to quality criteria from other countries.

Introduction

Environmental risk assessment and water quality management are becoming increasingly important issues, particularly in view of the large numbers of contaminants entering the aquatic environment that are harmful to the functioning of an ecosystem (Van Leeuwen, 1990). The water quality in South African rivers is gradually deteriorating and the social and economical changes taking place affect the way in which water quality has to be managed.

In South Africa water quality management is defined as the effort to control the physical, chemical and biological characteristics of water in such a way that the fitness-for-use, by recognised water users, is unimpaired (Moore et al., 1991). Prior to 1990 the Department of Water Affairs and Forestry (DWAF) controlled water quality and water pollution from point sources by requiring effluent to meet either uniform effluent standards (UES) or special effluent standards, which were set at technologically and economically feasible levels (Van der Merwe and Grobler, 1990). A new era in water quality management was entered with the promulgation of the new National Water Act (Act 36 of 1998). The central departure of the Act is the concept of resource use being dependent on resource protection. It also recognises that water quality should be extended to resource quality and include the quantity and quality of the water itself, the instream and riparian habitat (therefore the geomorphological structure of the system), the instream biota, and the associated riparian biota.

The aquatic environment differs from the other recognised water users (domestic, agricultural, recreational and industrial) in that aquatic ecosystems are essential to maintain the biological integrity necessary to ensure the sustained fitness-for-use of the water resources not only for the aquatic environment itself but also for the other user sectors. It is not a simple task to set water quality management objectives for the aquatic environment, since aquatic ecosystems may differ considerably from each other and have unique properties dictated by the natural conditions prevailing in a specific system. In addition change is an important characteristic of aquatic ecosystems since species composition, rate processes, as well as degree of complexity and many other community characteristics change over time (Chapman, 1991). It is for this reason that general water quality guidelines cannot be regarded as blanket values because they may be over- or under-protective (Moore et al., 1991). Water quality standards or guidelines must therefore be aimed at taking regional differences into account.

At present water quality guidelines are based on the overly simplistic and entrenched philosophy that emphasises only dissolved chemicals and the water column. Very little attention has been paid to developing criteria for sediment bound chemicals. In environmental chemistry the term equilibrium partitioning refers to the relationship between the concentration of a substance in the water column and the concentration in the non-water phase, which is in contact with the water. The equilibrium partitioning (EP) method was found to be a relatively simple and applicative method to derive quality criteria (Shea, 1988).

The EP method models the co-occurrence of chemicals in water and sediments as a state of thermodynamic equilibrium, which can be regarded as a sorption equilibrium. If a direct relationship can be formulated for a chemical, it is possible to estimate quality criteria for sediments from the quality criteria of water, which in turn, are derived from toxicity tests (Van der Kooij et al., 1991). The EP approach requires four major assumptions:

- Partitioning of chemicals (i.e. metal concentrations) between the overlying water and interstitial water is stable at equilibrium.
- The sensitivities of benthic species and species tested to derive water quality criteria, predominantly water column species, are similar.
- The levels of protection afforded by water quality criteria are appropriate for benthic organisms.
- Exposures are similar regardless of feeding type or habitat (USEPA, 1993).

It is acknowledged that the EP method is simplistic since it does not make provision for the route of exposure or environmental factors

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Received 30 October 1996; accepted in revised form 10 September 1999.