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TOXICITY ASSOCIATED WITH THE SUSPENDED PARTICULATES IN THE YAMASKA RIVER

by

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ABSTRACT

Laboratory studies were made to ascertain the suspended particle size which was most commonly found, and the particle size range that was closely associated with bacteria and toxicant activity in the Yamaska River, Quebec, Canada.

The observations indicate that 67% (by volume) of the suspended particulates were below 40 micron size. Particulates greater than 40 µm constituted only 26% of the floating particles. The particles retained on a 20 µm filter sieve which nominally represented the 20-40 µm range contained the highest bacterial load and toxicant levels relative to other size particles, implying that the microbia organic complex associated with the predominant particle size fraction may have a significant role in the fluvial contaminant transport process.

RÉSUMÉ

Des études en laboratoire ont été réalisées pour déterminer la classe granulométrique prédominante des particules en suspension de même que la classe granulométrique des particules qui ont la plus grande activité bactérienne et la plus grande charge de substance toxiques dans la rivière Yamaska, dans la province de Québec au Canada.

Les résultats montrent que 60 % (par volume) des particules en suspension avaient une dimension inférieure à 40 microns. Les particules supérieures à 40 microns constituaient seulement 26 % des particules en suspension. Comparativement aux autres particules, les particules qui étaient retenues par un tamis filtrant à mailles fines de 20 um, considérées comme des particules dont la dimension varie entre 20 et 40 um, contenaient la charge bactérienne et la quantité de substances toxiques les plus importantes. Cette observation révèle que le complexe formé de matières organiques et de bactéries, observé chez les particules qui représentent, suivant la dimension, la plus grande partie des particules en suspension, joue un rôle important dans le processus de transport des contaminants dans les cours d'eau.

MANAGEMENT PERSPECTIVE

The role of suspended particulates in the contaminant transport is well recognized. However, the effects of particle size distribution and bacterial organic matter in the contaminant transport process are not well understood. The present study demonstrates that a predominant suspended particulate fraction (20-40 µm) which contains the highest percentage of bacterial organic complex also contains the highest toxicant load. This means that the microbial-organic complex may have an equal or greater role in the binding of toxicants to the Yamaska River suspended particulates than the usually accepted physico-chemical forces on the surface of the particles. This also implies that the bulk of the toxicant transport is associated with the organic rich predominant size fraction. The information from this study will be of use to modellers to develop fluvial toxicant transport models.

PERSPECTIVE-GESTION

Le rôle des particules en suspension dans le transport des contaminants est bien connu. Cependant, les effets de la distribution granulométrique et du complexe formé de matière organique et de bactéries, en ce qui a trait au processus de transport des contaminants, ne sont pas très connus. Cette étude démontre que la classe de particules la plus largement représentée (20-40 um),dans laquelle se trouve la plus grande proportion de matières organiques contenant des bactéries, est aussi celle qui contient la plus grande charge de substances toxiques. Cette observation signifie que le rôle de la matière organique contenant des bactéries est peut-être aussi important, sinon plus important, dans le processus de fixation des substances toxiques sur les particules en suspension de la rivière Yamaska, que les forces physico-chimiques habituellement prises en compte agissant à la surface des particules. Cela implique aussi que la plus grande partie du transport des substances toxiques est attribuable aux particules de la classe granulométrique prédominante riche en matière organique. Les résultats de cette étude s'avéreront utiles pour la création de modèles de transport des substances toxiques dans les cours d'eau.

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(With 1 table)

Introduction

The Yamaska River, a tributary of the St. Lawrence River (approximately 60 km northeast of Montreal), is highly polluted and the water quality in the basin is generally low as a result of industrial discharges and inadequate domestic waste treatment facilities (TATE, 1972). Textile plants have been, and continue to be, major contributors to water pollution in the river basin.

In an attempt to understand the extent of downstream contamination from point sources, a study was initiated to ascertain the suspended particle size which was most commonly found in the river basin's waters and to identify the particle size range which was most closely associated with toxicant activity and bacterial transfer.

In this report, we present data on (1) particle size distribution in the Yamaska River waters (2) microbial content of the various sized particulates and (3) toxicant activity of the various sized particulates as assessed by the Microtox toxicant screening test. The implications of these data are discussed.

Methods

Sample Collection

In order to minimize the agitation and disintegration of suspended particles while being transported from the Yamaska River to our laboratory (750-800 km), the 200 L container was filled to capacity with river water so that no air space was left.

Particle Size Distribution Analysis

The water sample was subjected to particle size distribution analysis using a laser particle size analyser (Malvern Instruments Ltd.), particle size distribution within the sample was derived from measurements of the near forward fraunhafer diffraction spectrum that is provided by a particle (BALE and MORRIS, 1987).

Particle Size Fractionation

A 5 L sample of the river water was subjected to size fractionation using 80 µm, 64 µm, 40 µm, 20 µm, 8 µm and 3 µm filter sieves. The fractionation of the water sample was performed using the Cascade sieving procedure (De VITRE et al., 1988; LEPPARD et al., 1988 and 1989, and PERRET et al., 1988). This procedure has some limitations. During the filtration, as particles collect on the filter sieve surface, the filtering efficiency changes due to pore clogging and some of the smaller particulates are retained on the filter. Therefore the filtrate does not contain 100% of the smaller particulates that are expected to pass through each filter sieve. Also, the particles in the filtrate have a tendency to flocculate, thus the size distribution pattern found in the filtrate varies from particles below the sieve size to larger than the sieve pore size they passed through.

Extreme care was taken to minimize particulate disintegration and filter clogging by gentle mixing of the sample during filtration and gentle resuspension of the material on the sieve surface by dipping the sieve surface below the surface of the filtrate. Each of the fractions from each sieve filter were carefully resuspended in 200 mL distilled water and subjected to bacterial, toxicant analysis and particulate organic carbon and nitrogen.

Bacteriological Analysis

A 1 mL of 1/10 dilution of each fraction was homogenized (MARXSEN, 1988) using a vortex mixer at highest speed for 1 minute, to facilitate uniform dispersion of bacteria from the particulate aggregates. Bacterial content was then determined using acridine orange direct microscopic counting procedure and a phase contrast microscope (RAO et al., 1984).

Toxicity Assessment

A 50 mL aliquot of each of the 200 mL suspensions was filtered through a 0.2 µm nuclepore polycarbonate membrane filter. The filters were transferred into scintillation vials containing 0.5 mL DMSO (Dimethyl Sulfoxide) (100%) and were sonicated for 30 min in a sonic dismembrator (Branson, Smithkline Co.). After sonication, 49.5 mL Milli-Q reagent grade water was added to the vials in order to obtain a final DMSO concentration of 1.0%. The Microtox Toxicant Screening Test was then performed following the procedure detailed in Beckman Microtox System Operating Manual (1982) with 15 min. contact time (DUTKA and KWAN, 1982).

Particulate organic carbon and nitrogen analyses of the different fractions were performed following the procedure outlined in the "Analytical Methods Manual (1979) using the Perkin Elmer Model 2400 CHN Analyzer.

Results and Discussion

One of the factors controlling suspended sediment capacity for concentrating contaminants is the particle size (HOROWITZ, 1984). It has been shown that fluvial transport of particulate material in Canadian waters is mainly composed of suspended materials in the 2-62 µm range (BLACHFORD and DAY, 1988). In aquatic ecosystems the fate of many hydrophobic toxicants is dependent on the sorption capacity of suspended particulates, which are usually composed of organic and inorganic materials. The organic aggregates are composed of materials from plants and animals in various stages of decomposition, thus providing a nutrient source for microbes. In the Yamaska River, the particle size distribution analysis (Table 1) indicate that 67% (by volume) of the suspended particulates were below 40 microns in size. The particles retained on the 20 micron filter sieve represented the 20-40 micron range which were the predominant particle size in this river water. Particulates greater than 40 microns constituted only 26% of the floating particulate matter. It can be seen from Table 1 that particles in the 20-40 micron range contained the highest particulate organic carbon (7.74 mg/L), nitrogen (0.677 mg/L) and bacterial load (8.3×10^5/mL). The toxicant level as determined by the Microtox toxicant screening test was also found to be the greatest for this particulate fraction. The interesting relationship between the highest bacterial densities and the greatest concentration of toxicants on the same fraction should be noted. It is believed that extracellular polymeric substances secreted by the bacteria may have an affinity for toxicant molecules (FLETCHER and FLOODGATE, 1973; MARSHALL and CRUICKSHANK, 1973; MARSHALL, 1986). This may account for the higher toxicant concentration on these bacteria rich particles. Furthermore, these extracellular polymeric substances could act to delay the impact of toxicants on the bacterial cell.

These observations suggest that the microbial-organic complex may have an equal or greater role in the binding of toxicants to the Yamaska River suspended particulates than the usually accepted physico-chemical forces acting on the surfaces of the particles. If the surface forces were the primary controlling factor, then it would be expected that the finest fraction (3-8 µm) would have the greatest toxicant binding efficiency. The distribution patterns of predominant particle size and the relationship to bacterial densities and toxicant activity will be investigated in a variety of fluvial systems. If this pattern is observed in most systems, models for contaminant transport may be greatly assisted.

Table I

Bacteria, Particulate Organic Carbon, Nitrogen and Microtox Toxicity Associated with Different Particle Sizes in Yamaska River Water

Particle Size Range* (µm)	% Volume In the River Water	Bacterial Densities ($x10^5$/mL)	Microtox (EC_{50}) %	Particulate Organic Carbon (mg/L)	Particulate Nitrogen (mg/L)
3 - 8	18.5	3.5	-	-	-
8 - 20	20.2	3.7	44.90	5.06	0.393
20 - 40	28.0	8.3	4.62	7.74	0.677
40 - 64	13.7	6.8	13.11	1.61	0.103
64 - 88	6.6	3.6	90.89	0.75	0.041
>88	5.7	-	6.52	3.17	<0.002

* Measured by Malvern Particle Size Analyzer
- No data

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