

## Colloids, Carbon and Contaminants in Coastal Waters

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### Marine Colloids - A Global Reservoir of Reactive Carbon

The colloidal fraction of organic carbon in the world's ocean is one of the largest reservoirs of carbon on the planet, outweighing the "living" carbon stored in the biomass of phytoplankton, macrobiota (all commercial species), zooplankton and

bacteria by a considerable margin (Fig. 1). On a global scale, this pool of tiny (sub-micron) particles and aggregates is enormous - approximately equal to the carbon stored in the combined biomass of temperate and tropical forests (Hedges, 1987; Kepkay, 1994).

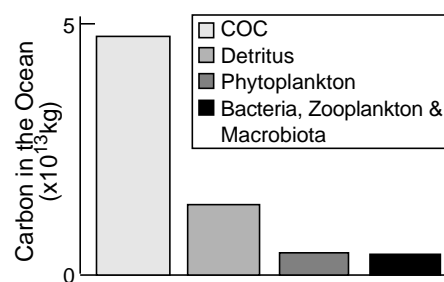


Figure 1: Colloidal organic carbon (COC), detrital carbon and the three major sources of "living" carbon (phytoplankton, macrobiota, zooplankton and bacterial biomass) in the world's ocean. COC is defined solely on the basis of size, and refers to organic carbon particles and aggregates that are between 0.001 and 1  $\mu\text{m}$  in diameter.

Added to the fact that colloidal organic carbon (COC) is a major fraction of the oceanic and planetary carbon budget, a substantial portion of this COC is reactive and

is broken down by respiration, releasing the carbon as CO<sub>2</sub> (Amon and Benner, 1994; Kepkay, 1994). The respiration of bacteria and other members of the microbial community is especially intense when colloids are clumped together into aggregates by ocean turbulence (Kepkay, 1994). The COC that escapes respiration is exported as aggregates to the ocean interior.

On a global scale, this downward export of aggregated carbon is a key element in the “biological pump” (Longhurst *et al.*, 1995) which absorbs CO<sub>2</sub> from the atmosphere at the ocean surface and stores it as “fixed” organic carbon in the deep ocean. The production of aggregates from colloids also acts as a mechanism for concentrating chemical contaminants (Niven *et al.*, 1995) and is one of the main pathways for transporting these contaminants between surface and deep water.

### Production and Degradation of Colloids

A number of biological and physical processes contribute to the production of marine colloids (Niven *et al.*, 1995), but the excretion of polymers by the phytoplankton is one of the most direct means of COC production. Once released, these exopolymers can take many forms (Hoagland *et al.* 1993), but are most commonly found as microfibrils of polysaccharides (Fig. 2). The microfibrils are thought to remain in the colloidal (submicron) size fraction for only a short time (hours to days) because they are aggregated by turbulence to form “TEP” or

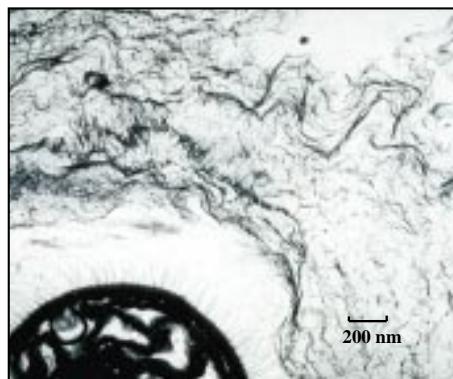


Figure 2: Transmission electron micrograph (courtesy of Dr G.G. Leppard, Environment Canada) of the margin of a phytoplankton cell exuding microfibrils of colloidal organic material.

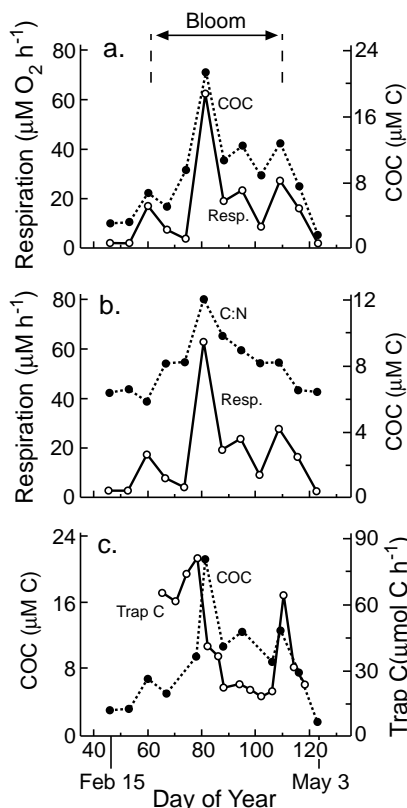


Figure: 3a. Respiration and colloidal organic carbon (COC) at a depth of 5 m during the 1995 spring bloom in Bedford Basin. b. Respiration and the carbon-to-nitrogen ratio of total organic matter (TOM) at the same depth. c. Colloidal organic carbon (COC) at 5 m and the rate of carbon transport into a sediment trap deployed at 15 m.

Transparent Exopolymer Particles. This clumping together of the fibrils into aggregates works in combination with bacterial respiration (Amon and Benner, 1994; Kepkay, 1994) to remove COC from surface waters. Respiration, however, is the major biological process regulating the net production of COC, i.e., the amount that remains to be exported deeper.

### The Spring Bloom in Bedford Basin - A Case Study

In the spring of 1995, a collaborative study of the annual diatom bloom in Bedford Basin was undertaken to determine the role of colloids in the transport of carbon and contaminants. During the bloom, respiration (primarily by the bacteria) was closely linked to the production of COC by diatoms (Fig. 3a). As Benner *et al.* (1992) have pointed out, the high polysaccharide and carbon content of COC exerts a large

influence on the cycling of carbon and the carbon-to-nitrogen (C:N) ratio. This was certainly true in the case of the bloom, where the release of COC by the diatoms initially drove the C:N ratio up (Fig. 3b); later on, the ratio was brought back down by respiration (Fig. 3b) and the settling out of aggregated colloids into deeper water (Fig. 3c). Results from the deployment of sediment traps (Cranford, 1995) suggest that scallop feeding was enhanced during the bloom, when the downward export of aggregates into the traps was at a maximum (Fig. 3c). This means that colloids could be a source of food for a commercially-important species of shellfish.

Results from measurements of the natural isotope, <sup>234</sup>Thorium (<sup>234</sup>Th) - a tracer of

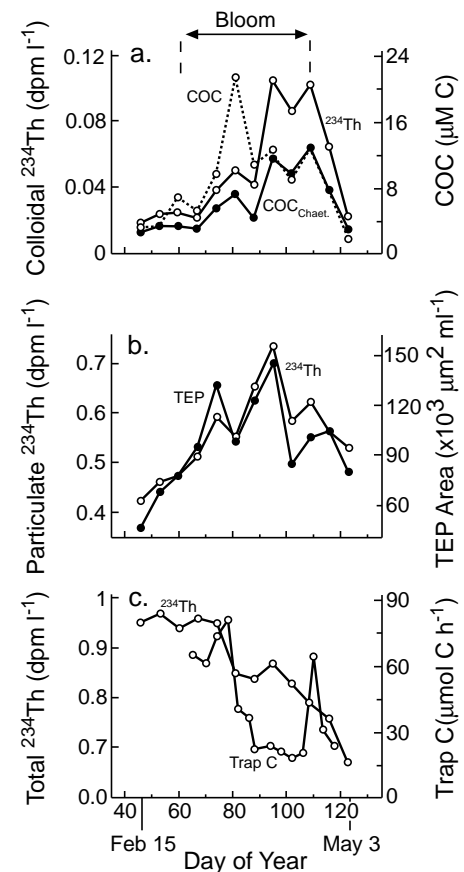


Figure: 4a. Colloidal <sup>234</sup>Thorium (<sup>234</sup>Th) and colloidal organic carbon (COC) at a depth of 5 m during the 1995 spring bloom in Bedford Basin. The association of colloidal <sup>234</sup>Th and COC was especially close later in the bloom, when the production of colloids by *Chaetoceros socialis* (COC<sub>Chaet.</sub>) was at a maximum. b. Particulate <sup>234</sup>Th and TEP area at the same depth. c. Decrease in the total activity of <sup>234</sup>Th at 5 m and the rate of carbon transport into a sediment trap at 15 m.

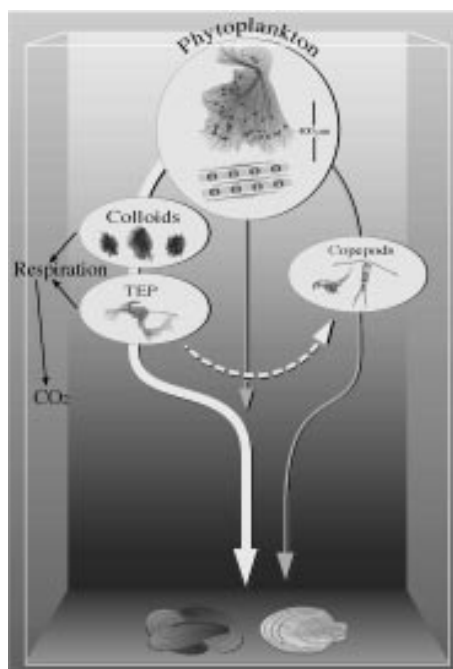


Figure: 5. Illustration of the relationship between colloid production by the phytoplankton (diatoms), colloid aggregation to form transparent exopolymer particles (TEP), respiration (producing CO<sub>2</sub> and possible pathways for the consumption of aggregated colloids by zooplankton (copepods) and benthic shellfish (scallops and mussels).

marine aggregates and an analogue of chemical contaminants (Niven *et al.*, 1995) - suggest that aggregated colloids may also have been a prime vector for the transport of contaminants to the scallops (Fig. 4). The release of COC by the diatoms, especially the COC associated with *Chaetoceros socialis* (Fig. 4a), transferred <sup>234</sup>Th from solution to the colloidal size fraction. Aggregation of the colloids and the formation of TEP moved the colloidal <sup>234</sup>Th further

up the size spectrum to the particulate fraction (Fig. 4b). Once the <sup>234</sup>Th reached the particulate fraction, it settled out of surface waters and into the sediment traps, resulting in an overall decrease in total <sup>234</sup>Th (Fig. 4c).

### Colloids - A Source of Food or Contaminants for Benthic Fisheries ?

COC may be an important source of food for filter-feeding shellfish or even the zooplankton (Fig. 5), but first the colloids have to undergo degradation by the respiration of bacteria and other members of the microbial community. Only then will the residual colloids remaining in aggregates become available for the filter feeders. Given the overwhelming size of the standing stock of COC in the ocean (Fig. 1), a substantial amount of carbon could be transferred to benthic fisheries. This is clearly a positive result of the production of colloids by diatoms but, at the same time, colloid aggregation may also transfer contaminants to the same fishery. This dual role of colloids in the maintenance of traditional and cultured living resources has not been included in current models of aquaculture or coastal management. It certainly merits further attention.

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