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Review Article

The Overlooked PM Cycle through Marine Animals

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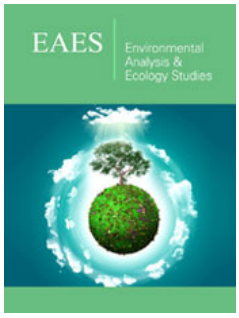

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Abstract

A portion of the charcoal and soot produced due to wildfires and combustion of fossil fuels on land enters the atmosphere and aquatic systems as black carbon (BC). Much of the airborne BC has a diameter of a few nanometers to tens of micrometers. This particulate matter (PM), especially around or smaller than 1um (PM1), can travel for thousands of kilometers and deposits in the oceans. Most of the riverine PM also discharges into the oceans eventually. It is known that the PM settles into the sediments, but it has only recently been reported that PM1 enters the sea anemone around the coastal waters of Taiwan. It is natural to suspect that sea anemones elsewhere and other marine animals would also absorb or otherwise retain PM in their bodies. Here we show that indeed PM is detected in corals. PM is often associated with potentially toxic trace metals and organic compounds; how PM would affect the physiology of marine animals and eventually influence human health deserves attention.

Introduction

The incomplete combustion of vegetation fires and burning fossil fuels release fire-derived carbon, often referred to as black carbon [1]. The BC constitutes a global environmental issue, especially those with diameters of a few nanometers to tens of micrometers. Like those with a diameter of around 1um (PM1) or smaller, small particles even affect human health.

Most of this BC enters the atmosphere, but the airborne BC eventually falls back to the ground or the oceans. A portion of what falls on land enters the rivers, which mostly empty into the oceans. Studies on the fate and impact of the PM in the oceans have mainly concerned input sources across the air-water interface and reactions in the water column and sediments. The atmospheric aerosol deposition is an essential source of macro and micronutrients (N, P, C, Si, and Fe) to the oceans. Most studies of such an aerosol deposition in the oceans relate to how they impact nutrients and toxic metals' biogeochemical cycles and how they affect primary productivity [2-4]. Investigation of PM in marine animals has largely been overlooked.

It has been shown in the laboratory that PM may generate inferior locomotion, feeding, growth, and fertility survival problems in aquatic snail *Parafossarulus striatulus* [5]and the rotifer *Brachionus calyciflorus* [6]. Although ingestion of PM by wild aquatic animals is also expected, to the best of our knowledge, PM1 has only been detected in wild sea anemones collected around coastal waters of Taiwan due to technical difficulties [7]. However, there is no reason for the absence of PM1 in sea anemones in other world regions, but this remains to be proven. Further, there is a reasonable ground for the existence of PM in other marine animals. Here we show that PM is indeed found in corals.

Small stony coral fragments of *Tubastraea* coccinea were collected from the Kuishantao Islet on the northeastern coast of Taiwan by SCUBA diving in June 2018. After narcotization, relaxation, fixation, and cleaning, the coral samples were decalcified in 5% HCl. The decalcified samples were washed by phosphate-buffered saline before conducting the histological sections. The sections were with or without *Giemsa stain* [8] and were examined under a light microscope equipped with a camera system. Detailed methods can be found in Liu et al. [7]. PM was observed in the mesenterial filaments of the stony coral *T. coccinea* (Figure 1). The PM was round with black color, which was evident in the non-staining micrograph. The size of PM varied from < 0.5 to 6.5 µm.

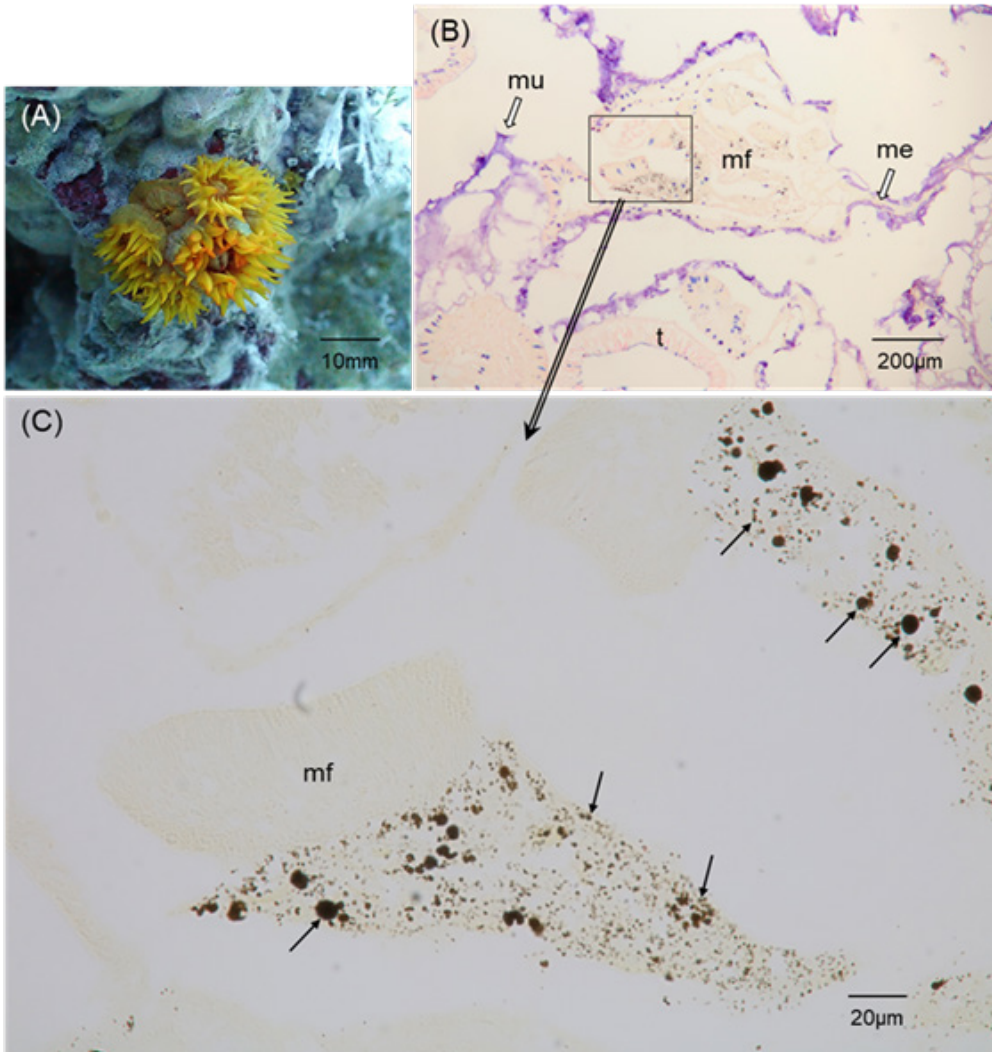

Figure 1: Distribution of particulate matter (PM) in the stony coral *Tubastraea coccinea* sampled at the Kuishantao Islet in June 2018.
A. External morphology.
B. PM in a cross-sectioned coral polyp with Giemsa stain.
C. Enlarged image of (B) without Giemsa stain. →: PM; me: mesentery; mf: mesenterial filaments; mu: mucocytes; t: tentacle.

Our studies on *sea anemones* [7] and the stony coral can at most be called exploratory. It is hoped that other studies would detect PM in other marine animals. Investigation into the physiological effects of PM and how it moves up the food web is also urgently needed [8].

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