RESPONSE OF BENTHIC ECOSYSTEMS TO DEEP OCEAN SEWAGE OUTFALLS IN HAWAII: NUTRIENT FLUXES AT THE SEDIMENT-WATER INTERFACE

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ABSTRACT

The Sand Island and Barbers Point deep-ocean sewage outfalls off Oahu, Hawaii, provided an experimental regime to assess the impacts of domestic effluent on nutrient cycling in the benthic boundary zone. The discharge rate at Sand Island was approximately 5 times larger than at Barbers Point, but primary treatment at the former outfall reduced the suspended particulate load to only 1.5 times greater than the raw discharge at Barbers Point.

Nutrient budgets derived from benthic respirometry and particle trap deployments revealed that removal of larger particulate fractions during primary treatment was sufficient to prevent any significant changes to benthic ecosystem function. Raw sewage discharge resulted in significant increases in benthic metabolism owing to rapid decomposition of labile sewage particulates on the sediment surface. Periodic pulse inputs of dissolved BOD from pineapple cannery waste caused the formation of microbial mats on the diffuser structure which functioned analogously to natural "trickling filters". Upon reaching a threshold thickness, the mats fragmented, were dispersed over the sediment, and fueled an increase in benthic nutrient flux at Sand Island similar in magnitude to the fluxes generated at Barbers Point by raw sewage discharge. Mean O_2 uptake

and dissolved inorganic nitrogen release within the influence of the outfalls were about 18 and 1.3 mmol m^2day^{-1}, respectively, compared to 5 and 0.2 mmol m^2day^{-1} at control sites.

A very small fraction (1%) of the discharged suspended solids reached the sediment surface within a zone less than 70 m wide around the diffuser structures; 99% of the effluent was dispersed by current flow. While dissolved nutrient fluxes correlated with discharge characteristics, there were only very slight increases in particulate organic material, or pore-water dissolved inorganic nutrients below the surface layer to a depth of 4 cm in the sediment column at either of the outfall sites.

The particulate material that reached the sediment surface in the vicinity of the outfalls is qualitatively very different from particulate fallout at a control site; the former is composed almost entirely of effluent particulates (C:N = 12), while the latter appears to be recycled detritus of inshore benthic origin (C:N = 53). Yet recycling of outfall-derived material at the sediment-water interface does not appear to be qualitatively different than metabolic processes at the control site. Stoichiometry of nutrient regeneration suggests that metabolism of sewage and natural particulates is primarily aerobic, with no substantial preferential release of N or P, while respiration and nutrient regeneration do not appear to be closely coupled.

At an ecosystem management level, the overall environmental effect of effluent on benthic and pelagic ecosystems is clearly insignificant, primarily as a result of effective dispersal and dilution. The insignificance of effect is especially apparent when the environmental alterations owing to the Oahu outfalls are compared to the impacts caused by an outfall approximately five times larger serving Los Angeles County. Off Oahu, sewage-related augmentation to benthic flux is substantial enough, however, to change the characteristics of the benthic boundary zone from that typical of the deep-sea to that of estuaries or coastal seas.