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TRANSPORT OF BIOLOGICAL PARTICLES IN STREAMS: DO PARTICLES REALLY SETTLE EXPONENTIALLY, AND SHOULD THEY?

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ABSTRACT: Biological particles in streams include fine and coarse particulate organic matter, microorganisms, and benthic invertebrates, as well as dissolved and colloidal substances such as dissolved organic matter. Most ecological studies of particle transport in streams have employed the Exponential Settling Model (ESM) to characterize the longitudinal pattern of particle settling or uptake. The ESM is fundamental to spiraling theories for seston and nutrients in stream ecosystems. It predicts that if particles are released into a stream and their downstream transport is monitored, then the proportion that have not yet settled will be an exponential function of transport distance and will be independent of the elevation above the bed at which the particles were released. To date, no credible basis in fluid mechanics has been established for this simple model, nor has it been rigorously tested against alternative models. Its prediction that settling will be both exponential and independent of the release elevation is particularly dubious immediately downstream from the release location. A plausible alternative to the ESM is the Local Exchange Model (LEM), which is a stochastic advection-diffusion model based on classical fluid mechanics and turbulence theory. I review properties of the ESM and LEM and compare these with available evidence from empirical studies of particle transport in streams and flumes, with particle types including benthic invertebrates, seston, and fine sediment. The evidence consistently supports the LEM, which predicts that settling immediately downstream from the release location typically will not be exponential and will depend strongly on the release elevation. But I show that the LEM also predicts that settling will become exponential in the far field, and that this prediction is supported by available empirical evidence. Thus, particle settling typically is not exponential in the near field but becomes exponential in the far field, partially reconciling the ESM and LEM and providing a new theoretical basis for far-field exponential settling that is firmly rooted in classical fluid mechanics.

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