Mass Transfer Rate of Non-Spherical Particles in Turbulence using Sugar-Glass Recipe

Theresa Oehmke[1] and Evan Variano[2]

[1]University of California Berkeley
[2]UC Berkeley

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Abstract

We evaluate the mass transfer rate from the surface of rod- and disc- shaped particles with various aspect ratios and surface areas. The method of particle fabrication used here builds off of both traditional gypsum plaster dissolution methods and advances in sugar-glass particle recipes. The particles were created in-house with a nearly neutrally buoyant formula and custom molds. They were then tested in homogeneous, isotropic turbulence. The decrease in particle weight was recorded and results were compared to the Hixson-Crowell model for dissolution. We hypothesized that the turbulent flow would affect the boundary layer surrounding these particles and therefor their mass transfer rate. Results from these experiments show the dependence of shape and surface area to mass transfer rate in turbulent flow. The related questions are relevant to cases of marine biology, carbon sequestration, and pollution by microplastics.

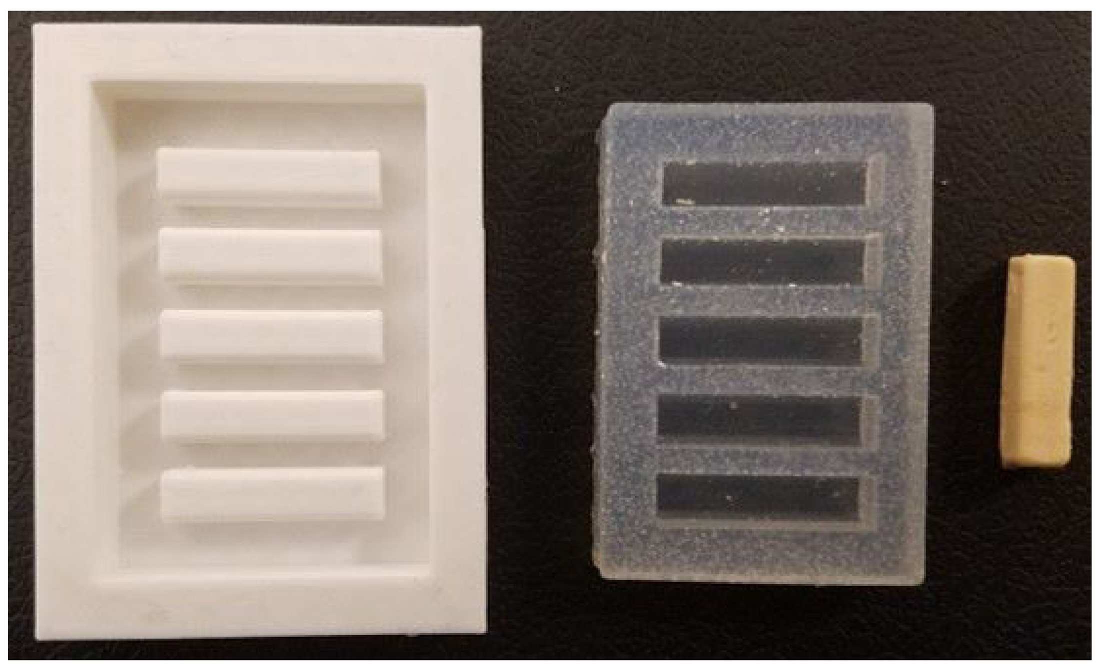
MASS TRANSFER RATE OF NON-SPHERICAL PARTICLES IN TURBULENCE USING SUGAR-GLASS RECIPE

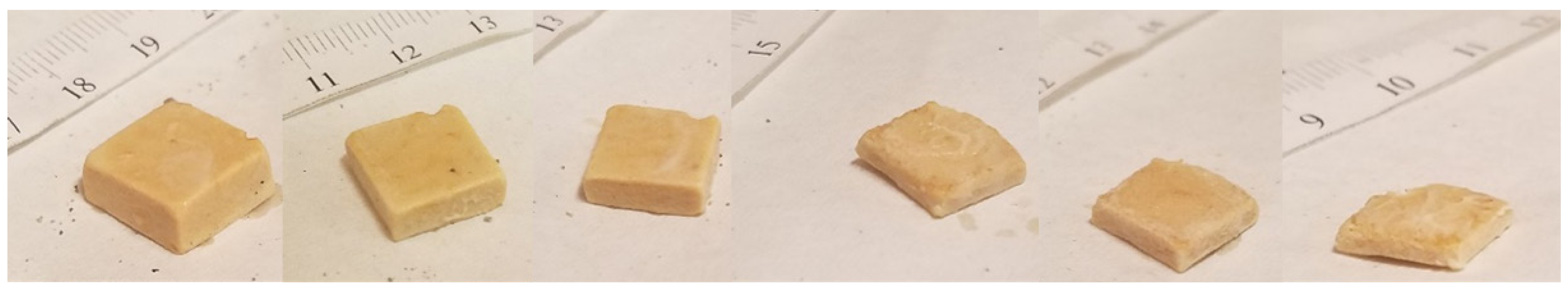
Theresa B Oehmke*, Evan A Variano
Department of Civil and Environmental Engineering,
University of California, Berkeley
*toehmke@berkeley.edu

Abstract

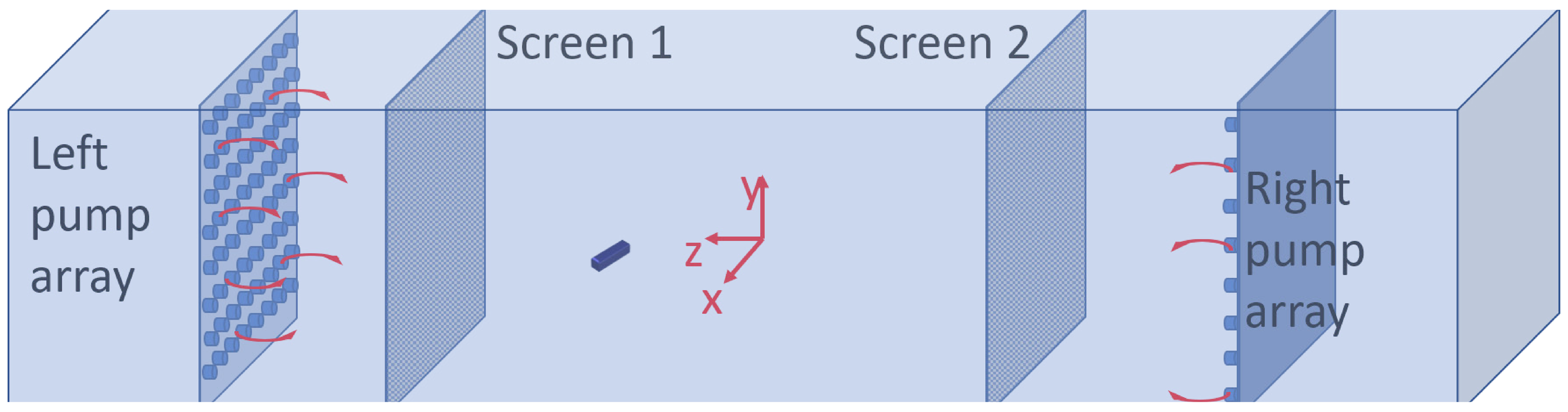
We evaluate the mass transfer rate from the surface of rod- and disc- shaped particles. The method of particle fabrication used here builds off of both traditional gypsum plaster dissolution methods and advances in sugar-glass particle recipes. We hypothesized that the turbulent flow would affect the boundary layer surrounding these particles and therefore their mass transfer rate. Results from these experiments show the dependence of shape and surface area on mass transfer rate in turbulent flow. The related questions are relevant to cases of marine biology, carbon sequestration, and pollution by plastics.

Methods





increasing time →



Custom manufactured sugar-glass particles are tested in homogeneous, isotropic turbulence.

Hixson-Crowell Law

Cube Parameters

$$\frac{d\forall}{dt} = 3r^2\frac{dr}{dt}$$

Noyes-Whitney

$$-\frac{dM}{dt} = \frac{D}{\delta}AC_s$$

Equating Changes in Mass and Volume:

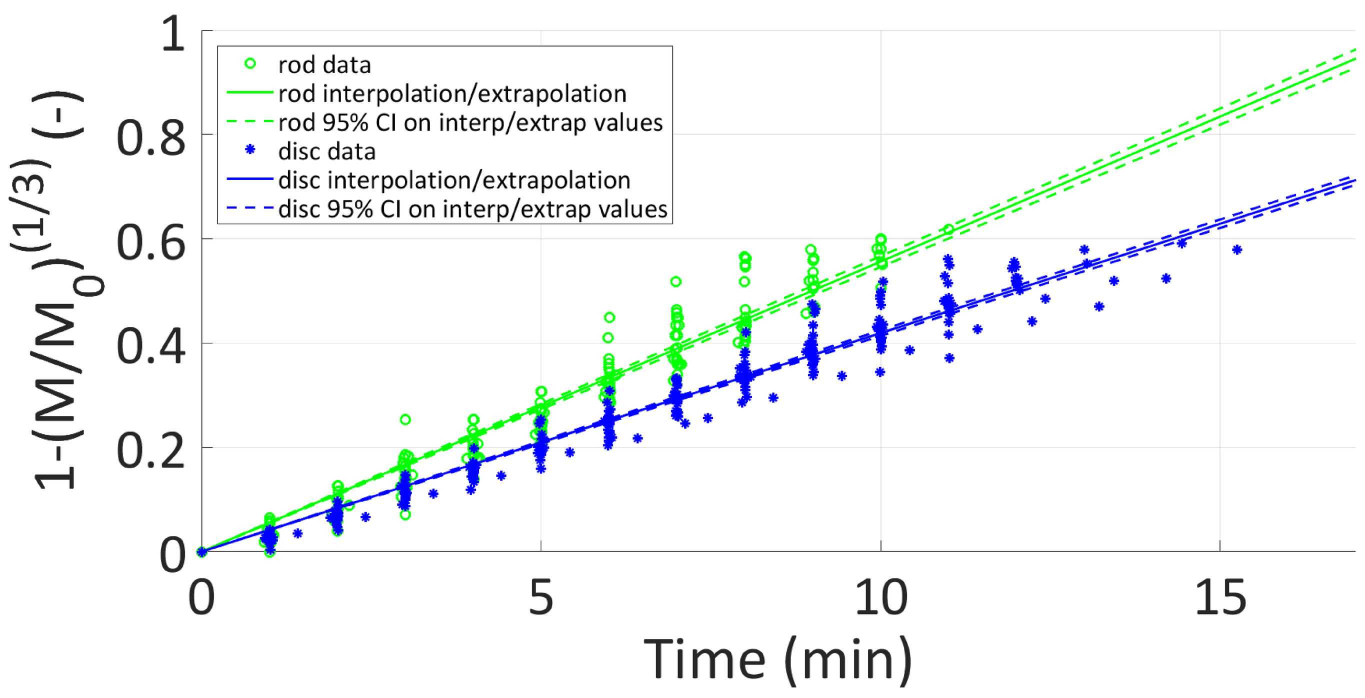
$$\rho\frac{d\forall}{dt} = \frac{dM}{dt} \Rightarrow \rho\, 3r^2\frac{dr}{dt} = -\frac{D}{\delta}AC_s$$

integrating, substituting $r = (M/\rho)^{1/3}$

and rearranging $\boxed{1 - \sqrt[3]{M_t/M_0} = k_0 t}$

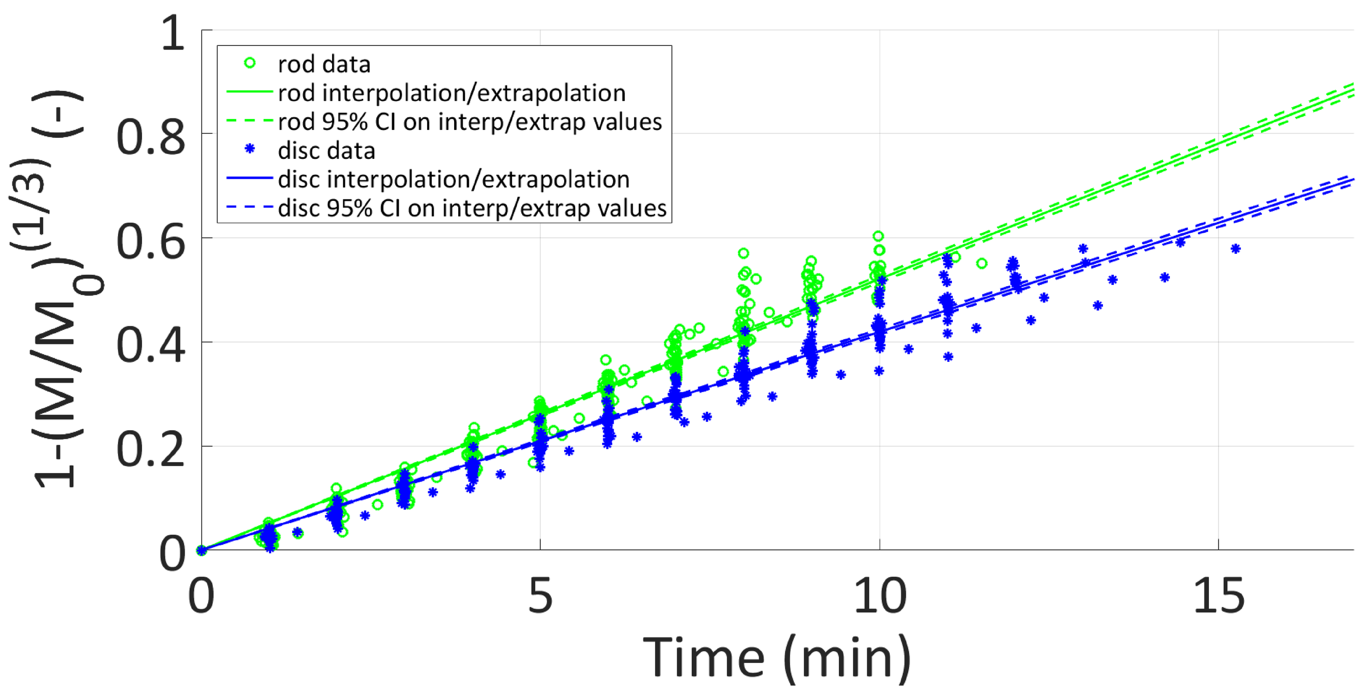
Results and Discussion

Volume Matched Particles



Particle type	Effective dissolution rate, k_0 [1/min]	Confidence interval [1/min]	R-squared value
Rod	5.56×10^{-2}	[5.46×10^{-2} 5.67×10^{-2}]	0.95
Disc	4.19×10^{-2}	[4.14×10^{-2} 4.25×10^{-2}]	0.97

Surface Area Matched Particles



Particle type	Effective dissolution rate, k_0 [1/min]	Confidence interval [1/min]	R-squared value
Rod	5.21×10^{-2}	[5.14×10^{-2} 5.27×10^{-2}]	0.96
Disc	4.19×10^{-2}	[4.14×10^{-2} 4.25×10^{-2}]	0.97

Acknowledgements

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