Geophysical Research Abstracts
Vol. 18, EGU2016-4999, 2016
EGU General Assembly 2016

On biofouling of microplastic particles of different shapes – some mathematics

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Transport of microplastic particles in marine environment is difficult to quantify because their physical properties may vary with time. We made an attempt to analyse the behaviour of *slightly buoyant particles* (e.g., polyethylene, polypropylene), most critical process for which is their fouling: it leads to an increase in the mean particle density and its sinking. Fouling covers the surface of a relatively light particle by a denser growing film; thus, the rate of increase in the total mass is directly proportional to the surface area, and the faster the fouling process is – the sooner the mean particle density reaches the water density; the particle begins sinking, leaves the surface layer with stronger currents and can no longer be transported too far.

A simplified model of biofouling in marine environment of a slightly buoyant microplastics ($\rho_p < \rho_w$) is applied to particles of different shapes – spheres, films and fibres. It is supposed that the thickness of biofouling cover (of density $\rho_b > \rho_w$) increases with time at constant rate, and thus it can be considered as time. Geometrical considerations link surface area of particles of different shapes with time rate of increase in its mass due to fouling up to the water density.

Geometrical calculations demonstrate that, for the same mass of plastic material, many small particles have larger surface area than one single large particle, and this way – macroplastics will stay longer at the water surface than microplastics. For spherical particles, the time of fouling up to the water density is *directly proportional to the radius of a sphere*: $\tau_{sink} \sim$ R$_0$/ 3n, where $n = R_0/R$, i.e., if the particle of radius R$_0$reaches the water density in time τ_{sink}, the particle of radius R$_0$/3 requires only τ_{sink}/9.

Spherical shape has (for the given mass m_0) the minimum surface area among all other possible shapes in 3-d space. The calculations performed for the same mass m_0 have shown that the ratio of surface areas of a sphere (diameter 5 mm), a film (thickness of 15-30 microns) and a fibre (diameter of 30-100 microns) is about 1 / (50-100) / (30-110) and thus, *fibres appear to have the largest surface area for the given mass, immediately followed by films.* Correspondingly, time of fouling up to sinking is of the same order of magnitude for films and fibres, and almost two orders of magnitude larger for spherical particles (of the same mass m_0). More generally speaking, time of fouling is linearly dependent on the characteristic length scale of a particle (*radius* of sphere, *thickness* of the film, or *radius* of a fibre): the smaller the scale of the particle is – the faster it is fouled up to the water density.

The conclusions are important for proper physical setting of the problem of microplastics transport in marine environment and for developing of physically-based parameterisations of microplastics particles properties in numerical models.

The investigations are supported by Russian Science Foundation, project number 15-17-10020.