Plastics in streams: transport dynamics and open questions

Arianna Varrani YP[1]*, Paweł M. Rowiński[1], Magdalena M. Mrokowska[1]

[1]Institute of Geophysics, Polish Academy of Sciences , Warsaw, Poland

*Correspondence YP: avarrani@igf.edu.pl

Institute of Geophysics
Polish Academy of Sciences

Abstract Rivers and streams act as pathways for both natural and artificial debris. While sediment transport processes have been thoroughly investigated, a lack of knowledge is present in what concerns the transport of anthropic material by flowing waters. Notoriously, plastics and microplastics (MP) are among such material. When transferring present knowledge on sediment transport to heavy-MP transport, we observed movement of MP grains on a plastic bed starting below the traditional Shields values, as results from other authors also suggest. This introduces a research thread, here briefly outlined. Unfortunately, due to internal and external forces, detailed experimental work has not yet started.

Keywords: microplastics, river, sediment transport, bedload.

Methods

With the aim to locate incipient motion of plastic particles in the available theory for the motion of natural sediments, a very simple approach is attempted.

Simple mobile bed experiments with PVC plastic grains were carried out at the Mountain Hydraulics Lab of the Politecnico di Milano (Italy) and serve here as proxy of the transport mechanism. Available data only include discharge and water level and, from camera captures, an estimate of bedload transport. From the flow variables, the mean bed shear stress was estimated with simple empirical formulas for turbulent flow:

1. deriving the wall resistance with Prandtl-Von Kármán

$$\sqrt{\lambda} = \frac{1}{2\,log_{10}\,{2R_H}/{d_{eq}} + 1.74}$$

2. calculating the energy losses

$$i_E = \frac{\lambda}{4R_H}\frac{u_{mean}^2}{2g}$$

3. estimating mean bed shear stresses

$$\tau_{mean} = g\rho_w R_H i_E$$

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Results

Mobilisation of microplastic particles appears to occur with lower values of bed-shear stress than those proper of natural material. This is in line with the fact that weight acts as stabilizing force, hampering the movement of a single particle.

- Similar experiments performed by [1] pointed out that very weak bedload appeared for u^*/u^*_c=1.11.
- The present findings, which refer to turbulent flow conditions, agree with the outcomes reported by [2], though determined in laminar flow conditions.

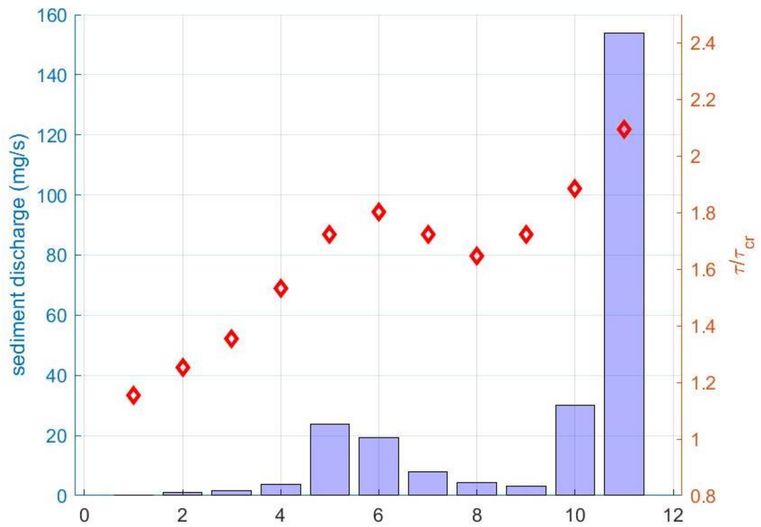

Figure 1: Preliminary results show that for ratios between mean bed shear stress τ and theoretical critical stress τ_c greater than 1.2 bedload transport occurred.

Conclusions

This rough preliminary analysis relates incipient motion to the density of the grain and to average flow conditions. However, the lack of information about the flow field does not allow to provide additional insights on the effect of the turbulence. To fill this, we plan to carry out mobile bed experiments coupling ADV measurements and image-analysis for retrieving information about the flow field and the grains' movement respectively.

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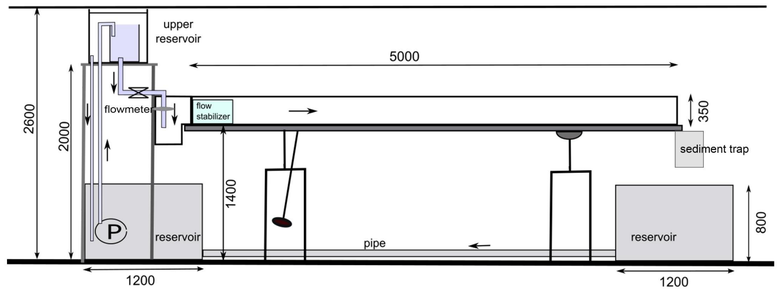

Figure 2: Hydrodynamic Models Laboratory flume sketch.

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