A "sediment transport" perspective on microplastics movement: incipient motion

Institute of Geophysics
Polish Academy of Sciences

Arianna Varrani

Institute of Geophysics, Polish Academy of Sciences, Warsaw, Poland

avarrani@igf.edu.pl

Abstract Plastics entering rivers are transported by the current. The transport mechanisms for this anthropic debris, is supposedly similar to that of natural sediments, but experimental evidence lack, hindering a deeper understanding of the transport process. Borrowing the methods from sediment transport research, a preliminary experimental study is here presented. The aim was to identify the conditions for the onset of motion of plastic particles lying on a uniformly composed plastic bed. The results show that, for transitional to turbulent flows, bedload motion occurs for mean bed shear stresses

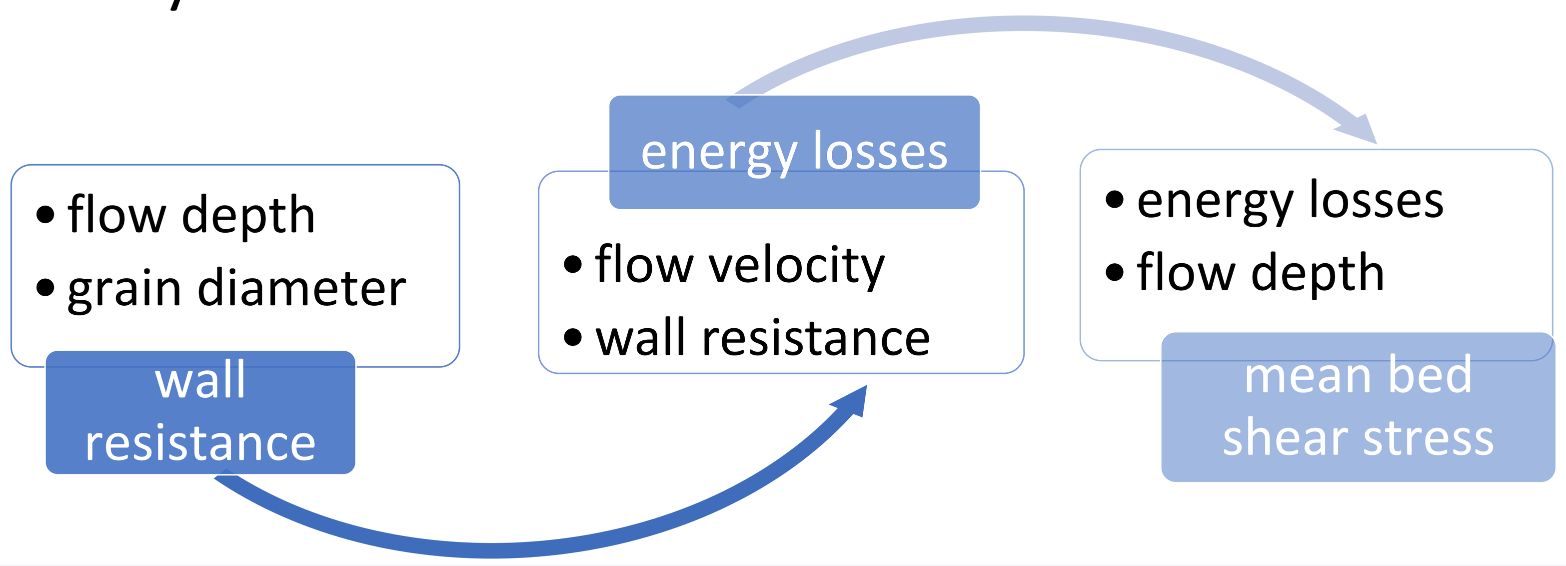
Introduction

Rivers and streams act as vectors of plastic debris to their final sink. Transport mechanisms for lightweight materials are assumed to follow the same principle as for natural heavier sediments. The theory developed for determining the threshold conditions triggering motion - incipient motion conditions - in natural sediments (started with the pioneering work by A. Shields, 1936) can be therefore used for a first assessment of erosion behaviour.

Methods

The experimental setting sees a 5 m-long flume, bedded with a 5 cm-thick layer of plastic particles. A series of runs with steady flow conditions and increasing discharges allowed to see the onset of bed particles movement. Incipient motion conditions were related to the presence of bedload transport in the interrogation area.

From the flow variables, the average bed roughness was computed, therefrom the mean bed shear stress was estimated. This was compared with a theoretical range of values derived by Shields' data for transitional to fully turbulent flow conditions.



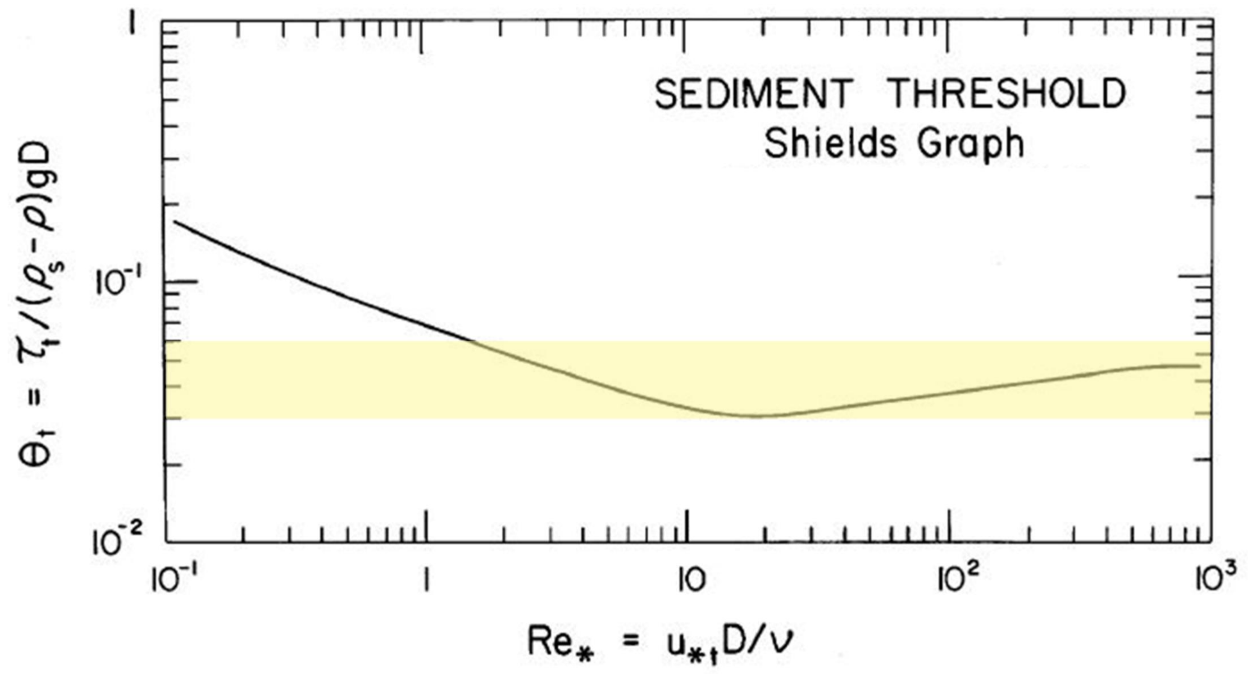


Figure 1: Investigated range for incipient motion threshold (modified from Komar, 2007)

Preliminary results

The flow conditions for all tests varied from transitional to turbulent. This allow to locate the critical (Shields' Θ_t) shear parameter in the yellow range (Figure 1). These values were used to define the upper and lower threshold for incipient motion conditions.

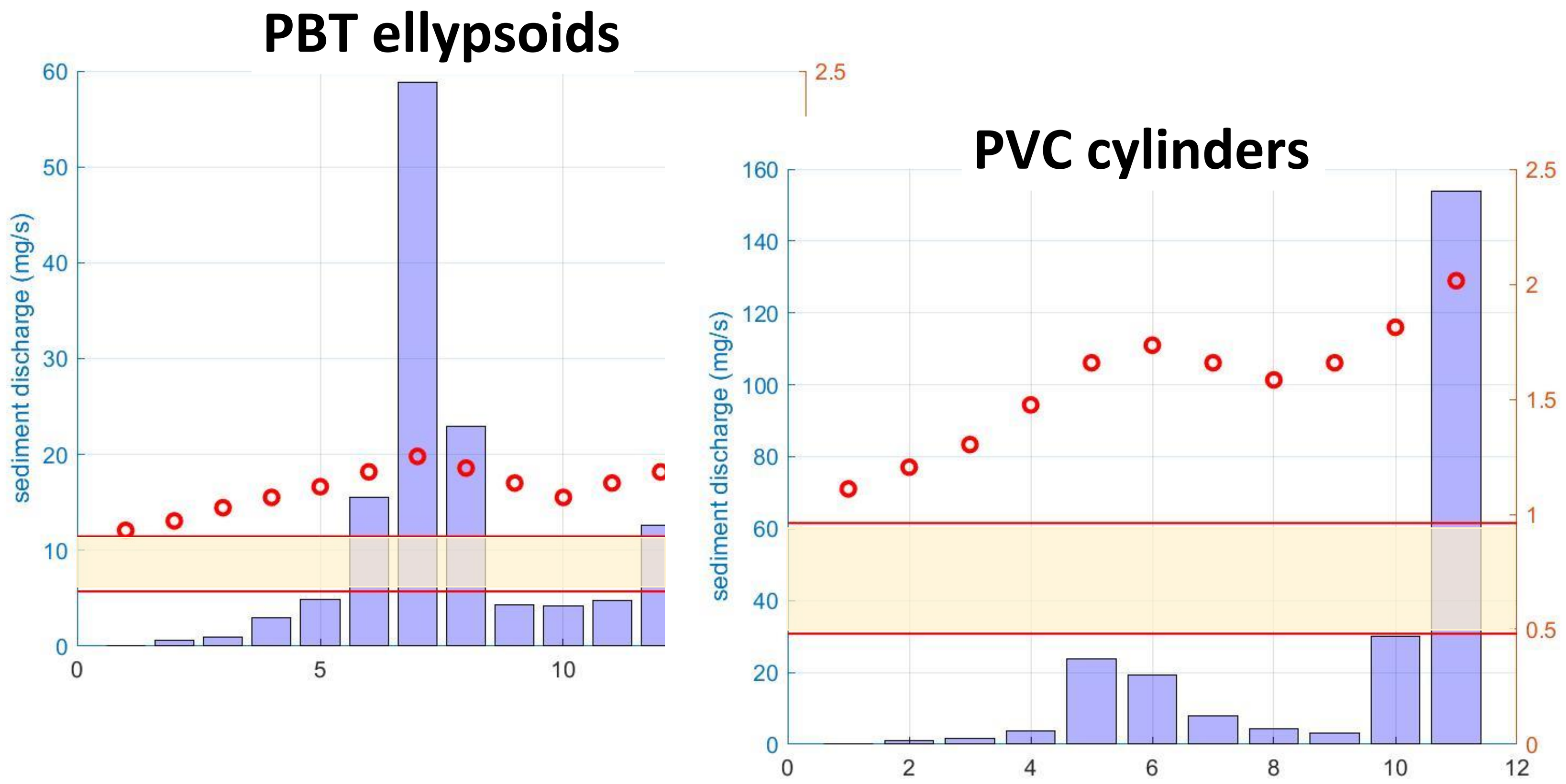


Figure 2: Values of mean bed shear stresses exceeds the threshold range for incipient motion for both materials.

The present analysis of threshold of plastic particles is in line with previous results for laminar flows by Waldschläger & Schüttrumpf (2019) and transitional to turbulent flow by Ballio & Radice (2007).

Conclusions

Clearly, more detailed information about the near-bed flow field are needed, to estimate the near-bed velocity which relates to triggering of particle movement. Still in most cases the only available data regard discharge and water depth, and therefore the simple methods briefly outlined can be of use in case of lack of detailed information on the near-bed the flow field.

References

Ballio, F., & Radice, A. (2007). Grain kinematics in weak linear transport. *Archives of Hydro-Engineering and Environmental Mechanics*, 54(3), 223-242.

Komar, P. D. (2007). The entrainment, transport and sorting of heavy minerals by waves and currents. *Developments in Sedimentology*, 58, 3-48.

Shields, A. (1936). Anwendung der Aehnlichkeitsmechanik und der Turbulenzforschung auf die Geschiebebewegung. *PhD Thesis Technical University Berlin*.

Waldschläger, K., & Schüttrumpf, H. (2019). Erosion Behavior of Different Microplastic Particles in Comparison to Natural Sediments. *Environmental Science & Technology*, 53(22), 13219-13227.

Acknowledgements

Sincere thanks to prof. Radice, for hosting me at his laboratory; dr.ing. Mrokowska for setting up a new lab at IG-PAS; and dr.ing Nones for countless support and inspiration. The work was supported within statutory activities No. 3841/E-232 41/S/2020, Ministry of Science and Higher Education of Poland.