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NOTE

Proposed retrofit for sediment settling velocity tubes (SVTs)

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In order to determine the distribution of sediments, bottom-withdrawal settling velocity tubes (SVTs) are used. This technique is, for example, often applied in estuaries. Yet, these tubes have serious disadvantages. Several papers call for the use of video applications in preference. However, not only that this technique has many disadvantages as well, it generally does not suit the need of hydro-/marine geochemical research. Particularly if a project needs to analyse different fractions separately, for example in order to determine and model the transport of suspended materials, video analyses are not a feasible alternative. Therefore, this note aims to describe a number of improvements to compensate for previously observed weaknesses. Particularly the addition of a simple funnel, mimicking a natural environment without walls, could increase the general reliability of bottom-withdrawal techniques with sediment settling velocity tubes.

Keywords: sediment settling velocities, sediment distribution, Owen tube, QUISSET, SVT

INTRODUCTION

In 1976, HR Wallingford published a report describing an apparatus to determine settling velocities of suspended particular material (Owen, 1976). These "Owen tubes" or settling velocity tubes (SVTs) have been widely used since, either in their original version or in form of a derivate, like the Quasi-In-Situ Settling Tube (QUISSET; Jones and Jago, 1996), Field Pipette Withdrawal Tube (FIPIWITU; Cornelisse, 1996), Rijkswaterstaat (RWS) field settling tube (Van Leussen, 1996) and BIGDAN (Puls and Kühl, 1996). Several designs have been reviewed by Dyer *et al*. (1996) and more recently by Mantovanelli and Ridd (2006).

However, bottom-withdrawal techniques attracted a number of critiques, most notably by Dearnaley (1996). Typically, this methodology is associated with a number of problems, namely: (1) less efficient in low concentrations (although no uniform threshold value is indicated in literature), (2) turbulence when returning into upright position, (3) floc formation within the tube, causing a differential settling which increases the measured velocities, (4) external influences (e.g., sunlight) causing convection currents, (5) capturing the sample itself will cause substantial turbulence and (6) distortions from the wall, as flocs do not necessarily move vertically down and are affected by the finite extend of the tube.

Another approach is to apply optical measurements (for example laser or video based; e.g., Dearnaley, 1996; Fennessy *et al*., 1994; Van Leussen and Cornelisse, 1993) in preference to bottom-withdrawal techniques. However, such methods have two major disadvantages:

(1) The camera cannot be deposited without a tube, as currents, convections, living organisms and other interferences would render this approach pointless except in the most ideal of environments. On the other hand, if the camera is used together with a tube, many—if not most—of the problems inherent to Owen tubes will apply as well.

(2) Particles/flocs of different sizes, densities and compositions show different properties (including suspension, flocculation and distribution patterns). Many geochemical projects aim to analyse and model the fate of chemicals. It is imperative for such projects to know the exact composition of the different weight fractions (for example, in regard to carbon/nitrogen, metals, chlorophyll or lignin). The optical approach does not separate the sample material and hence there is no possibility for geochemical analyses of different fractions.

Consequently, replacing the bottom-withdrawal techniques with purely optical solutions is not a feasible option for geochemical applications and in many cases bottom-withdrawal SVTs will remain the superior tool. Yet the serious critiques must be considered as well. Instead of replacing SVTs, it is therefore prudent to improve their design.

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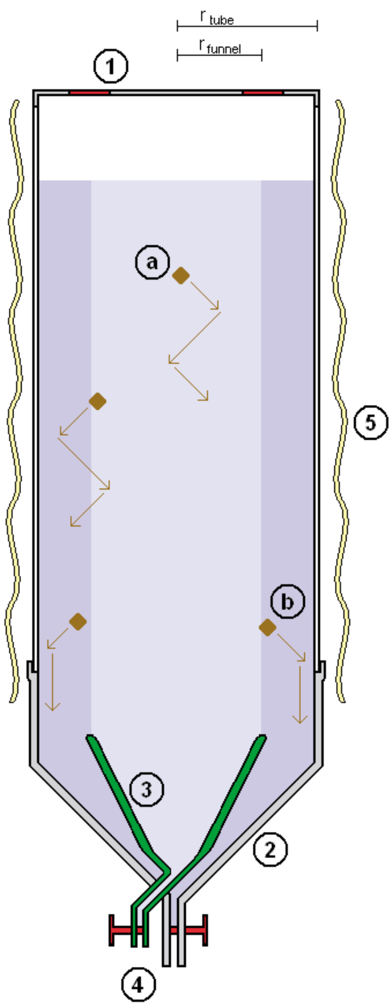

Fig. 1. The proposed improvement of settling velocity tubes based on the original QUISSET design by Jones and Jago (1996). Legend: (1) upper part of the original design, allowing water flow through the tube during extraction; (2) lower part of the original design, now only collecting the outer fraction; (3) added funnel, collecting the inner fraction/primary samples; (4) taps for the inner and outer fraction; (5) sun-cover/jacket with integrated water flow; (a) example of a particle moving freely in the inner fraction; (b) example of a particle in the outer fraction affected by the finite extend of the tube.

Proposed Improvements

Figure 1 shows the proposed improvements. As basis, the closing mechanism developed for the QUISSET tubes by Jones and Jago (1996) has been utilised, which provides a free water flow through the tube, both during capturing and sequential sampling. This way, turbulences during initial deployment and later sample extractions are considerably reduced. Firstly, the diameter of the tube is significantly increased. The original Owen tube and many of its derivates are very slender (cf., Table 1). Consequently, even minimal turbulence will cause the particles to collide frequently with the tube walls.

Within the lower section of the tube a funnel with a separate outflow can be added. This filters out impacts from the wall. Particles can move freely horizontally and vertically—in and out of the fraction sampled—hence the tube is mimicking the natural environment without walls. The less affected fraction in the middle ends up in the final water sample, while the fraction with direct wall-interaction is discarded. For a consistent flow, it is imperative that the rate of sample extraction must be equal for both fractions. Therefore, it would be easiest to keep both fractions identical in size (alternatively adapt the outflow diameters). Equating the volume inner fraction (cylinder) with the volume outer fraction (hollow cylinder) gives: $r_{funnel} = 0.70711 \cdot r_{tube}$. Consequently, the radius of the funnel (i.e., the radius of the inner fraction) should be 70.71% the complete tube's radius. As the funnel wall will prevent free movement between the fractions from the upper border of the funnel downward, the volume which the funnel can hold should ideally not exceed one sampling unit. A tube with a diameter of 12 cm would require a funnel with a diameter of 8.5 cm. Given a height of 80 cm, such a tube would have a sample capacity of ~4.5 litres, i.e., 9 reasonably sized sub-samples, sufficient to allow a wide range of analyses. Like most of the previous designs, such a tube could still be handled by two persons.

There is no reason for a constant visual inspection of the sample. Translucent areas will allow sunlight into the sample. This, in turn, will increase the risk of bias through induced convection and phytoplankton activity. However, if the walls would be completely opaque, it would not be

Table 1. Comparison of some bottom-withdrawal SVT-types

Tube Source	Owen tubes (Owen, 1976)	BIGDAN (Puls and Kühl, 1996)	QUISSET (Jones and Jago, 1996)	QUISSET Mk. 2 (theoretical design)
Diameter tube	2.5/5.0 cm	19 cm	9 cm	12 cm
Height tube	120/100 cm	100 cm	80 cm	80 cm
Diameter funnel	N/A	N/A	N/A	8.5 cm
Proportion of sample used	100%	100%	100%	50%
Actual sample volume	0.6/2.0 litres	28.4 litres	5.1 litres	4.5 litres

possible to check if any undesired elements (e.g., small fishes, which can easily be caught in riverine and estuarine environments) have been accidentally trapped in the tube. Therefore, the tube should be supplied with a separate sun-cover, which can be fixed around the tube immediately after collection and initial inspection. Any further viewing would be both risky and unnecessary. Consequently, volumetric bottles are required (the original tube designs had a scale for volume determination). In warmer environments, temperature based convection can be reduced or neutralised by a cold water circulation integrated into the jacket. Either artificially cooled water, or water pumped directly from the environment (maintaining ambient temperature) can be channelled through the jacket. Such isolation jackets are currently successfully applied by the School of Ocean Sciences, Bangor University, for its QUISSET tubes.

Reflocculation caused by bottom-withdrawal cannot be ruled out; it is inherent to any design that extracts regular water samples. Given a constant water flow, avoiding fast and abrupt water extractions, this effect should be reasonable low in the interior part of the sample, while friction may cause some turbulence close to the wall. To reduce this effect further, it would be very beneficial if the tube's interior, but at least the funnel, would be laminated with an anti-friction material. Since this is fairly expensive, longitudinal riblets, increasingly used to reduce drag on flat surfaces, would constitute a more economic solution.

Reflocculation during longer sampling periods cannot be ruled out, either. However, this effect would also occur *in-situ*. It could even be argued that this kind of reflocculation is advantageous, as it shows the degree of inherent reflocculation without currents and other disruptive impacts happening in natural environments.

As for the problem of a reduced efficiency in low concentrations: this is at least partially obsolete, as significant advances have been made concerning membrane filters and scales. In addition, more recent designs have significant larger capacities (cf., Table 1). This allows for larger sample sizes and therefore an increased effectiveness in low concentrations.

Conclusion

Naturally, this design cannot eliminate all problems associated with Owen tubes and their derivates. However, such tubes are reliable tools with potential for improvement; and the remaining problems are largely affecting alternative methods (i.e., optical analyses) as well. The QUISSET tube was already a major improvement of the original design and solved several of its problems. The here proposed improvements are a further step in making the methodology more reliable. Most importantly, by mimicking the natural environment without walls, particles now can move freely within the tube. An additional benefit of the update is that is can be added with minimal effort to existing SVT models with sufficient diameter. Comments and suggestions are invited before an actual tube is retrofitted in this way.

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