RRB-88-82

DEWATERING SUSPENDED SOLIDS BY CONTINUOUS-FLOW CENTRIFUGATION: PRACTICAL CONSIDERATIONS

by

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October 1988
NWRI Contribution #88-105

ABSTRACT

Horowitz et al. (1989) have reported upon a quality assurance study for metals for two continuous-flow centrifuges commonly used for environmental applications in field situations. Their work is at an experimental level and avoids discussion of practical considerations involving portability, flow rates, maintenance, etc. In this paper we examine these practical considerations which should be included in application decisions.

RÉSUMÉ

Horowitz *et al*. (1988) ont terminé un programme utile de contrôle de la qualité des métaux entrant dans la fabrication de deux centrifugeuses à débit continu fréquemment utilisées pour des applications environnementales sur le terrain. Leur travail a été fait au niveau expérimental et ne traite pas de considérations pratiques comme la commodité, le débit, l'entretien, etc. Le présent rapport traite plutôt des points pratiques qui devraient être pris en considération lors des décisions relatives aux applications des appareils.

MANAGEMENT PERSPECTIVE

Horowitz _et_ _al_. (1988) have completed a useful quality assurance for metals of two continuous-flow centrifuges used by Environment Canada. Their work is at an experimental level and avoids discussion of practical considerations involving portability, flow rates, maintenance, etc. In this paper we examine these practical considerations which should be included in application decisions.

PERSPECTIVE-GESTION

Horowitz et al. (1988) ont terminé un programme de contrôle de la qualité de deux centrifugeuses à débit continu utilisées par Environnement Canada. Leur travail s'est fait au niveau expérimental et ne traite pas de considérations pratiques comme la commodité, le débit, l'entretien, etc. Ce rapport traite plutôt des points pratiques qui devraient être pris en considération lors des décisions relatives aux applications des appareils.

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Horowitz et al. (1989) provide a very useful comparison of the two centrifugal, continuous-flow (centrifuge) clarifiers (Westfalia and Alfa-Laval) commonly in use for dewatering suspended particulates for aquatic environmental applications. In our experience their work is scaled down to enable laboratory comparison and does not represent typical field operating situations. Moreover, there are a number of other practical implications which their study do not address and which are very germane to centrifuge selection and application. We have used both types of machines since the early 1970's, and our comments reflect field programs by truck, ship and small boats across Canada and in the United States. Our experience with the Alfa-Laval includes work with an MAB-102 (discontinued) and the comparable but slightly larger model reported by Horowitz et al.

In addition to environmental characterization of suspended sediment, bulk sampling of suspended matter by continuous-flow centrifugation has many other practical advantages in research, monitoring and enforcement programs. For example, continuous-flow centrifugal sampling does not require sample storage or multi-pass concentration as is the case for tangential flow filtration. Bulk samples permit extremely low detection levels for trace organic contaminants; they also significantly reduce the potential for contamination of microsamples during sampling and handling. Bulk sampling integrates the natural variability through time and space which is common for most water quality parameters collected over short intervals. The ability to carry out replicate analysis on a bulk sample is very useful for establishing analytical precision criteria.

Disc versus Chamber Clarifiers

Westfalia: This clarifier is a four chamber, bowl centrifuge. Separation of solids is achieved by high gravitational forces acting on the suspension at the edge of each concentric bowl. A particular advantage of the Westfalia is that the bowls are smooth and are easily cleaned. The disadvantage is that the Westfalia clarifier must operate at very high centrifugal speeds to achieve separation (≈9,700 rpm). The weight of the bowl at such speeds can produce severe wear on alignment springs for supporting bearings; bearing failure has been a problem on a moving platform such as a ship or small craft. Also on ship or small craft use the rotating bowl can contact the stationary cover and stainless pump due to lateral movement of the bowl against the alignment springs; thus causing abrasion of the steel surfaces with concomitant contamination of sample.

Discharge is through an enclosed stainless steel tube. Separation is more effective, with application of some backpressure; however, care must be exercised to ensure that the outflow is never less than the inflow, otherwise flooding of machine casing and gearbox will result with consequent bearing failure. Flooding on start-up by inexperienced operators is not uncommon. The centrepital pump on the outlet side is useful for pumping the clarified sample to subsequent apparatus. Bowl locks on the Westfalia will damage the electric motor and drive assembly if inadvertently left in "locked" position.

Alfa-Laval: This clarifier uses a disc separation technique (an industrial version of the cream separator) in which the suspension travels down the centre of the bowl through a distributor, is forced to the outside edge of the bowl and then inwards through a series of conical discs (generally 52 discs). Separation occurs within the discs. Essentially, the discs perform much in the manner of a fixed-angle centrifuge; the distance required for separation is the horizontal distance between each disc (in the order of a millimeter). The solid particles migrate down the underside of each disc and are flung out to the bowl wall where they accumulate as dewatered sediment. Disc separation permits recovery comparable to the chamber-type centrifuge (per Horowitz *et al*., and our own work) but at lower rotational speeds (<8900 rpm). As a result we have not yet experienced bearing failure despite routine use on platforms which may be moving over 30 degrees of arc (as on a ship or small craft). This is achieved, however, at the expense of having to clean the disc set (approximately 0.25 h).

All surfaces of the Alfa-Laval system are accessible for field cleaning. The system is unpressurized, and cannot flood at recommended flow rates; clarified water discharged from the bowl is captured in an aluminum or stainless cover (depending upon model) and flows from the machine under gravity. Unlike the Westfalia we have not experienced problems with metal-to-metal contact between bowl and covers arising from motion on small craft.

Portability

Westfalia: This machine is supplied by the manufacturer for fixed installations, especially in the food and beverage industry. For environmental applications fixed installations have proven to be very reliable. For safety reasons, it is not approved nor recommended by the manufacturer for portable situations. Power is normally applied through a direct drive and 2.0HP electric motor. For portable use the factory-supplied split phase induction motor should be replaced with 2.0HP repulsion start-induction run electric motor. The theoretical starting wattage is 4200 watts at 220 volts; in practice we use a 6 kw, 220 volt, diesel generator to provide necessary start-up power. The portable Westfalia should not be used in small craft.

Alternatively, the Westfalia can be re-engineered for portable use, by removing the large and very heavy metal base plate and by combining a gasoline engine, hydraulic coupling and re-manufactured main driveshaft of the centrifuge. In this configuration, the engineering is critical; Westfalia representatives declared one such installation unsafe due to vibration. A major safety concern with a gasoline-powered drive is the lack of an effective limitation on maximum speed. Engine speed is controlled only by a mechanical governor which can come out of adjustment and is easily adjusted upwards. This is not a problem for skilled operators with proper equipment but could pose a significant hazard for occasional or untrained users. This problem can be minimized by use of a gasoline engine having a 2:1 gear-reduction box so that maximum output rpm is ≈1800 rpm. It is not known whether a gasoline engine coupled to the centrifuge can create an external contaminant source (e.g., PAHs) which could be introduced into the sample during handling.

The Canada Centre for Inland Waters has used Westfalia units in both electric and gasoline mode for many years without incident. The Centre has its own engineering facilities and generally overhauls each unit annually. We understand that requests have been made, however, for remote shut-down switches for reasons of operator safety. The Westfalia must <u>always</u> be handled with care, and personnel must be trained in operating procedures. Failure to do so results in costly breakdowns.

<u>Alfa-Laval</u>: A specially modified Alfa-Laval centrifuge is manufactured for portable use and is available commercially in

configurations for immediate field use. This unit was originally designed for oil/water/particle separation in marine and other applications. For portable use the power supply is a 3/4HP (120 volt) electric motor applied through a centrifugal clutch. The power supply can be kept a considerable distance downwind to avoid sample contamination by exhaust. In small craft use, we route the exhaust overboard into the water column, downstream of sample intake. Alfa-Laval has not yet authorized a gasoline conversion for safety reasons noted above.

The centrifugal clutch reduces start-up load so that the unit can be operated with a small portable generator. Theoretical start-up load is 2600 watts at 120 volts; however, we usually use a 3700 watt (120 volt) generator for field applications. Reduction to half horsepower with commensurate reduction in generator size is anticipated in the near future. The principal problem in field use arises from a poorly maintained power source (incorrect frequency) which can damage the electric motor. The speed of an electric motor is controlled by the frequency of the generator output. Although frequency is a function of generator speed, frequency tends to vary within a fairly narrow range. Additionally, a generator which produces an incorrect frequency (easily checked and adjusted) usually damages the electric motor on the centrifuge which effectively brings the system to a halt or prevents initial start-up. Two Alfa-Laval (or Westfalia) units can be operated from a single portable power supply due to the low power draw once each machine is running at operating speed. In our own work we usually use two machines to reduce the sampling time, or to provide a split sample because of the different field-handling requirements of sediment destined for organic contaminant analysis versus sediment destined for metals and other physico-chemical analyses.

Operators must be properly trained in use of a high speed centrifuge. Although not recommended, we are aware of units in the field that have been in use for many years without maintenance or overhaul, although frequency of use may be less than for some Westfalia units used by the Canada Centre for Inland Waters.

Construction Materials and Sample Contamination

The Westfalia bowl unit and covers are entirely of machined stainless steel. The inner bowl tends to distort over time and chipping has been reported (with commensurate sample contamination). With care, however, this should not pose a problem for careful users.

The Alfa-Laval model tested by Horowitz et al. consists of cast aluminum covers (not recommended if the clarified liquid is to be used for chemical analysis) and a bowl unit of stainless steel with the exception of the distributor and top disc which are of brass. The primary constituents of brass in this unit are Cu (85%), Pb and Zn.

Horowitz et al. comment upon high levels of contamination of the Alfa-Laval samples by Cu and Pb. Other published data cited by Horowitz et al. and those reported below (Table 1), using the same or comparable equipment, do not support their findings. The Joseph data are from irrigation return flows in the areas for which background data are reported by Blachford. Certain of Blachford's and Ongley's data (centrifuged river sediments) are below major outfalls and are known to be enriched, producing considerable and expected variation in the data. They are, however, an order of magnitude less than values reported by Horowitz et al.

The consistency between background lead (Blachford) and centrifuged samples (Joseph) is notable and quite inconsistent with the enrichment reported by Horowitz et al. We find values comparable to Joseph and Blachford in other work (unpublished - noted in Table 1). Possibly the larger sample sizes used in our studies is a factor.

Table 1. Comparative Cu and Pb Data for Alfa-Laval Centrifuges (μg/g).

Joseph	Blachford	Ongley	Horowitz
Copper - Field Centrifuge			
20-30	15- 32 (spring)*	19-47 (spring)*	105-500
20-46	32-120 (summer)*	17-97 (summer)*	
9-41			
19-75			
20-52			
Copper - background			
--	12- 20		38-270
Lead - Field Centrifuge			
10-13	10- 45 (spring)*	11-30 (spring)*	93-530
9-15	30-165 (summer)*		
6-14		9-49 (summer)*	
10-12			
13-20			
Lead - Background			
--	7- 13		24-130

Source: Joseph and Ongley, 1986
Blachford and Ongley, 1982
Horowitz et al., 1988
Ongley (unpublished data for North Saskatchewan River)
* data set includes anthropogenically enriched samples

Joseph and Ongley (1986) reported enrichment of Cu in centrifuged samples by a factor of x2, which is consistent with but not nearly as large in percentage or absolute terms as values reported by Horowitz et al. It is uncertain whether differences in analytical procedure are responsible for the differences between Horowitz et al. and other data. Joseph & Blachford used concentrated HCl/HNO_3 digestion; Ongley used $HClO_4/HNO_3$, while Horowitz et al. used $HF/HClO_4/HNO_3$. The HF digestion may explain the much larger Pb and Cu values reported by Horowitz et al. if the cause of enrichment is slight abrasion of the distributor accelerator veins which bring the water up to bowl speed. We have avoided HF digestion because HF-extractable metal is regarded as including metals held in the silicate lattice and which are not bioavailable in normal environmental situations.

Although Horowitz's data are for single sites the degree of sample contamination for Cu and Pb appears to be highly variable. In our own work we find highly consistent spatial and temporal trends within rivers which indicate that any errors which do exist must be very uniform (Blachford and Ongley, 1982; unpublished data).

Horowitz et al. also include data (his Table V) for a stainless steel distributor for the Alfa-Laval. The stainless steel distributor supplied to Horowitz was specially procured and is not a commercially available item. Like the brass distributor it was a casting and has a slightly textured inside surface where the suspension is being accelerated up to bowl speed. We expect a low level of abrasion associated with these castings but which, as we note above, is not evident in large samples using HCL/HNO_3 or $HClO_4/HNO_3$ digestion for lead. Alfa-Laval now manufactures a completely stainless steel unit (covers and bowl parts); however, it has not, to date, been subject to quality assurance for metal contamination. Because stainless steel is much harder than brass, we would expect equal or improved performance.

Sample Size

In our experience with both centrifuges, sample size is in the order of several to tens of grams of recovered sediment. The former for metals, phosphorus, particle sizing, etc., and the latter for organic contaminant analysis and bioassay. Horowitz et al. report sample sizes ranging from 1.0 to 10 g. Percentage recovery is expected to improve with increasing sample size, especially in the case of the Alfa-Laval, due to the fractional amount of material on the discs for which, in a large sample, is so minute relative to the weight of material collected from the bowl wall, we do not attempt to recover it.

Processing Rate

Horowitz et al. report an increase in recovery efficiency for low input sediment concentrations when reducing processing rate from 4.0 to 1.0 L/min. They recommend a rate of 2.0 L/min. Their observation confirms our own observations; however, the tradeoff of sampling time versus recovery efficiency are not attractive for most practical purposes. Using the maximum recovery improvement (31%) cited by Horowitz et al. as an example, at an input concentration of 50 mg/L, and presuming one needs a 40 g sample for organic contaminant analysis, one requires 4.8 h (at 4 L/min and 70% recovery) versus 14.5 h (at 1 L/min and 92% recovery). In most situations, recoveries are much better at 4 L/min than this example, (generally >90% for the Alfa-Laval - Ongley & Blackford, 1982), in which case the sampling time at 4 L/min is less than this example and the tradeoff at 1 L/min is much worse.

Although not examined systematically, our data do not suggest any relationship between grain size distribution and recovery efficiency. We did note in early laboratory tests, some reduction in fine-particle retension at 6 L/min. We fixed upon 4 L/min after many years of field experience and laboratory trials as a reasonable tradeoff between sampling time and recovery efficiency.

Quality Assurance: Metals and Organic Contaminants

To our knowledge and apart from our own work, there has been no other systematic quality assurance of either centrifuge for metals. In connection with a major study of the North Saskatchewan River (Ongley et al., 1988), Birkholz (1988) has completed a quality assurance program for the Alfa-Laval centrifuge and peripheral apparatus for 42 base/neutral and 11 acid extractable EPA Priority Pollutants. He found no evidence for internal contamination of sample either in his laboratory experiments or in field samples. We are unaware of any similar study of the Westfalia.

Cost

The cost of centrifuges has risen considerably over the past several years, especially for the Westfalia. At the time of writing, the Westfalia clarifier, before applying an electric motor or undertaking any re-engineering, is now quoted at approximately C$35,000. A spare bowl (most operators use two) ≈C$21,000. Commercial re-engineering for portable use is likely to cost at least another three to four thousand dollars. In cases of breakdown, we have found that parts may be difficult to obtain and may require lead times of up to several months. The Alfa-Laval unit in portable mode currently sells for about half that of the Westfalia (depending upon model); spare parts are stock items. For both centrifuges users should maintain an inventory of spare parts. The Westfalia in portable mode, however, makes use of a number of custom manufactured and non-standard components which should be held in inventory.

ACKNOWLEDGEMENTS

We appreciate a critical review of the manuscript by H.A. Savile and M.R. Mawhinney, both of whom have had considerable experience with the Westfalia centrifuge.

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