

**EVALUATION OF EFFLUENT CENTRIFUGATION:
LESSONS LEARNED**

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ABSTRACT

During 1989 and 1990 the Environmental Investigations and Laboratory Services (EILS) Program purchased two flow-through centrifuges and installed them in an outfitted trailer. This self-contained "centrifuge system" has been used to collect suspended particles from NPDES-permitted waste-streams, rivers and storm water.

This paper summarizes the general success of efforts to collect, analyze and evaluate data from these particulate samples. Issues addressed include the resources (time and money) required to obtain samples and data, and special problems encountered in analyzing the particulate samples.

The efficacy of using centrifuge-collected particulate data for three likely objectives is discussed. These objectives are:

- 1) to screen effluents or surface waters for the presence of compounds associated with the particulate phase;
- 2) to use chemical data from particulate analysis to quantify pollutant loads associated with the particulate phase of effluents or surface waters; and
- 3) to use data from particulate analysis (organic chemical, TOC, grain size, etc.) to assist in modeling or otherwise predicting the impact of discharges on nearby sediments.

INTRODUCTION

During the 1980's researchers, resource agencies and the public in Washington State became increasingly concerned about bottom sediment contamination in Puget Sound and other waters, both fresh and marine. In response, the Puget Sound Water Quality Authority (PSWQA) and the Washington State Department of Ecology (Ecology) -- as well as other state, local and federal entities -- began to identify, understand and control significant sources of sediment contamination.

One of these efforts, begun by Ecology's Environmental Investigations and Laboratory Services (EILS) Program in the late 1980's, was an evaluation of the use of flow-through centrifuges as tools to collect particles suspended in treated effluents. By designing and fabricating a portable centrifugation system, using it in diverse settings to separate particles from waste streams, and analyzing the collected solids; we have learned much about the capabilities and limitations of this tool.

This paper provides a shorthand description of the system, cites documents that describe its operation, recounts how the centrifuge has been used, and references reports that provide the data from these applications. It then summarizes the strengths and constraints associated with centrifugation and notes how Ecology and others might best apply this tool.

A BRIEF HISTORY AND SYSTEM DESCRIPTION

Ecology's centrifugation system consists of two 3/4 horsepower Alfa-Laval (Model WSB/MAB 103) stainless steel, flow-through centrifuges; a six-kilowatt portable generator with auxiliary gas tank; peristaltic pumps to deliver sample water to the centrifuges; replacement sample tubing and plumbing (mostly teflon); valves and instrumentation to measure and balance water flow through the centrifuges; and the wiring/outlets required to provide power to the centrifuges, either from the generator or from a site-based source. All these components are installed in an insulated, dual axle, 13 foot, enclosed trailer. This trailer is also outfitted with shelves and drawers for tools, spare parts and other sampling equipment.

Ecology purchased the components of the self-contained centrifuge trailer during the first half of 1989. EILS' compliance monitoring staff assembled the system and it was operational by October 1989. A draft "operations guide" (Seiders, 1990) provides a detailed description of the system, associated schematics, safety considerations, and specific guidance for the preparation, setup, sampling, and cleanup required to operate the system.

The formal part of the centrifuges' field testing included sample collection at eight major NPDES dischargers during Class II compliance monitoring inspections. These inspections were conducted between December 1989 and September 1990. Table 1 summarizes information including facility name, location, timing, and a citation for the inspection report.

Table 1. Class II Inspections Using Flow-Through Centrifuges

Facility	Location	Inspection Date	Citation
Wenatchee Municipal	Wenatchee	Dec. 1989	Andreasson, 1990b
ALCOA Aluminum Reduction	Vancouver	Jan. 1990	Zinner, 1990
Reynolds Aluminum Reduction	Longview	Feb. 1990	Heffner, 1991
Weyerhaeuser Pulp & Paper	Longview	Apr. 1990	Andreasson, 1990a
Kaiser Aluminum Rolling Mill	Trentwood	May 1990	Glenn & Nell, 1991
Longview Fiber Pulp and Paper	Longview	May 1990	Das, 1991
James River Pulp and Paper	Camas	June 1990	Andreasson, 1991a
Inland Empire Paper	Millwood	Sept. 1990	Das & Zinner, 1991

After these inspections were completed, Andreasson (1991b) compiled some of the data in a working draft. The centrifuges have not been used recently in association with compliance monitoring. EILS investigators have however used them in two other applications.

Since 1990, Ecology has monitored dioxin/furan contamination in the Upper Columbia River at the Canadian border to track contamination trends in fish tissue, water and sediment. Dioxin/ furan concentrations in whole water can raise health concerns at concentrations well below conventional analytical detection limits. Because these compounds have a strong affinity for particles, the centrifuges have been used to collect suspended sediment from large volumes of water. These samples of suspended sediment have then been successfully analyzed for a range of chlorinated dioxin/furan congeners. Johnson *et al.* (1991) and Serdar *et al.* (1993) describe these collection efforts and resulting data.

A third application for the centrifuges has been in collecting samples of sediment suspended in storm water. The centrifuges are helpful when other means of collecting storm water sediments are not feasible (e.g., there are no depositional locations within a storm water drainage system that are accessible). To date, the centrifuges have been used to collect a single storm water sediment sample from a storm drain in Bremerton (Cabbage, in prep.). This sample was analyzed for a range of organic priority pollutants and metals.

FINDINGS: STRENGTHS AND WEAKNESSES OF USING IN-FIELD
CENTRIFUGATION TO COLLECT PARTICULATES FROM
WASTE WATER AND SURFACE WATER.

General

Housing the centrifuge system in a trailer has provided an integrated, portable, self-contained system that functions well in a range of locations. Because the trailer is insulated, it serves as a functional platform even when the weather is cold, hot or otherwise inclement.

Security can be a concern. The original cost of system components was about \$60,000; if left unprotected, the equipment is vulnerable to vandalism. When we need to run the centrifuges for several days, there are cost advantages to leaving the system unattended. Although this has not been a problem at enclosed, secure sites (most treatment facilities) the need for our continuous presence at urban (storm water sampling) and rural (ambient river sampling) sites can increase personnel costs.

Because the equipment is sophisticated, operator training is essential to assure careful, knowledgeable operation. Even employees well-trained and competent in other aspects of water and waste-water sampling need at least a one-day training session. In addition, several days of actual hands-on use are advisable before field personnel operate the system without supervision.

Personnel and Time Requirements

A major constraint of the centrifuge system is the time invested in collecting samples. Mobilization and demobilization of the centrifuge system, when added to the time required to collect the field samples, can make sample collection costly. Table 2 estimates the time required for preparation (cleaning and assembly), on-site setup, on-site demobilization, and post-survey cleanup. These time estimates were provided by Keith Seiders (personal communication) for compliance monitoring, Dave Serdar (personal communication) for river sampling, and Jim Cabbage (personal communication) for storm water sampling.

Table 2. Estimated Time Requirements for Mobilizing and Demobilizing Centrifuge System (Person-Days)

Function	Compliance Monitoring	River Monitoring	Storm Water Monitoring
Preparation	3	2.5	3
On-Site Setup	1	2.5*	1
On-Site Demobilization	0.5	1 *	.5
Post Survey Cleanup	1.5	2.5	1.5
Total	6.0	8.5*	6.0

* The greater time required for river sampling is associated with deploying the intake line with a boat. Also, sample line lengths and required pumping elevations are greater requiring more time to deploy successfully.

The actual collection of samples takes additional time. The time required to collect an adequate sample depends on:

- ◆ The suspended solids concentration in the sample stream.
- ◆ The amount of solids required to conduct necessary analyses.

- ◆ The rate at which the sample stream is fed to the centrifuges.
- ◆ The efficiency with which the centrifuges separate out the solids.

Table 3 summarizes the amount of sample needed for various analyses. These amounts are estimates based on information provided by the Ecology Laboratory (Magoon, 1993; Stinson, personal communication). Where conversion from total (wet weight) solids was necessary I assumed sediment samples contain 33% solids. Considerations specific to a particular study (required detection limits, QA requirements, number of individual laboratories involved) may change these requirements.

Table 3. Estimated Minimum Amounts of Dry Solids Required for Analyses

Analysis	Minimum Sample Size (Dry Grams)
Percent Solids	2*
TOC	1
Grain Size	20
Priority Pollutant Metals	5
Semivolatile (BNA) Priority Pollutants	10**
Priority Pollutant Pesticides/PCBs	10**
Dioxins/Furans	10
Bioassays	3-100***

* All tests require % solids determination for conversion to dry weight

** Requires 30 g wet weight; these two analyses can be extracted from the same aliquot.

*** Sample size depends on bioassay chosen (Stinson, personal communication).

Table 4 provides an example of how required sample times vary with flow rate to the centrifuges and suspended solids concentration in the sample stream. This table shows the amount of time required to collect 100 g of dry sediment if the centrifuges remove 75% of incoming suspended solids. The results of Andreasson (1991b), Johnson *et al.* (1991,) and Serdar *et al.* (1993), show that 75% collection efficiency is typical. Collection efficiency is discussed in more detail later.

The maximum flow rates reported by Andreasson were 3.32 gpm. As the lift and distance required to get the sample stream to the centrifuges increase, the delivery rate decreases. Serdar (personal communication) reports a delivery rate of about 0.8 gpm for his dioxin/furan sampling in the Columbia River. When low suspended solids concentrations combine with low delivery rates, long sample times are required. Collection of about 15 dry grams of sediment for dioxin/ furan and metals analysis from the Columbia River (suspended solids concentration approximately 2 mg/L) required 59 hours of actual centrifuge operating time (Serdar, *et al.*, 1993).

Table 4. Centrifugation Time (in Days) Required to Collect 100 g (dry) of Solids
(Assumes 75% Collection Efficiency)

Flow Rate to Centrifuge (gal./min.)	Suspended Solids Concentration (mg/L) in Sample Stream					
	2.5	5	10	25	50	100
0.5	19.5	9.7	4.9	1.9	1.0	0.5
1.0	9.7	4.9	2.4	1.0	0.49	0.24
1.5	6.5	3.2	1.6	0.65	0.33	0.16
2.0	4.9	2.4	1.2	0.49	0.24	0.12
2.5	3.9	1.9	1.0	0.39	0.20	0.10
3.0	3.2	1.6	0.8	0.32	0.16	0.08
3.5	2.8	1.4	0.7	0.28	0.14	0.07

Analytical Considerations

One tacit assumption in using the centrifuge to collect samples of suspended solids was that there would be no special problems associated with analyzing the samples collected. We were optimistic.

Ease of analysis was related to the origin and characteristics of the solids collected. Samples consisting primarily of inorganic, mineral solids -- e.g., samples from the effluents of primary metals facilities without biological treatment and samples from the free-flowing Columbia River--caused few problems. On the other hand, samples with high concentrations of "biogenic" material, especially effluents from secondary treatment, posed the greatest difficulties.

Organics

Analyses for organic compounds were often difficult. These difficulties were aggravated because analyses were conducted at several different laboratories.

One general problem was blank contamination. Organic-free water was passed through the system prior to sampling. These "field transfer blanks" were analyzed to evaluate what contaminants might be associated with the sampling process. The following compounds were detected in field transfer blanks during the eight compliance monitoring inspections (frequency in parentheses): acetone (5), methylene chloride (2), diethylphthalate (2), naphthalene (2), toluene (1), bis(2-ethylhexyl)phthalate (1), chloroform (1), phenol (1), 4-methylphenol (1), and pyrene (1). Compounds that showed up in laboratory blanks included lindane and di-n-butylphthalate (Andreasson, 1991b).

Issues raised by the analysis of specific organic fractions are addressed below.

Volatile Organics (VOAs) Analysis of particulate matter for volatile organics was abandoned early in the project. This decision was based on early results (consistent with theory) suggesting that these compounds did not partition strongly to particulates.

Base/Neutral/Acid Extractables (BNAs) As noted above, the difficulties associated with analyzing centrifuged particulates for organic compounds were generally associated with high concentrations of "biogenic" material (Huntamer, personal communication). Similar problems are experienced with sludges, biosolids and samples from sediment traps located in areas where settling particulate matter is high in organic content.

"Biogenic" material can include microorganisms (algae and bacteria) as well as detritus, oil and grease. Separating non-target organic compounds (many of which are associated with biogenic solids) from target compounds removes interferences and improves detection limits. The standard cleanup for BNA analysis is gel permeation chromatography (GPC). This procedure is not particularly effective in removing certain non-target compounds (e.g., fatty acids, resin acids) which cause rapid degradation of the gas chromatography (GC) columns. Analysts often dilute extracts to reduce this degradation. This dilution compromises detection limits.

The most straightforward way of overcoming these difficulties is by targeting specific compound groups (for instance; PNAs, phenolics, phthalate esters), and then clean up the extract to focus on those specific groups. NPDES methods 604-607 and 609-612 each focus on one of these groups; for instance, method 610 uses silica gel to clean up extracts prior to PNA analysis. The drawbacks of additional cleanup can include increased costs, elimination of some compounds from the target list, and increases in required sample size.

Pesticides/PCBs The extract analyzed for pesticides/PCBs is refined using gel permeation chromatography (GPC) and fluorocil cleanup. Although this provides a cleaner extract than that used for BNA analysis, numerous small molecules still pass through to the final extract. These non-target compounds created some interference when analyzed with the electron capture detector (ECD) used during these studies. In 1991 the Manchester Environmental Laboratory began using an atomic emission detector (AED), which is very specific in its response to atoms associated with contaminants (chlorine, for instance). The AED eliminates interferences from non-target molecules and atoms. It also allows the analyst to identify a much wider range of compounds (Carrell, personal communication). The down side is that the AED is less sensitive than the ECD. Analysts can overcome this problem by injecting larger extract volumes which can, in turn, require larger sample volumes.

The practical result is that to obtain the same detection limits previously available with ECD, BNA and Pesticide/PCB extractions would not be obtained from the same 30 gram wet (10 gram dry) sample (see Table 3). Instead, the pesticide/PCB extraction alone would require about 30 wet (10 dry) grams of sample. BNA analysis would require additional sample. This, of course, would require longer centrifugation times (see Table 4).

Dioxins/Furans Sample preparation, extraction and cleanup for dioxin/furan analyses are extensive. Specifically, analysis includes isotope dilution (to correct for analyte loss through

the process), washing with concentrated sulfuric acid followed by sodium hydroxide, alumina column elution, and carbon column cleanup. Silica gel cleanup can be added for complex samples. This preparation makes these analyses expensive, but removes the interfering compounds that created analytical problems the organic fractions described previously. Dioxin/furan analyses of Columbia River sediments have given very satisfactory results.

Bioassays Attempts to perform bioassays on sediment samples collected with the centrifuge posed two problems. The first was associated with collecting enough material. As noted in Table 3, relatively large sample sizes can be required. For multiple bioassays, required sample volumes are even larger.

The second problem was associated with the biological activity of the samples. Gas production (photosynthesis, respiration, decay) frequently caused sample sediments to float to the top of the test chamber (Stinson, personal communication), negating the results. The use of extraction tests that require relatively small volumes (e.g., Microtox) might provide a solution to some of the practical, logistic problems. However, clarifying the environmental significance of Microtox test results for centrifuged sediments is likely to pose ongoing difficulties.

Metals Digestion of particulate samples for metals analysis was also compromised by high concentrations of organics (oils, greases, and other "biogenic" material). Remnants of this material (apparently the longer chain, paraffin-like compounds) can coat the sample introduction system of graphite furnace atomic absorption spectrophotometers (Kammin, personal communication). This, in turn, can lead to decreased recovery of metals in some samples, and subsequent underestimates of metals concentrations.

More rigorous digestion techniques (e.g., microwave digestion) are now available. These may overcome the problems encountered earlier with this matrix. In addition, methods that require no digestion (neutron activation, X-ray fluorescence) are also available.

A final point: unlike organics, the distribution of metals between the liquid and particulate phase can be evaluated using another approach. There are approved methods for determining total and dissolved metals concentrations in effluent and water samples. By determining metals concentrations in water samples before and after filtration, and knowing the concentration of suspended solids, a good estimate of particulate-bound metals concentrations can be calculated. This approach becomes more useful as detection limits for metals in water decrease. Where appropriate, total and dissolved metals analyses are much more cost effective than collecting centrifuged particulates.

Theoretical Considerations

In retrospect, there appear to be three potential objectives or applications for data derived from samples collected using the flow-through centrifuges. These objectives are:

- 1) To screen effluents or surface waters for the presence of compounds associated with the particulate phase.

- 2) To use chemical data from particulate analyses to quantify pollutant loads associated with the particulate phase of effluents or surface waters.
- 3) To use data from particulate analyses (organic chemical, TOC, grain size, etc.) to assist in modeling or otherwise predicting the impact of discharges on nearby sediments.

Although centrifuge data may be useful in meeting Objective 1, they can meet Objective 2 only in certain, specific cases. Additionally, the expectations raised by Objective 3 may be unrealistic. The basis for these conclusions is discussed below.

Objective 1 -- *To screen effluents or surface waters for the presence of compounds associated with the particulate phase.*

While using centrifuges to collect samples from NPDES-permitted discharges, samples of whole effluent, centrate (the clarified water discharged from the centrifuge), and particulates were analyzed for BNAs and pesticides/PCBs (and, in a few cases, VOAs). Andreasson (1991b) summarized compounds detected in these three media. Appendix A presents these data in a way that addresses Objective 1.

Table 5 is based on Appendix A and shows how often specific organic priority pollutants were detected in each of the three effluent media tested. The analysis of particulates clearly increased the chances of detecting priority pollutant organics. The detection of PNAs and PCBs was especially improved by particulate analysis. The detection of dioxins and furans is also much improved by particulate analysis in subsequent studies (Johnson *et al.*, 1991; Serdar *et al.*, 1993).

Table 5. Detection Frequency of Organic Priority Pollutants in Centrate, Whole Effluent and Particulates (derived from Appendix A).

	<u>Centrate</u>	<u>Whole Effluent</u>	<u>Centrifuged Particulates</u>
Number of Detections	6	25	55

There may be techniques with lower resource requirements that can meet the objective of screening effluents for specific organics. Andreasson (1991b) included data generated by analyzing potential "surrogate indicators," including primary sludge, secondary sludge, and return activated sludge. Unfortunately, these analytical data appear, in many cases, to be flawed. Further evaluation is necessary before efficacy of these surrogate indicators or other lower cost sampling techniques like sediment traps can be determined.

Objective 2 *To use chemical data from analyses of particulates to quantify pollutant loads associated with the particulate phase of effluents or surface waters.*

The progression from screening for pollutants to providing accurate quantification of pollutant loads raises several difficulties. As mentioned earlier, the high "biogenic" content of many samples reduces the accuracy of standard analyses for priority pollutant organics. Of the organic analyses, only those for dioxins/furans routinely include techniques like isotope dilution that allow for correction for losses during the extraction and cleanup.

A second area of uncertainty that may introduce error is the representativeness of the sample stream. Although sample intake locations are chosen to draw in a well-mixed portion of effluent or water body, representing the entire load is difficult. Transport in a nephloid layer or as part of the bed load may not be included. In addition, no effort has been made to determine the need for isokinetic conditions at the intake; that is, assuring that the velocity at which a sample stream is drawn into the intake is equal to the velocity of the effluent or stream at the intake). The potential for skewing the particle size/density distribution by biases created by turbulence at the intake has not been evaluated.

A third area of concern is centrifuge capture efficiency. Lower capture efficiencies may bias chemical results if size/density fractions introduced to the centrifuge are not equitably represented in the final sample. One way to accomplish this is to retain in the centrifuge all of the introduced particles. Although 100% particle retention is not possible, reducing the flow rate to the centrifuges seems to improve retention.

During the initial compliance monitoring inspections, suspended solids concentrations were measured entering and leaving the centrifuge 106 times (Andreasson, 1991b). Simultaneous (total) flows through the two centrifuges were also recorded. Although reported capture efficiencies ranged from less than 0% to essentially 100%, nearly all values fell between 50% and 100%. Flows through the centrifuges ranged from 0.6 gpm to 3.32 gpm. A linear regression between flow rate and capture efficiency shows an inverse relationship, with capture efficiency falling as flow rates increase. The regression equation is:

$$\text{Capture Efficiency in Percent} = 107 - (20 \times \text{Flow Rate in GPM}) \quad (R = 0.57)$$

This equation implies that average capture efficiencies of greater than 85% can be achieved if the total flow rate to the centrifuges is kept below 1 gpm. Unfortunately, a reduced flow rate decreases the net rate at which sample is accumulated, making longer sample times necessary.

Characteristics of specific effluents may also affect capture efficiency. Efficiency was much lower (around 50%) at one of the eight monitored waste-water treatment facilities (James River Pulp and Paper Mill). Although particle size/density characteristics are the suspected cause, this is not definitive.

The analysis of centrifuged particulates to estimate pollutant loads has been successful with dioxin/furan studies on the Columbia River below the Canadian border. Dioxin/furan loads measured using data from centrifuged samples compared well with loads measured at the major Canadian source (Johnson *et al.*, 1991); and have been used to document reductions in receiving water loads associated with treatment upgrades at the source (Serdar, *et al.*, 1993).

If quantifying particulate-bound loads of organic contaminants is an important study objective, there appear to be no reasonable alternatives to centrifugation. To determine loads accurately, with confidence, improvements in sampling and analytical protocols may be required.

Objective 3 *To use data from particulate analyses (organic chemical, TOC, grain size, etc.) to assist in modeling, or otherwise predicting, the impact of discharges on nearby sediments.*

This is the most ambitious of the three objectives and does not appear to be currently feasible--especially for discharges to marine receiving waters. In addition to the difficulties noted above, there are a range of poorly understood transformations that occur when fresh water effluents are mixed with marine receiving waters. These phenomena include shifts in speciation, partitioning and phase association of contaminants. One example is the creation of new particles in the mixing zone through coagulation and flocculation.

A major implication of these transformations is that conditions inferred from effluent particulate data may have little resemblance to conditions in the mixing or sediment impact zones. The Puget Sound Water Quality Authority's Committee on Research understood this problem well when it listed, as its first research priority: *"Develop a better understanding of speciation, partitioning, and phase association of chemicals in the mixing zone."* (PSWQA, 1988). As far as we know, this research need has not yet been addressed.

CONCLUSIONS

- 1) The centrifuge system, housed in a trailer, provides an integrated, portable, self-contained system that functions well in a range of locations and conditions.
- 2) Use of the centrifuge system is resource intensive. The initial cost of the system is high--about \$60,000. Major costs are also associated with the time required to prepare, clean, set up and disassemble the system; collect an adequate amount of sample; and maintain the equipment.
- 3) Special analytical difficulties (especially with priority pollutant organics) arise in analyzing centrifuged particulates high in "biogenic" materials. Although some of these problems may be overcome with additional cleanup procedures, these will increase analytical costs and may require collecting more sample, which will further increase on-site sampling time.
- 4) Conducting bioassays on centrifuged solids is generally not practical. These solids are generally biologically active and often float. A need for high sample volumes, as well as difficulties in interpreting the results, further complicate efforts to bioassay centrifuged solids.
- 5) By comparison to whole effluent analysis, analysis of effluent particulates increases the frequency with which many priority pollutant organics are detected: especially PNAs, PCBs, and dioxins/furans. Less resource intensive techniques (use of "surrogate

indicators" like sludges, use of sediment traps) may work as well to meet the objective of screening effluents or streams for particulate-bound contaminants. However, further evaluation is necessary before the efficacy of these techniques can be determined.

- 6) Analysis of centrifuged particulates from effluents and streams may provide the only practical way of quantifying particulate-bound pollutant loads of organic chemicals. This will work best if special analytical techniques (e.g., extract cleanup targeted to specific contaminant groups and isotope dilution) are used.
- 7) Low flow rates through the centrifuges seem to improve capture rates (i.e., higher percentages of influent suspended solids are retained). This, in turn, minimizes the chance for bias through differential capture of various size/density fractions. On the other hand, high flow rates increase the rate at which total sample mass is collected.
- 8) Major gaps in our understanding of physical-chemical transformations in the mixing zone (changes in speciation, partitioning and phase association) are likely to severely limit the application of effluent particulate data to modeling or other attempts to predict the effects of discharges on nearby bottom sediments. This will probably be a greater problem with discharges to marine/estuarine environments than with discharges to fresh waters.

RECOMMENDATIONS

- 1) Continue to use the centrifuge system for selected applications where there is no effective, less expensive option. One such application is in quantifying organic pollutant loads associated with the particulate fraction of rivers or waste streams.
- 2) Assure high quality organics analyses of centrifuged solids, including targeted cleanup of extracts and isotope dilution where appropriate. Any studies conducted to further address particulate contamination should include careful evaluation of quality assurance and quality control to assure that data collected are accurate and comparable.
- 3) Evaluate the use of lower cost technologies to characterize suspended particulates. Although they require further evaluation, use of sediment traps and/or "surrogate indicators" like sludge may provide alternatives when screening rivers or waste streams for toxics. Analyzing total and dissolved metals in effluents and streams may be more cost effective than collecting centrifuged solids.
- 4) To assure that the centrifuge system continues to function, a specific person should be assigned the responsibility for maintaining the system and the spare parts inventory. If possible, this person should accompany all field uses of the system and provide training to other staff. Because there are no specific, foreseen uses for the centrifuge system in the near future this resource commitment may not be supportable. In that case, we should consider surplusing the system.

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APPENDIX A

Organic priority pollutants detected in waste waters tested during centrifugation tests at eight NPDES-permitted facilities.

All data associated with transfer blank contamination are excluded. Compounds included in organic priority pollutant analyses are listed on the left-hand side of the table -- from those with the lowest octanal/water partitioning coefficient (K_{ow}) to those with the highest. Solubility in water is also given. To the right, the frequency with which each compound was detected is shown. The possible combinations of media in which compounds could have been detected in each test of the centrifuge system arrayed from left to right across the top of the table: in centrate only, both in centrate and whole effluent, in whole effluent only, in centrate and whole effluent and particulates, in whole effluent and particulates, and, finally, in particulates only. The order in which these combinations are listed suggests a preference for the liquid phase on the left; preference for the particulate phase on the right.

As one moves down the list (higher log K_{ow}) there is a clear shift to the right. Most of the organics detected during this work appear to be fairly strongly associated with the particulate phase, except volatiles and phenols. The detection of diethylphthalate only in the centrate (two occasions) may be associated with contamination during sampling.

Priority Pollutant	log K _{ow}	solubility	cent ¹ only	whole ² +cent.	whole ³ only	all ⁴ 3	whole ⁵ +part	part. ⁶ only
Bis(chloromethyl)ether	-0.38	22000 ppm						
Acrolein	-0.09	208000 ppm						
Dimethylnitrosamine	0.06	miscible						
Chloroethene	0.60	60 ppm						
Chloromethane	0.91	6450-7250 ppm						
Bromomethane	1.10	900 ppm						
Methylene choride	1.25	13200-20000 ppm						
Bis(2-chloroethoxy)methane	1.26	81000 ppm						
2-Chloroethyl vinyl ether	1.28	15000 ppm						
Di-n-propylnitrosamine	1.31	9900 ppm						
Phenol	1.46	93000 ppm			2			1
1,1-Dichloroethene	1.48	400 ppm						
1,2-trans-Dichloroethene	1.48	600 ppm						
1,2-Dichloroethane	1.48	8690 ppm						
2,4-Dinitrophenol	1.53	5600 ppm						
Chloroethane	1.54	5740 ppm						
Bis(2-chloroethyl)ether	1.58	10200 ppm						
Isophorone	1.70	12000 ppm						2
2-Nitrophenol	1.76	2100 ppm						
1,1-Dichloroethane	1.79	5500 ppm						
Benzidine	1.81	400 ppm						
Nitrobenzene	1.85	1900 ppm						
Bromodichloromethane	1.88	no data						
4-Nitrophenol	1.91	16000 ppm						
Chloroform	1.97	8200 ppm			1		2	1
1,3-Dichloropropene	1.98	2700-2800 ppm						
2,4-Dinitrotoluene	2.01	270 ppm						
Benzene	1.95/2.13	820-1800 ppm						
2,6-Dinitrotoluene	2.05	no data						
Dibromochloromethane	2.09	no data						
Dimethylphthalate	2.12	4000-5000 ppm		1				1
Dichlorodiflouromethane	2.16	280 ppm						
2-Chlorophenol	2.17	28500 ppm						
1,1,1-Trichloroethane	2.17	480-4400 ppm						
1,1,2-Trichloroethane	2.17	4500 ppm						
1,2-Dichloropropane	2.28	2700 ppm						
Trichloroethene	2.29	1100 ppm						
Tribromomethane	2.30	3100 ppm						
2,4-Dimethylphenol	2.50	17000 ppm						
Trichlorofluoromethane	2.53	1100 ppm						
1,1,2,2-Tetrachloroethane	2.56	2900 ppm						
Diphenylnitrosamine	2.57	no data						
Bis(2-chloroisopropyl)ether	2.58	1700 ppm						
Carbontetrachloride	2.64	785 ppm						
Toluene	2.69	535 ppm			1			2
2,4-Dichlorophenol	2.75	4500 ppm	1				1	
Chlordane	2.78	.056-1.85 ppm						
Chlorobenzene	2.84	448-500 ppm						
4,6-Dinitro-o-Cresol	2.85	no data						
Tetrachloroethene	2.88	150-200 ppm						2

Priority Pollutant	log K _{ow}	solubility	cent ¹ only	whole ² +cent.	whole ³ only	all ⁴ 3	whole ⁵ +part	part. ⁶ only
p-Chloro-m-Cresol	2.95	3850 ppm						
Ethylbenzene	3.15	152 ppm						
Diethylphthalate	3.22	896-1000 ppm	2					
Toxaphene	3.30	.5-3 ppm						
Hexachloroethane	3.34	50 ppm						
Napthalene	3.37	31.7-34.4 ppm						
2,4,6-Trichlorophenol	3.38	800 ppm		1		1		
1,2-Dichlorobenzene	3.38	145 ppm						
1,3-Dichlorobenzene	3.38	123 ppm						
1,4-Dichlorobenzene	3.39	79 ppm						
alpha Endosulfan	3.55	.164-.6 ppm						
beta Endosulfan	3.62	.06-.28 ppm						
Endosulfan sulfate	3.66	.117-.22 ppm						2
gamma-Hexachlorocyclohexane	3.72	2.15-12 ppm					1	
Hexachlorobutadiene	3.74	2 ppm						
beta-Hexachlorocyclohexane	3.80	.13-.7 ppm						
alpha-Hexachlorocyclohexane	3.81	1.21-2.0 ppm						2
Hexachlorocyclopentadiene	3.99	1.8 ppm						
Acenaphthylene	4.07	3.93 ppm						
4-Chlorophenylphenylether	4.08	3.3 ppm						
PCB 1221	4.09	15 ppm						
2-Chloronapthalene	4.12	6.7 ppm						
delta-Hexachlorocyclohexane	4.14	8.6-31.4 ppm						
Fluorene	4.18	1.69-1.98 ppm						
1,2,4-Trichlorobenzene	4.26	30 ppm						
4-Bromophenylphenylether	4.28	no data						
Acenaphthene	4.33	3.42 ppm						2
PCB 1016	4.38->5.5	8.42 ppm						
Anthracene	4.45	.045-.073 ppm						2
Phenanthrene	4.46	1.0-1.29 ppm					1	1
PCB 1232	>4.54	1.45 ppm						
Pentachlorophenol	5.01	14-80 ppm	1					
Di-n-butyl phthalate	5.20	13 ppm						
Pyrene	5.32	132-140 ppb					2	1
Fluoranthene	5.33	260 ppm					2	1
PCB 1242	>5.58	130-340 ppm						
Endrin	5.60	250 ppm						
Chrysene	5.61	2 ppb					1	2
Benzo(a)anthracene	5.61	9-14 ppb					1	2
pp'DDE	5.69	14-120 ppb					1	
op'DDE	5.78	140 ppb						
Butylbenzyl phthalate	5.80	2.9 ppm						
Dibenzo(a,h)anthracene	5.97	0.5 ppb						1
pp'DDD	5.99	20-90 ppb						1
Benzo(a)pyrene	6.04	3.8 ppb					1	1
op'DDD	6.08	100 ppb						
PCB 1248	>6.11	54 ppb						2
PCB 1254	6.03	12-56 ppb						1
PCB 1260	>6.11	2.7 ppb						
Hexachlorobenzene	6.18	6-20 ppb						

Priority Pollutant	log K _{ow}	solubility	cent ¹ only	whole ² +cent.	whole ³ only	all ⁴ 3	whole ⁵ +part	part. ⁶ only
pp'DDT	6.19	5.5-25ppb					1	
Benzo(b)fluorathene	6.57	no data						1
Benzo(k)fluoranthene	6.84	no data					1	1
Benzo(g,h,i)perylene	7.23	.26 ppb					1	1
Indeno(1,2,3-cd)pyrene	7.66	no data					1	1
Bis(2-ethylhexyl)phthalate	8.73	.4-1.3 ppm			1			3
Di-n-octyl phthalate	9.20	3 ppm						1
Aldrin	no data	17-180 ppb						
Dieldrin	no data	186-200 ppb						
Heptachlor	no data	.056-.180 ppb						
Heptachlor epoxide	no data	.11-.35 ppb						
TCDD	no data	0.2 ppb						
Total			4	1	5	1	18	36

Log K_{ow} and Solubility Data from: EPA, 1979. Water-related Environmental Fate of 129 Priority Pollutants. (2 Volumes) EPA-440/4-79-029)

1. Compound detection centrate only.
2. Compound detected in whole effluent and centrate.
3. Compound detected in whole effluent only.
4. Compound detected in centrate and whole effluent and particulates.
5. Compound detected in whole effluent and particulates.
6. Compound detected in particulates only.