CORNWALL SEDIMENT TREATABILITY STUDY

Prepared for:

St. Lawrence (Cornwall) Remedial Action Plan

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1.0 INTRODUCTION

Bulk analytical testing and treatability testing was performed on sediment samples collected from the St. Lawrence River near the Courtaulds Fibres plant. The sediment was collected by river bottom dredging over an area considered to be representative of the range of contamination. Sediments in this area are known to be contaminated above Ontario's severe effect levels (SEL's) for several metals and some polycyclic aromatic (PAH's) compounds. As the St. Lawrence Remedial Action Plan (RAP) team has chosen the Courtaulds site as a possible location for a large scale demonstration of sediment removal and treatment technologies, the Wastewater Technology Centre's (Operated by Rockcliffe Research Management Ltd.) was contracted to perform preliminary treatability testing in order to determine possible pre-treatment and treatment options which might be used.

In developing technologies for treatment of contaminated sediments, treatability testing is always a necessary precursor to bench and pilot scale studies. The tests carried out in this study consisted of bulk analytical testing, particle size characterization and analyses, and sedimentation testing.

The principle objective of this work was to perform complete characterization and treatability tests on the supplied sediment to aid RAP team decision makers in their selection of appropriate remedial measures.

1.1 Scope of Work

Sediments requiring remediation can vary widely in terms of physical and chemical properties. In terms of physical characteristics, texture or particle (eg. sand, silt, & clay) size distribution are of primary interest. Generally, fine textured sediments have much greater affinities for all classes of contaminants, while sandy sediments have little attraction for toxic metals or synthetic organics. Therefore, determining sediment physical characteristics and measuring the extent of contamination within each particle size range are significant first steps in determining treatment options for a contaminated sediment. As described in the WTC/RRM workplan, a series of physical and chemical treatability tests were performed on the Cornwall sediment. The testing included:

- Bulk sediment physical testing for

    1) Water content;
    2) Wet density & dry density;
    3) Particle size analysis;
    4) Total suspended solids (TSS), volatile suspended solids (VSS), inorganic content & Loss-on-ignition (LOI) analysis.

- Bulk sediment, particle size fraction, and density fraction chemical analysis including:

    1) Priority pollutant metals including iron, copper, zinc, manganese, nickel, mercury, lead, cadmium, and chromium;
    2) Total oil & grease analysis;
    3) Polycyclic aromatic hydrocarbon (PAH) analysis.

- Settleability testing at three different water contents

2.0 BULK SEDIMENT PHYSICAL TESTING

2.1 Method

The Cornwall Integrated sediment sample was received in a plastic bag, containing standing water within a plastic cooler. For the bulk sediment testing, a 5 L grab sample of the raw sediment slurry was collected and placed in a 20 L plastic container, and then homogenized by stirring.

Small subsamples of known volume were then collected from the grab sample, weighed and then dried overnight in a muffle oven set at 105°C. Moisture content, total suspended solids, and dry density were subsequently determined from the weight and volume of the dried sample (Table 1.). VSS and LOI analyses were used to approximate the organic content of the sediment. Oven dried samples of sediment were weighed, heated to 552°C for approximately 8 hours, and then removed and cooled in a desiccator before re-weighing.

A further two-litre subsample of raw sediment was subsequently passed through a series of pre-weighed sieves (total of 7) with mesh sizes ranging from .038 mm to 1.0 mm (38 µm - 1000 µm). The wet solid material retained on the sieve was weighed and then oven dried overnight at 105°C. The weight of the dried material on each sieve was then used to calculate the weight distribution of particle sizes in the sediment (Figure 1).

2.2 Results

As shown in Table 1., the slurry like sediment contained a relatively high moisture content (80%), with particulates of relatively low bulk weight (wet density < 1.0 g/ml). The raw sediment was very dark (dark grey/black slurry like), fine textured, and appeared to contain very little coarse matter, with total suspended solids averaging approximately 200 g/L. A VSS and LOI analysis of the bulk sediment revealed that a significant portion of the sediment solids (9.8%) was organic material. It was reasoned at the time that this organic material may be natural organic matter (eg. humic material) rather than contamination. The presence of naturally occurring humic material, derived from the decay of plant and animal life, is typical of fine textured sediments. The results of a subsequent chemical analysis of the bulk sediment for organics contamination is discussed in Section 3.2.

The results of the wet screening process shown in Figure 1. indicated that the slurry was composed primarily of very fine material with over 70% of the particulates less than 38 µm in size. An additional 15% of the sediment could be found in the 38 - 150 µm mesh size range, with the remaining bulk of the sediment particulates greater than 150 µm in size. Given that the bulk of the raw sediment was composed of these fine particulates (less than 38 µm), it was reasoned that treatment of the Cornwall sediment would probably not require any complex screening or crushing as a pre-treatment.

3.0 BULK SEDIMENT, PARTICLE SIZE FRACTION, AND DENSITY FRACTION CHEMICAL TESTING

3.1 Method

A subsample of raw sediment was collected and analyzed in WTC laboratories for priority metals (Cd,Cr,Cu,Fe,Mn,Ni,Pb,Hg & Zn) by acid digestion (HCL:HNO_3:HF) and ICP determination, for oil and grease and for polycyclic aromatic hydrocarbons (PAH's) by soxlet extraction with Acetone/Hexane followed by GC/MS analysis.

Parameter	Raw Sediment
Moisture Content, % w/w	80
Bulk (wet) density, g/mL	0.997
Dry (Particle) density, g/mL	0.979
TSS, mg/L	199,586
VSS & (LOI), mg/L & (% w/w)	19,500 (9.8)
Inorganic content, mg/L & (% w/w)	180,000 (90)

Table 1. Physical properties of Cornwall sediment.

All analytical results are presented on a dry weight basis. Laboratory results reported on a wet weight (ie. total sample) basis were converted to a dry weight basis using the following relationship:

Concentration of metal = Concentration of metal (mg/L) wet weight basis x 100/% w/w solids)
(µg/g dry weight)

After an evaluation of the particle size distribution (see Section 2.2) of the sediment, it was reasoned that chemical analysis of the solids **not retained** on the 38 µm mesh size sieve (ie. < 38 µm), a composite of solids retained on mesh sizes ranging from 38 - 75 µm, and a composite of solids retained on mesh sizes ranging from 75-1000 µm, would provide a reasonable determination of contaminant levels over the range of particle sizes in the sediment. Therefore, a second two-litre subsample of raw sediment was passed through the same series of seven sieves. The retained solids in the mesh size ranges described above were also analyzed for priority metals (Cd,Cr,Cu,Fe,Mn,Ni,Pb,Hg & Zn), oil and grease and for polycyclic aromatic hydrocarbons (PAH's).

Subsequent to the particle size chemical testing, a 1 L subsample of sediment was collected in a "wide-mouth" 600 ml glass beaker. The beaker contents were initially stirred and then allowed to settle for a period of approximately 4 hours. The supernatant contents of the beaker were subsequently decanted to drain. The settled volume was approximately 450 ml. Using a long handled stainless steel spoon, three layers (300-450 ml, 150-300 ml, & 0-150 ml), presumed to be of increasing density, of the settled sediment were collected and placed in 150 ml amber glass jars. Small aliquots of each jar were collected and measured for total solids content and wet & dry density. The remainder of the samples were submitted to WTC laboratories for chemical analysis for priority metals, total oil & grease, and PAH content.

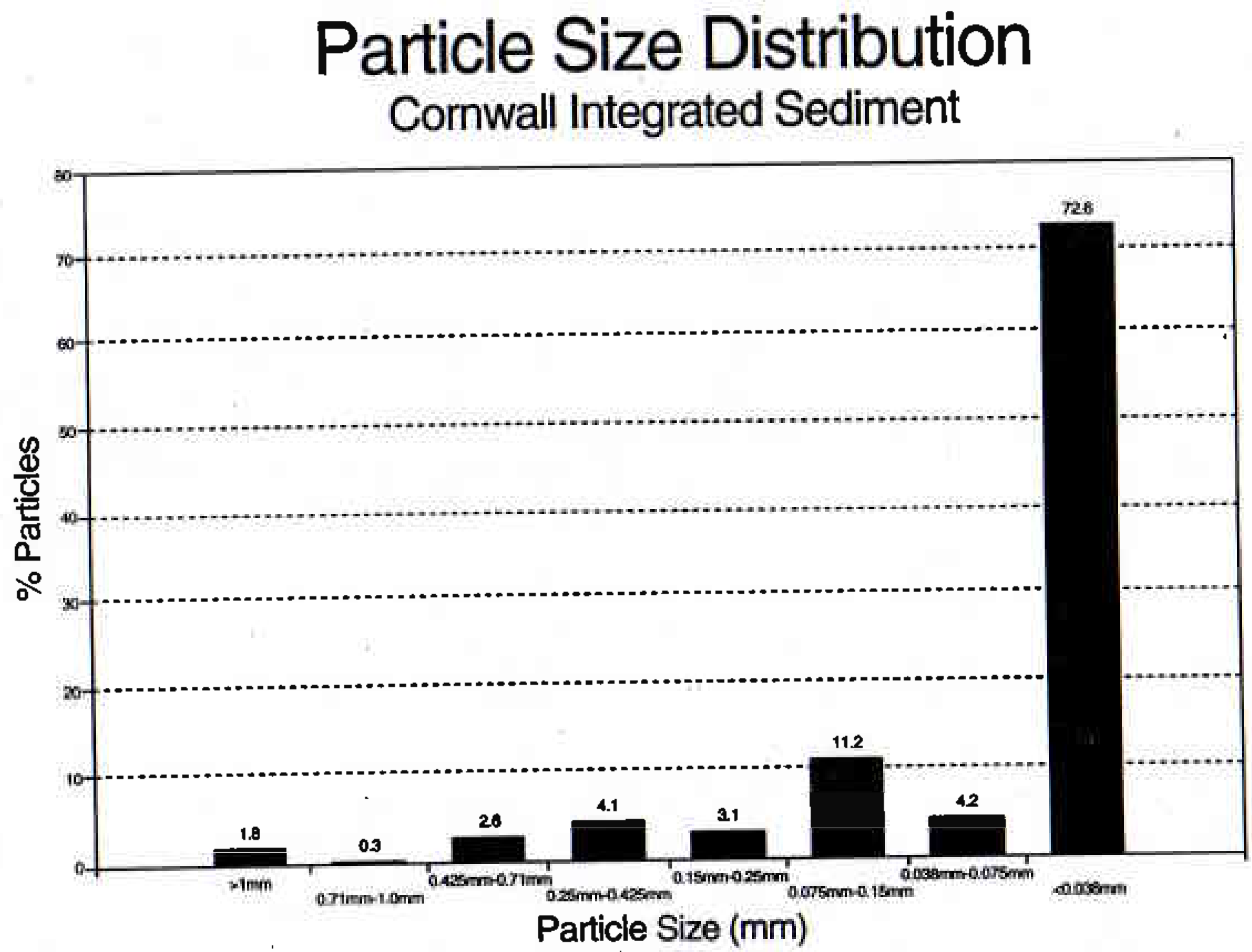


Figure 1. **Distribution of particle size fractions in Cornwall sediment.**

all values in µg/g dry weight, unless otherwise indicated

SAMPLE	Oil & Grease,%	Cu	Ni	Pb	Zn	Cr	Fe	Mn	Cd	Hg
Raw Sediment	0.67	62	29	69	1030	51	26000	328	< 1.0	0.22
OMOEE Sediment Quality Guidelines Lowest Effect Level Severe Effect Level	0.15* -	16 110	16 75	31 250	120 820	26 110	20000 40000	460 1100	0.6 10	0.2 2

* From Open Water Disposal Guidelines

Table 2. Metal contaminant levels in Cornwall sediment

Parameter	Concentration (µg/g dry weight)	Provincial Sediment Quality Guidelines (µg/g dry weight)	
	Raw Sediment	Lowest Effect Level	Severe Effect Level*
Anthracene	< 0.3	0.22	36.3
Benz[a]anthracene	< 0.5	0.32	145
Benzo[k]fluoranthene	0.78	0.24	131
Benzo[a]pyrene	0.40	0.37	141
Benzo[g,h,i]perylene	< 0.3	0.17	31.4
Chrysene	< 0.3	0.34	45.1
Dibenzo[a,h]anthracene	0.12	0.06	12.7
Fluoranthene	0.82	0.75	100
Fluorene	< 0.4	0.19	15.7
Indeno[1,2,3-cd]pyrene	< 0.3	0.20	31.4
Phenanthrene	< 0.5	0.56	93.1
Pyrene	0.73	0.49	83.3
PAH (total)	5.4	4	980

Table 3. PAH contaminant levels in Cornwall sediment

* SEL as µg/g organic compound = organic carbon(9.8%) X SEL as µg/g organic carbon.

3.2 Results

Table 2 presents the concentrations of metals of concern and oil & grease in the raw sediment. In general, the concentrations of all but one of the metals were on average nearly double the provincial "Lowest Effect Level (LEL)" (ie. level of sediment contamination that can be tolerated by benthic organisms). Although, these concentrations would be considered relatively low for contaminated soil or sediment. Typical background concentrations of priority heavy metals in clean soil are: Cr(total)= 20 µg/g dry weight, Cu= 30 µg/g, Pb = 25 µg/g, Ni = 20 µg/g, Cd = 0.5 µg/g. As the integrated sample represents sediment collected by river bottom dredging over a wide area, beyond the outfall of the Courtalds plant, the dilution effects caused by mixing with less contaminated sediment would explain the observed concentrations. In the case of zinc, however, the metal contaminant level was considerably higher than the "Severe Effect Level (SEL)" (ie. the sediment concentration of an element or compound that would be detrimental to the majority of benthic species).

The analysis for organic contaminants revealed very little organic contamination, as evidenced by the relatively low total oil & grease (Table 2) and PAH levels (Table 3). With the exception of a few exceedences for certain compounds, the total PAH (ie. the sum total concentrations of the 12 compounds of concern) content of the sediment was approximately equivalent to Ontario's LEL, and was well below the SEL guideline.

As shown in Table 4 , chemical analysis of the three particle size fractions of the sediment indicated that the majority of heavy metals present were largely associated with the coarser sediment fractions (75-1000 µm), while the much finer fractions (less than 38 µm) contained metal levels which were on average 72% less than those of the coarser fractions. This result is surprising given that fine textured materials in sediments such as silt and clay are known to have a much greater affinity for all classes of contaminants. However, particulate organic matter is also known to have a high affinity for contaminants as well and in this sediment the particulate organic matter represents a significant fraction of the total. Generally, heavy metal concentrations in each of the sediment size fractions were on average three times larger than Ontario's LEL's, with some metal (eg. Pb, Cu, & Cr) concentrations approaching the SEL's.

The individual sediment size fractions also contained relatively little organics contamination, as evidenced by the PAH concentrations shown in Table 5. The majority of compounds were measured at the analytical detection limit, although a number of LEL exceedences were observed in the 75-1000 µm particle size fraction range. The larger organic contaminant levels in the coarse sediment fraction range is reflected in the total oil & grease concentration (0.34%) reported in Table 4. Given the minimal presence of organic contaminants, therefore, the organic content of the sediment (9.8%) as measured by the LOI test in Section 2.2 was probably natural humic or other vegetative matter. As natural organic matter (typically less than 200 µm particle size) is known to contain many organic functional groups which have a strong affinity for metals and non-polar organics, the reported results in Table 4 would seem to indicate that the majority of metal contamination resided in the natural humic component of the sediment.

The results of physical and chemical analysis of the density fraction isolates (Tables 6 & 7) indicated that a density separation could be used to isolate a significant quantity of the metal contamination in the sediment. The lighter fraction (probably organic matter) would contain much higher concentrations of contaminants. All isolates contained significant quantities of all the priority metals, well above Ontario's SEL's (Table 7 & Figure 2).

all values are µg/g dry weight basis, unless otherwise indicated

Size Fraction	Oil & Grease (%)	Cu	Ni	Pb	Zn	Cr	Fe	Mn	Cd	Hg
75 - 1000 µm	.34	89	40	241	448	69	11,956	200	6.3	0.76
38-75 µm	.04	72	42	243	350	105	13,600	231	6.9	0.46
< 38 µm	.07	18	12	65	172	14	4543	61	1.6	0.22
OMOEE Sediment Quality Guidelines Lowest Effect Level	0.15*	16	16	31	120	26	20000	460	0.6	0.2
Severe Effect Level	-	110	75	250	820	110	40000	1100	10	2

* From open water Disposal Guidelines

Table 4. Metals contaminant levels in specific size fractions of the Cornwall sediment

Parameter	Concentration of particle size fraction (µg/g dry weight)			Provincial Sediment Quality Guidelines (µg/g dry weight)	
	< 38 µm	38-75 µm	75-1000 µm	Lowest Effect Level	Severe Effect Level*
Anthracene	< 0.7	< 0.7	0.8	0.22	36.3
Benz[a]anthracene	< 0.9	< 0.9	2.8	0.32	145
Benz[k]fluoranthene*	1.2	1.4	5.1	0.24	131
Benzo[a]pyrene	< 0.6	0.63	2.2	0.37	141
Benzo[g,h,i]perylene	< 0.7	< 0.7	1.5	0.17	31.4
Chrysene	0.55	0.66	2.7	0.34	45.1
Dibenzo[a,h]anthracene	< 0.6	< 0.6	< 0.6	0.06	12.7
Fluoranthene	1.0	1.3	5.7	0.75	100
Fluorene	< 0.8	< 0.8	< 0.8	0.19	15.7
Indeno[1,2,3-cd]pyrene	< 0.7	< 0.7	1.4	0.20	31.4
Phenanthrene	< 0.9	< 0.9	3.4	0.56	93.1
Pyrene	< 0.9	1.1	4.9	0.49	83.3
PAH (total)	9.5	10	32	4	980

Table 5. PAH contaminant levels in specific size fractions of Cornwall sediment

* SEL as µg/g organic compound = organic carbon (9.8%) X SEL as µg/g organic carbon.

Sample	TSS (g/L)	Solids Content (%)	Bulk Density (g/ml)	Dry Density (g/ml)
Density Fraction #1	182	18	0.94	1.09
Density Fraction #2	240	24	1.05	1.20
Density Fraction #3	333	33	1.10	1.60

Table 6. Physical properties of Cornwall sediment density fraction isolates

all values µg/g dry weight basis

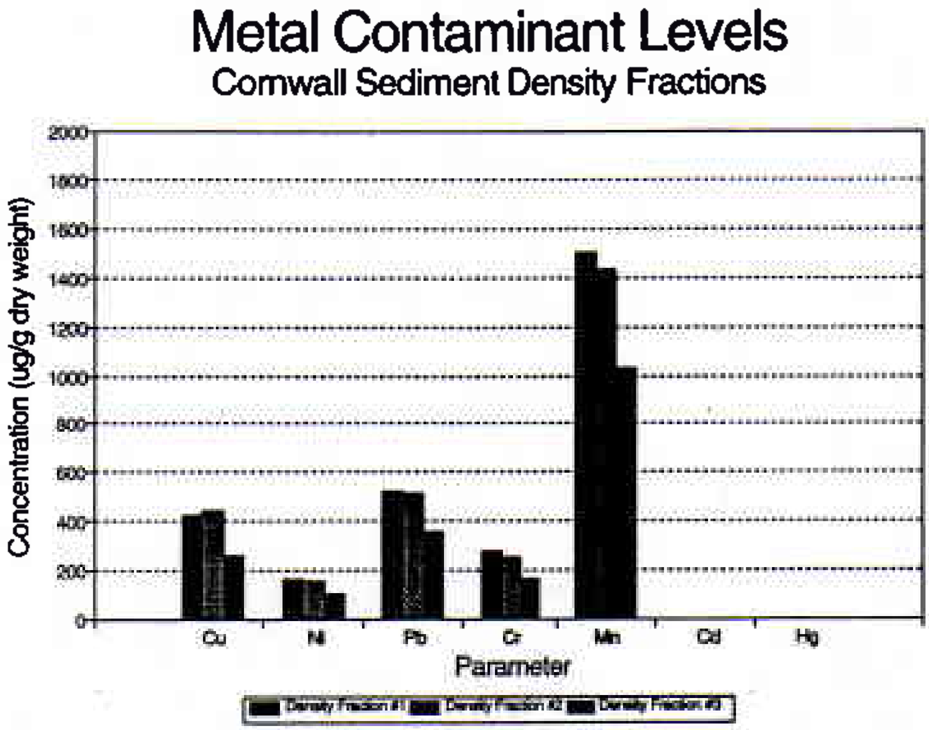
Sample	Cu	Ni	Pb	Zn	Cr	Fe	Mn	Cd	Hg
Density Fraction #1	435	167	530	7355	277	132,000	1505	0.90	1.0
Density Fraction #2	450	160	521	10,333	254	140,000	1437	2.8	0.64
Density Fraction #3	267	110	361	4212	171	99,393	1036	1.0	< 0.0075
OMOEE Sediment Quality Guidelines									
Lowest Effect Level	6	16	31	120	26	20000	460	0.6	0.2
Severe Effect Level	110	75	250	820	110	40000	1100	10	2

Table 7. Metals contaminant levels in Cornwall sediment density fraction isolates

Parameter	Concentration (µg/g dry weight)			Provincial Sediment Quality Guidelines (µg/g dry weight)	
	Density Fraction #1	Density Fraction #2	Density Fraction #3	Lowest Effect Level	Severe Effect Level*
Anthracene	0.14	0.16	0.12	0.22	36.3
Benz[a]anthracene	0.36	0.31	0.25	0.32	145
Benz[k]fluoranthene	0.67	0.62	0.60	0.24	131
Benzo[a]pyrene	0.35	0.31	0.22	0.37	141
Benzo[g,h,i]perylene	0.45	0.36	0.28	0.17	31.4
Chrysene	0.94	0.89	0.65	0.34	45.1
Dibenzo[a,h]anthracene	0.37	0.30	0.22	0.06	12.7
Fluoranthene	0.65	0.58	0.48	0.75	100
Fluorene	< 0.2	< 0.2	< 0.2	0.19	15.7
Indeno[1,2,3-cd]pyrene	0.23	0.18	0.16	0.20	31.4
Phenanthrene	0.44	0.45	0.33	0.56	93.1
Pyrene	0.56	0.54	0.40	0.49	83.3
PAH (total)	5.4	4.9	3.8	4	980

Table 8. PAH contaminant levels in Cornwall sediment density fraction isolates

* SEL as µg/g organic compound = organic carbon (9.8%) X SEL as µg/g organic carbon



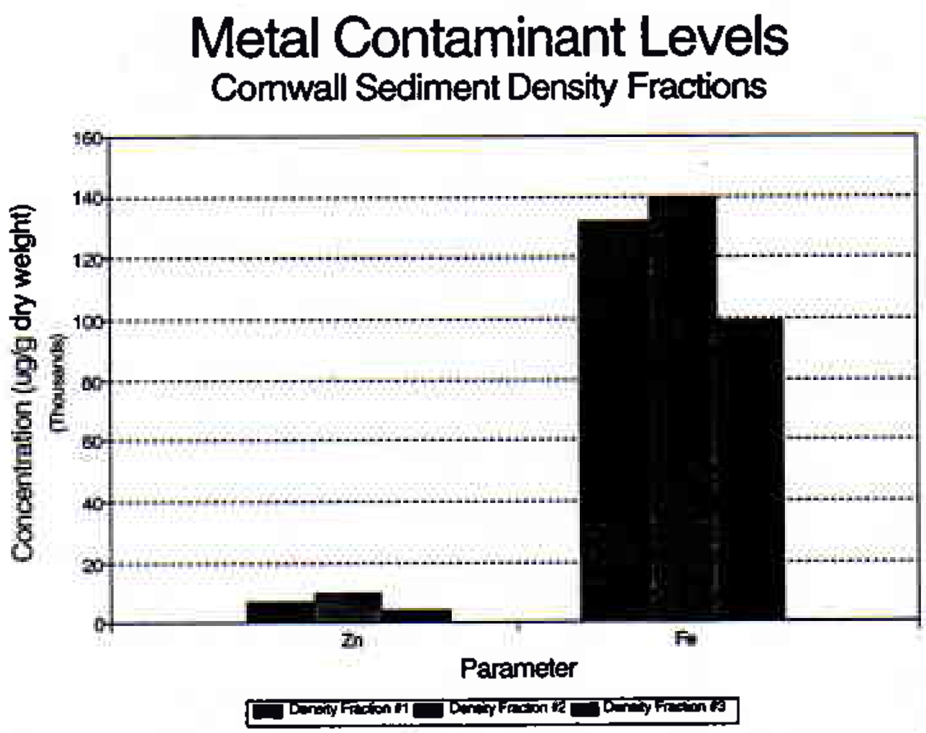


Figure 2. **Distribution of heavy metals in Cornwall sediment density fraction isolates**

In particular, the lightest isolates with dry densities of 1.09 and 1.2 g/ml contained significant levels of iron (13 & 14%, respectively) and zinc (7355 & 10,333 µg/g, respectively). Given their low bulk densities, these fractions were presumed to contain the majority of humic material present within the sediment. Chemical analysis of the density isolates for PAH's (Table 8) revealed minimal evidence of any synthetic organic contamination of the Cornwall sediment. The total PAH levels for each of the isolates were at or below Ontario LEL's.

4.0 SEDIMENTATION TESTING

4.1 Purpose

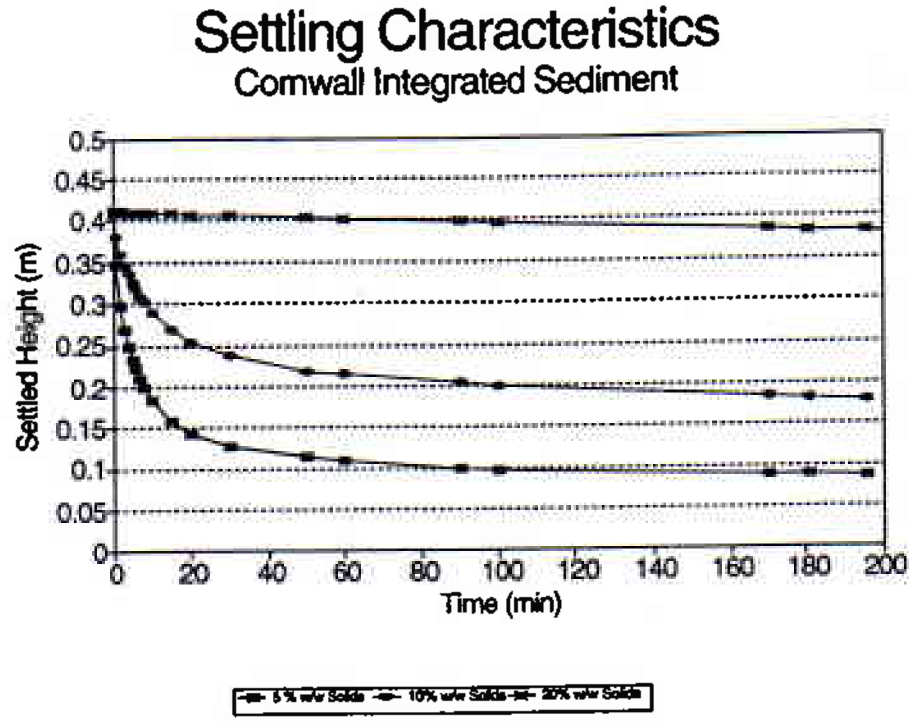
Settling tests were performed to characterize the settling properties of the sediment at various solids concentrations. The results of this type of test could be used as preliminary engineering design criteria for the sizing of a settling/thickening facility used as a pre-treatment step to dewater the sediment. Generally, solids concentration and zone settling (ie. region in a sedimentation basin where contacting particles settle as a zone, or "blanket", maintaining the same relative position with respect to each other, thereby forming a distinguishable sludge-liquid interface) velocity are considered the most significant of sludge characteristics in establishing clarifier design criteria.

4.2 Method

After the determination of moisture content in the raw sediment sample, sediment suspensions of varying solids concentrations (approximately 5%, 10%, & 20% w/w) were prepared in 2 L graduated cylinders. The chosen concentrations were considered to represent a typical range of untreated sediment suspensions entering a sediment dewatering facility. The 5% and 10% suspensions were prepared by diluting a subsample of the raw sediment with the appropriate quantity addition of tap water. The 20% sample consisted essentially of raw undiluted sediment. Initially, all suspensions were manually mixed to re-suspend all particulates and create a uniform concentration throughout the entire volume of the graduated cylinder. The sedimentation test was then initiated. Over the duration of the settling test the volume of sediment-liquid interface in each of the graduated cylinders was read, initially at 1 minute intervals but subsequently at 5, 10, and finally at 30 minute intervals. For the 5% and 10% suspensions, the total time for the settling test was approximately 3 hours. For the 20% suspension, however, the test period was extended to 2 days because of minimal settling over the course of the three hour test. After the sedimentation tests, the supernatant from each of the 2L graduated cylinders were collected and analyzed separately for priority metals.

4.3 Results

Settling data at the three solids concentrations were plotted against time (Figure 3). The settling curves shown in Figure 3(a) correspond to the 3 hour settling test, while the curve shown in Figure 3(b) corresponds to the settled heights for the 20% suspension expanded to 2 days. Based on the final settled heights recorded at the end of the sedimentation testing, the decanted supernatants represented volume reductions of 80%, 57% and 35% for each of the 5%, 10%, and 20% suspensions, respectively. The settling curves for the 5% and 10% suspensions are characteristic of sedimentation systems containing suspensions of relatively high concentration, whereby discrete and flocculant settling occur initially, followed by zone and compression settling. The initial settling velocity for the 5 % suspension, measured as the slope of the tangent to the straight line portion of the settling curve was 1.4 m/hr, compared to 0.8 m/hr for the 10% suspension. These settling velocities would be considered relatively low for typical sediments at these concentrations. The raw sediment (20% w/w), however, exhibited minimal settling over the course of the 3 hour test.



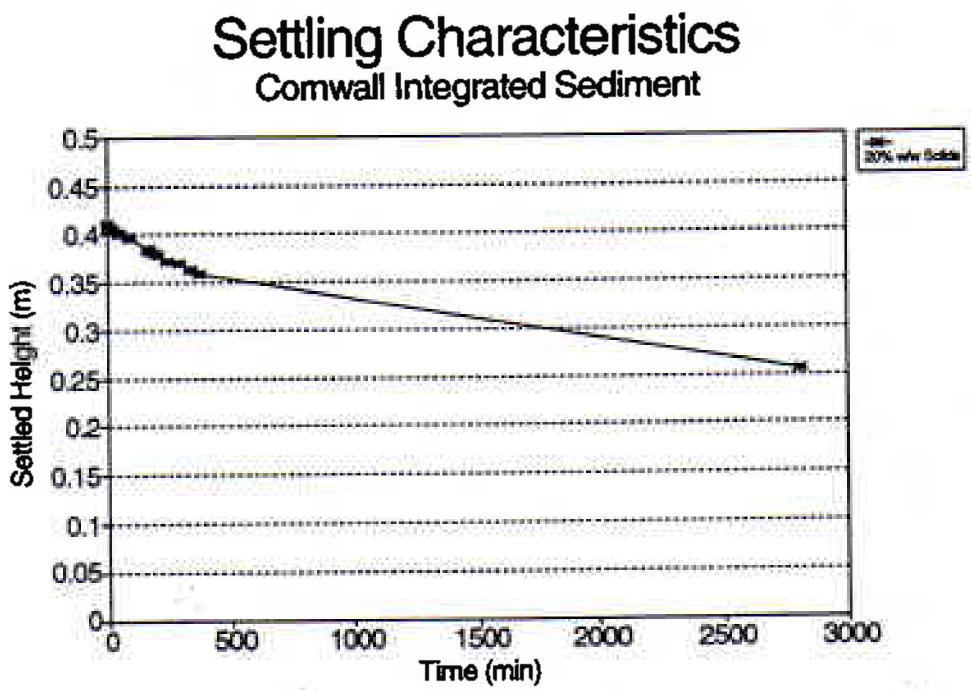


Figure 3. **(a) Relationship between solids concentration and sediment settleability**
(b) Raw sediment settleability over a two-day period.

Sample	TSS (mg/L)	Bulk Density (g/ml)	Dry Density (g/ml)
Raw Sediment (20% w/w solids)	223,460	0.997	0.979
Supernatant (after 48 hrs settling)	60	-	-
Mixture (10% w/w solids)	105,592	1.07	1.00
Supernatant (after 3.25 hrs settling)	650	-	-
Mixture (5% w/w solids)	49,972	1.02	0.993
Supernatant (after 3.25 hrs settling)	466	-	-

Table 9. Physical properties of sediment suspensions and decanted supernatants after sedimentation testing

Unless otherwise indicated, all values in mg/L

Sample	Cu	Ni	Pb	Zn	Cr	Fe	Cd	Mn
Supernatant (from 20% w/w solids) (after 48 hrs settling)	0.03	0.04	< 0.04	0.23	< 0.02	6.8	< 0.02	0.52
Supernatant (from 10% w/w solids) (after 3.25 hrs settling)	0.04	0.03	0.05	0.77	0.09	17	< 0.01	0.38
Supernatant (from 5% w/w solids) (after 2.25 hrs settling)	0.07	0.06	0.05	1.3	0.15	19	< 0.01	0.47
CCME** Remediation Guidelines for freshwater aquatic life	.002	.025	.001	.03	.002	.30	.0002	-

Table 10. **Metal contaminant levels in sediment suspensions and decanted supernatants after sedimentation testing**

** Interim Canadian Environmental Quality Criteria for Contaminated Sites, Canadian Council of Ministers of the Environment, Sept. 1991

Presumably, this was due to the low particle density which would have been inhibitory to floc formation. The initial settling velocity determined from the settling curve of Figure 3 (b) was .008 m/hr, or 100-fold less than the settling velocity for the 10 % suspension. Clarifier/thickener design criteria would be based on the relationship between settling velocity and suspended solids level. However, the determination of these criteria was considered beyond the scope of this study.

Tables 9 & 10 present the concentrations of selected parameters in the supernatant decanted from each of the suspensions after the settling test. Greater than 99% of the settleable matter was removed from the suspensions as a result of 3 hours and 48 hours of sedimentation. In addition, as shown in Table 10 heavy metal removal was very well correlated with suspended solids removal over the range of concentrations tested. Although significant heavy metal reductions were achieved by sedimentation, each of the supernatants would probably require further polishing to further reduce heavy metal content to below CCME guidelines.

5.0 SUMMARY/CONCLUSIONS

- The Cornwall integrated sediment sample was a dark brown/fine textured sediment containing 80% moisture and approximately 200 g/L total solids.

- Particle density testing indicated that the sediment consisted of very light materials, with both wet and dry densities less than unity.

- Particle size testing indicated that more than 70% of the particulates were less then 38 µm.

- A Loss-on-Ignition test indicated the presence of 9.8 % organics, presumed to be natural humic matter or other vegetation.

- Bulk sediment chemical analysis indicated that the sample was contaminated primarily with heavy metals (Pb,Cu,Cr,Fe,Mn,& Ni) at dry weight concentrations which were higher than LEL levels, and greater than the SEL for zinc (1030 µg/g dry weight). Chemical analysis of the bulk sediment for organics revealed minimal levels of PAH contamination (PAH_{total}=5.4 µg/g dry weight)

- Chemical analysis of the particle size fractions revealed that on average, heavy metal concentrations in the 75-1000 µm particle size range were 72% greater than those for particulates less than 38 µm. Total PAH contamination (10 µg/g) was highest in the 75-1000 µm particle size range, although this contaminant level was considered to be low. Particle size separation could be used to isolate a significant portion of the metal contamination, with the contaminants reporting to the larger fractions.

- Chemical analysis of the density fractions revealed that density separation could be used to isolate a significant portion of the contamination within the sediment, as evidenced by heavy metal concentrations which were well above Ontario's SEL's. Contaminants would be concentrated in the lighter fraction. Although, there was minimal PAH contamination measured in the density fraction isolates.

- Sedimentation testing with sediment suspensions of 5%, 10%, and 20% w/w solids determined initial settling velocities of 1.4, 0.8, and 0.008 m/hr, respectively. These velocities are considered low for sediment at these solids concentrations.

- Sedimentation testing revealed that the settled sediment resisted dewatering to a level greater than about 20% solids. This is likely due to the high amount of light particulate organic matter in the sediment.

- The sedimentation test also demonstrated that suspended solids removal was very well correlated with heavy metals removal over the range of sediment concentrations tested, and that significant removals of suspended solids and heavy metals were achievable.

6.0 RECOMMENDATIONS

Given the relatively large proportion of less highly contaminated fine particulates in the Cornwall sediment, there is the potential for a significant volume reduction of contaminated sediment requiring treatment. Hydraulic classification or hydrocyclones may be used to separate the more highly contaminated coarse sediment fractions for later treatment. As gravity thickening, and subsequent density fraction chemical analysis did indicate a substantial ferrous and non-ferrous metals content in the density fraction isolates, a number of separation technologies may be suitable for consideration; they are:

-> Froth flotation for separating mineral phases (most suitable for particle sizes ranging from 5 µ to 500 µ)

-> Magnetic separation testing to remove ferrous components, followed by washing to remove any non-magnetic material.

-> Metal leaching of the tailings from flotation, and subsequent recovery technology

Also, given the relatively high moisture content, low density (wet & dry) and slow settling observed for the Cornwall sediment, gravity thickening may not be the appropriate dewatering technology. Alternative technologies which could be investigated are:

-> Belt filter press technology;

-> Chamber filtration technology;

-> Vacuum Rotary filtration;

All of the above technologies are suitable for fine grained sediments. To more fully define appropriate remedial strategies, however, a number of additional tests (eg. magnetic removal, flotation testing, metals leachability) should be performed.

7.0 KEY AREAS FOR PHASE II TESTING

Phase II testing should include:

(a) Froth flotation bench test;

(b) Magnetic separation test;

(c) Metal leaching tests on the tailings from the froth flotation test;

(d) Comparison of froth flotation results with particle size separation results of this study.