VI. BARRIER RESEARCH

A. Background

The problem of PCB contamination at Resolution Island is unique. The scale of contamination, the remoteness of the site, the nature of the bedrock and the topography of the contaminated area illustrate this. The excavation of contaminated soils at the site is being conducted in the same manner as would be done elsewhere in Canada. It is not possible, however, to excavate all the PCB contaminated soil. Some of this soil is trapped in the fractured bedrock or is present on very steep terrain that cannot be accessed for logistical and safety reasons. Currently much of the contaminated surface soil is stabilized by lichens, dwarf plants and by compaction since it has been undisturbed for many years. Excavation of this soil will leave a small amount of material in place which will be much more subject to erosion, particularly by runoff. In order to control the mobilization of this material within the S1/S4 drainage system after excavation is complete, permanent barrier systems have been proposed for the top of the cliff and adjacent to the sea.

PCBs are generally transported on land absorbed to fine particles carried by water runoff. Organic matter in the soil increases this absorptive capability. A small fraction of the PCBs present may be dissolved in the water. The partition coefficient for PCBs between the liquid phase and particulate matter can change if hydrocarbons are also present. The effect of temperature on this is unknown. The general concept for the design of a barrier to prevent migration of the PCBs is therefore one which removes particulate matter and also has a component to remove any soluble fraction.

In a southern location, silt fences or hay bales are used to curtail the movement of fine material being eroded from construction sites. These materials are clearly unsuitable for long-term use in the Canadian Arctic. There are many absorbent materials available for removal of organic material from water. These are used for oil spill containment and four different materials were used in the barriers constructed in 1994 at the site. These barriers have worked well although they are now silting up. However, the efficiency of the different materials for removal of PCBs at low temperatures is unknown.

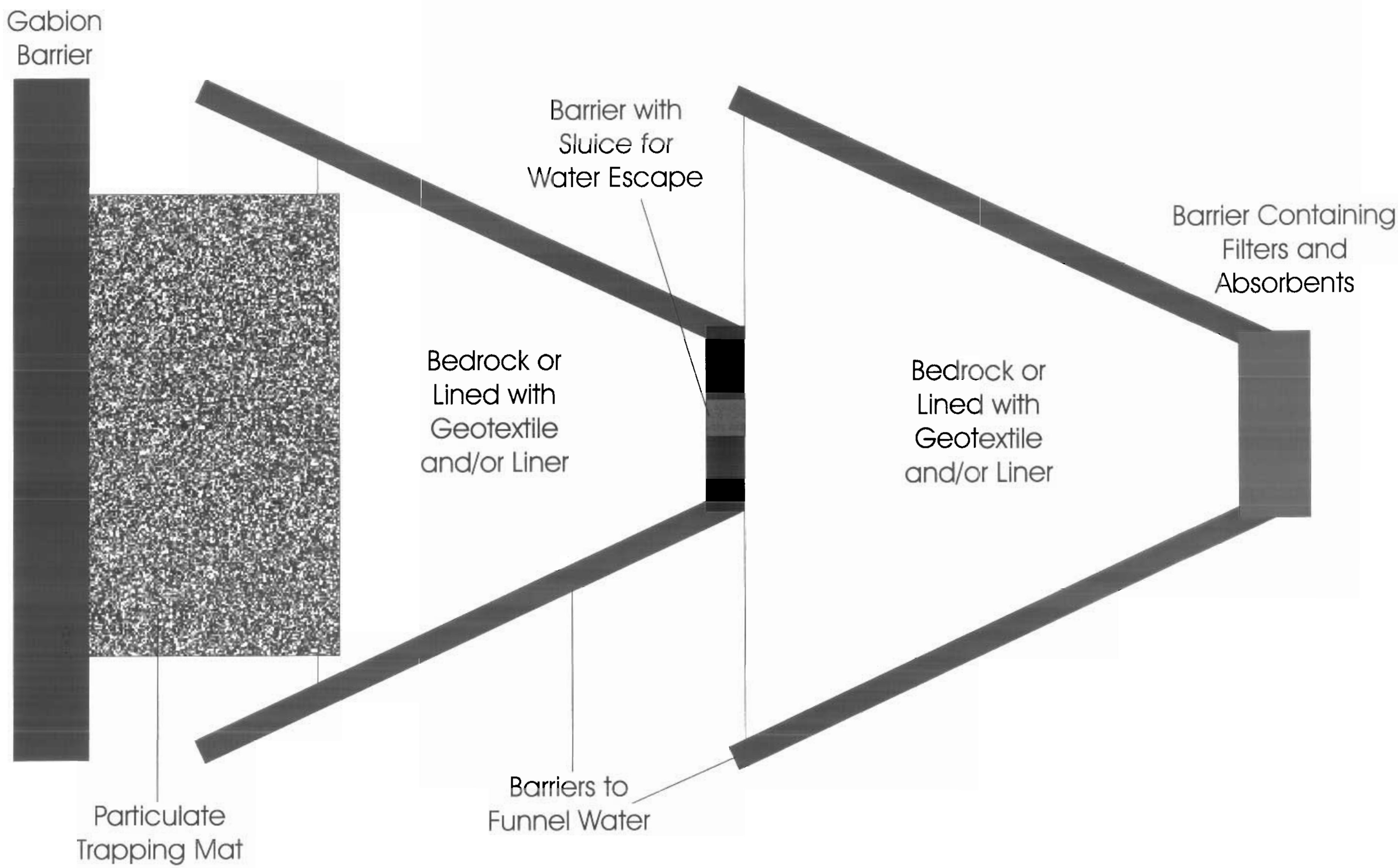
The Analytical Services Unit at Queen's University has been contracted by INAC to design containment barriers for the S1/S4 drainage system at Resolution Island. In the proposed plan, trial systems will be constructed in 2003 and 2004 with final installation in 2005 at the top of the cliff and next to the sea. The plan also includes the concept of periodical removal of silt from the barriers, if necessary. This would be integrated into the site long term monitoring plan. Related research is being conducted by the Australian Antarctic Division of Environment Australia and links between the ASU and researchers in Antarctica have been active for several years. The ASU will work cooperatively with the Australian research group such that the work complements rather than competes with that being conducted in the southern hemisphere.

B. Design Concepts

It is envisaged that each barrier system would consist of three parts. The first part would be a series of small settling ponds or interceptor barriers where silt, carried in the stream that flows down the valley, would be trapped. Finer material would not settle out but would be trapped in a series of filters which would form the second part of the barrier system. The filters would be built into a modular system across the valley floor. Finally oil absorbent or similar material would be used to remove any dissolved PCBs. A funnel and gate system is envisaged and all three parts could be included in each or only the final one. Figure VI-1 illustrates the concept design.

Two systems are being studied for the ponding and trapping of larger particles. Each system would probably entail a series of two or three units which would each trap particulate matter through settling in the ponded area and by the use of a perforated mat designed to capture silt. In the first type (system A), creosoted timbers present at the site would be used to create the funnel. These would be set up in the valley such that a pond would be formed behind them. Stainless steel supports would be constructed and securely fixed to the bedrock. An alternative design (system B) would employ a sheet of liner and/or geomembrane over which the stream would flow and which would be held in place by gabions. The ground beneath the liner could be suitably contoured to form the settling areas.

Figure VI-1: Design Concept for the Permanent Barriers to be Installed at Resolution Island



For system A, research is needed to find a suitable filler and bonding material to seal the timbers to the bedrock such that a durable water tight seal is formed. This may prove difficult to find. For system A, a space would be left between two of the timber barriers forming the funnel and a sluice gate system or modular filter/absorbent barrier installed so that water could be drained away. This would facilitate removal of silt material during annual or periodic maintenance. For system B physical removal of the trapped material might damage the liner. The liners would need to be durable but could be replaced periodically. The liner would be held in place by a double gabion fence. The outer gabion would form the funnel while the inner would rest upon the liner to secure it in place. As with system A, the gate would be either a sluice gate system (first pond) or a modular filter/absorbent barrier (final pond).

A gabion barrier would be placed up stream of these interceptor barriers to trap and contain large boulders and rocks. In addition, material would be placed on the ground behind this gabion fence that would trap particles as they flowed over it. Small trial systems will be constructed in the Kingston area to test both systems. Bonding materials and liner material will be researched and tested if system A is to be used. System B is currently preferred.

The alternative concept of a sand filter system, such as is used in drinking water purification facilities has been rejected, at present, because it is thought that the wet sand would often be frozen and therefore be ineffective. Other researchers found that using a charcoal barrier by placing activated charcoal in an interceptor trench failed because the trench remainder frozen while the hydrocarbon contaminated soil passed over it[1]

C. Soil Characterisation

Two samples of Resolution Island soil have been used to characterize its particle size distribution. These two samples were formed by mixing soil samples that had been

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[1] Snape I, Morris C.E. and Cole C.M. (2001). The use of permeable reactive barriers to control contaminant dispersal during site remediation in Antarctica. Cold Regions Science and Tech. 32, 157-174

previously collected from the site over the past few years. Sample A was of a mixture of samples having PCBs concentrations in the range 0.5 to 2 ppm while Sample B was from samples containing PCBs in the range 50-500 ppm. Approximately 25 litres of each soil type was thoroughly mixed and a sub-sample wet sieved. This involved thoroughly washing the soil through each of five sieves of decreasing mesh size. The final wash material (4 L) that had passed through the finest sieve was allowed to settle overnight and decanted to form a settled and a suspended fraction. The suspended fraction was allowed to evaporate at room temperature to produce a solid sample. The mass fraction of each particle size fraction was recorded and each fraction was analysed for PCB content. Tables VI-1 and VI-2 show the results obtained.

Table VI-1: Particle Size Distribution and PCB Content in Resolution Island Soil Sample A (1.03 ppm)

Size Fraction mm	Dry Weight g	Mass %	PCB Conc. µg/g	Mass of PCBs µg	PCB %
0 – 0.075(s)	4.53	0.7	5.1	23.3	3.5
0 – 0.075	54.1	8.5	6.7	374.4	56.7
0.075 – 0.5	190.6	29.9	0.87; 0.82	165.8	25.2
0.5 – 1.0	84.9	13.3	0.35	29.7	4.5
1.0 – 4.75	156.4	24.4	0.22; 0.22	34.4	5.2
>4.75	147.8	23.2	0.22	32.5	4.9

(s) suspended

Table VI-2: Particle Size Distribution and PCB Content in Resolution Island Soil Sample B (98 ppm)

Size Fraction mm	Dry Weight g	Mass %	PCB Conc. µg/g	Mass of PCBs µg	PCB %
0 – 0.075(s)	0.6	0.6	790	474	5.1
0 – 0.075	6.2	6.3	58	359	3.9
0.075 – 0.5	28.2	28.7	93	2619	28.4
0.5 – 1.0	12.8	13.0	88	1126	12.2
1.0 – 4.75	25.3	25.7	80	2039	22.1
>4.75	25.3	25.7	103	2611	28.3

The results are consistent with the dry sieving results presented in Chapter III Tables III-8d, 8e and 8f. For sample A with a PCB concentration of 1.03 ppm, most of the PCBs are in the 0 - 75 um fraction. For this sample, the mass of soil from particles with diameters less than 0.5 mm was 39 % but this contained over 85 % of the PCBs in the sample. For sample B with a concentration of 98 ppm, for the soil fraction less than 0.5 mm the % mass was 36 % while the % PCBs was 37 ppm. A possible explanation for the difference between the two soil samples could be that the higher PCB levels penetrated further into the rocks or that the more highly contaminated soil came from a different locations with less fine material. Both results show that the challenge in designing an interceptor system will be to isolate the PCBs from the very fine particulate matter.

D. Particulate Filtration and PCB Absorption

The test results given in this section are of a preliminary nature and further testing is on-going to verify the results. The modular barrier is envisaged to comprise up to four separate filters and absorbent materials.

The results given above show that silt fences would not be effective in trapping PCBs at the site since their pore size is of the order of 0.6 mm. The use of finer filters to trap the PCBs is clearly required. However, the finer the filters, the slower the flow of water through them. A likely optimum pore size would be between 25 and 100 um. Some filter materials are designed to trap organic compounds while others may do so by their nature. Some materials such as activated charcoal are frequently used to trap organic compounds. Oil absorbent materials are generally hydrophobic and would not likely be effective in this application since water will not pass through them in sheet material form. There are however commercially available hydrophilic oil absorbing materials.

A number of samples of representative materials have been obtained and tested. Some of these materials are listed in Table VI-3. Other materials are still being investigated or awaiting delivery to the laboratory.

An initial test was designed to screen materials for their relative ability to remove PCBs by filtration. One of the objectives of this test was to select one coarse filter material to remove particles of size > 500 um and a second which would remove particles to a size of about 50 - 100 um.

Table VI-3: Materials Tested for Suitability in Barrier Use

Sample Name	Supplier and Product Number	Description
200W	Terrafix	Woven geotextile - pore size 600 um with good permeability
1200R	Terrafix	Non-woven geotextile - pore size 50-150 – strong thick fabric
800R	Terrafix	Non-woven geotextile - pore size 50-150 – thinner material than 1200R
Terradrain 600	Terrafix	Woven polystyrene geotextile
Terradrain 900	Terrafix	Woven polystyrene geotextile
Mycelx	Hazmasters	Pillow coated with patented yellow material designed to absorb organic materials
Envirosolv	RMS Enviro Solv	Grey non-woven liner for turbo phase separator
White Chemical Sorbent	3M - Product No. P-200	Hydrophilic boom – white material within the boom used in this study
Activated Carbon	A C Carbone Canada	BC-1240
Sorbent	Quatrex - Product No 02USMRO1719	Grey hydrophilic non-woven pads
Chemical Sorbent Pad	3M - Product No. C-PD914DD	Yellow high capacity pads
Chemical Sorbent Roll	3M - Product No. C-FL550DD	Yellow high capacity folded roll
High Performance Filter Bag	3M - Product No. Series 500-527.	15 um air filter material
Ultra Vera	Tenax - Product No UV 1132	uv stable non-woven geotextile – pore size 75 um

In these tests 10 g of the 1.03 ppm standard soil was stirred with 500 mL water for 1 hour. A pressure filtration system (Millipore hazardous waste pressure filter system - Photograph VI-1) which accommodated filters of 15 cm diameter was then used to filter the resulting slurry. The filtration was conducted by placing a pre-weighed test filter or medium above a pre-weighed < 6 um filter paper (Whatman no. 3). The < 6 um filter was used to trap all particles that were not trapped by the test filter or media; the water passing through the filter paper was found to contain a negligible amount of PCBs. The 500 mL slurry was filtered through the unit and then washed through with 300 mL of distilled water. Both the test filter or medium and the filter paper together with associated soil materials were then air dried and weighed. The test filter or medium and the filter paper were then weighed and the mass of soil associated with each determined. The PCBs associated with both fractions was then determined.

Preliminary results show that the 3M Chemical sorbent roll was the most effective filter and that activated carbon was the best material for removing PCBs under the conditions of this experiment. Considering the results obtained so far together with other factors such as strength of material, and suitability for use on a filter frame, the two materials currently selected for the modular barrier as the coarse and fine filters were Terrafix 200W and Terrafix 1200 materials respectively.

A second experiment was designed to determine the relative ability of the materials to absorb PCBs. In this experiment 500 mL water was placed in a 1 litre teflon bottle. A 0.05 mL aliquot of 1000 ppm Aroclor 1260 standard in methanol was added and a portion of filter material or medium was added. The bottle was sealed and rotated at a rate of 30 revolutions/minute for 1 hour. The filter material or medium was removed and water squeezed from it and returned to the bottle. Then 50 mL hexane was added to the bottle which was shaken vigorously for 2 minutes. After settling a sample of the hexane layer was removed and analyzed for PCBs. The results suggest that the 3M White chemical sorbent was the best material for absorbing PCBs. Rotation times are being varied to see how quickly absorption took place.

When the filter/absorption system is placed at the site, water will be continually flowing through it during the summer months. It is therefore important to know if the filters and/or absorbent media will retain trapped PCBs or if the PCBs will slowly be leached from them. An experiment was designed to address this issue.

A system was set up (Photograph VI-2) to pass water over and through either soil, filters or filter medium. A shower head was attached to a laboratory tap and the flow rate through it was determined. The material to be tested was placed on a container and water sprayed on it for a fixed period of time such that 1000 L of water were used. In the first experiment the fraction of the 1.03 ppm PCB soil which had a particle size between 1.0 - 4.74 mm was used. The washing with 1000 L of water decreased the concentration of PCBs in the soil from 0.56 ppm to 0.12 ppm PCBs. It is interesting to note that for the 5.42 g of soil used the concentration loss was 0.44 ppm. In 1000 L of water this corresponds to a concentration in the water of 2.4 parts per trillion. Preliminary results from a similar experiment using 3M chemical sorbent rather than soil indicated that the PCBs were not lost from this material to the 1000 L of water.

It thus appears that appropriate materials are available and that a series of filters and materials can be obtained which, when used in series, will remove the PCBs.

A further question that still needs to be addressed is whether the kinetics of the absorption of PCBs on to the absorption media are such that transference of the PCBs will actually take place in the field unit.

E. Freeze Thaw and UV Light Experiments

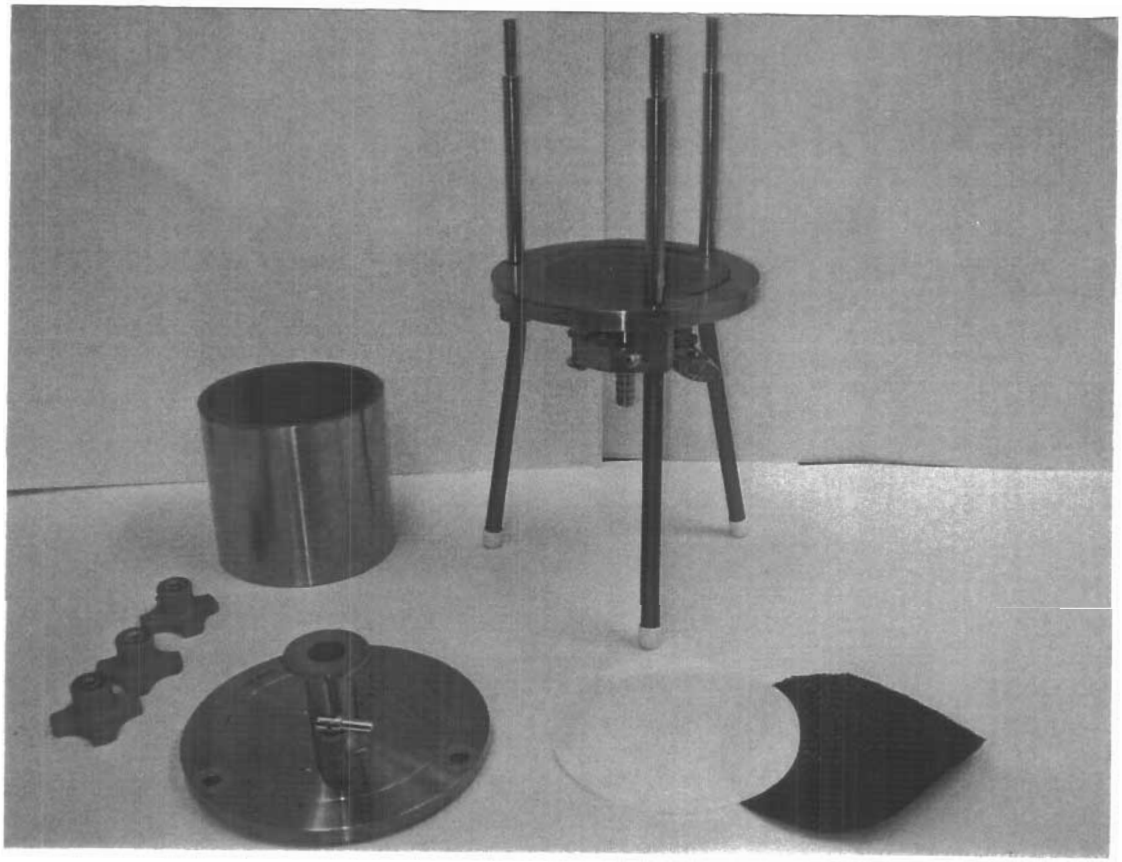
Selected materials are currently undergoing daily freeze thaw cycles. After 100 such cycles the materials will be tested to determine if freezing and thawing have affected their material strength and their ability to trap PCBs. Similarly materials will be placed in sunlight on the roof of the Biosciences Complex at Queen's University for three months and again tested to determine if their properties have changed.

F. Barrier Filter Design

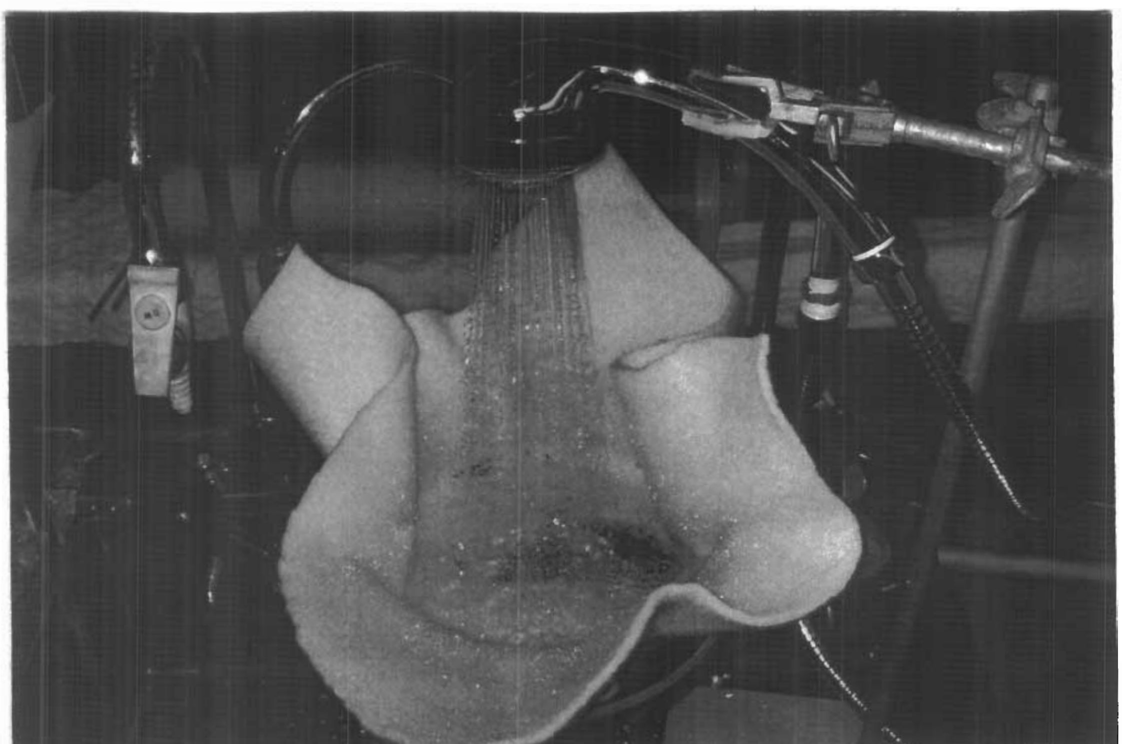
Modular Filtration System:

A sturdy steel framed series of units that would hold several filters or absorption media materials in series is envisaged. The framed units approximately 60 cm tall and 60 cm wide would ultimately be constructed with galvanized steel or stainless steel. Initial prototypes have been constructed of wood (Photographs VI-3 and VI-4) and will soon be tested at the Queen' University Biology Field Station. Units can be bolted together. The filters are envisaged to fit into slots but during the annual or periodic maintenance, the filters will need to be replaced and the modular assembly cleaned. There will need to be a fairly tight seal between the filters and the frame.

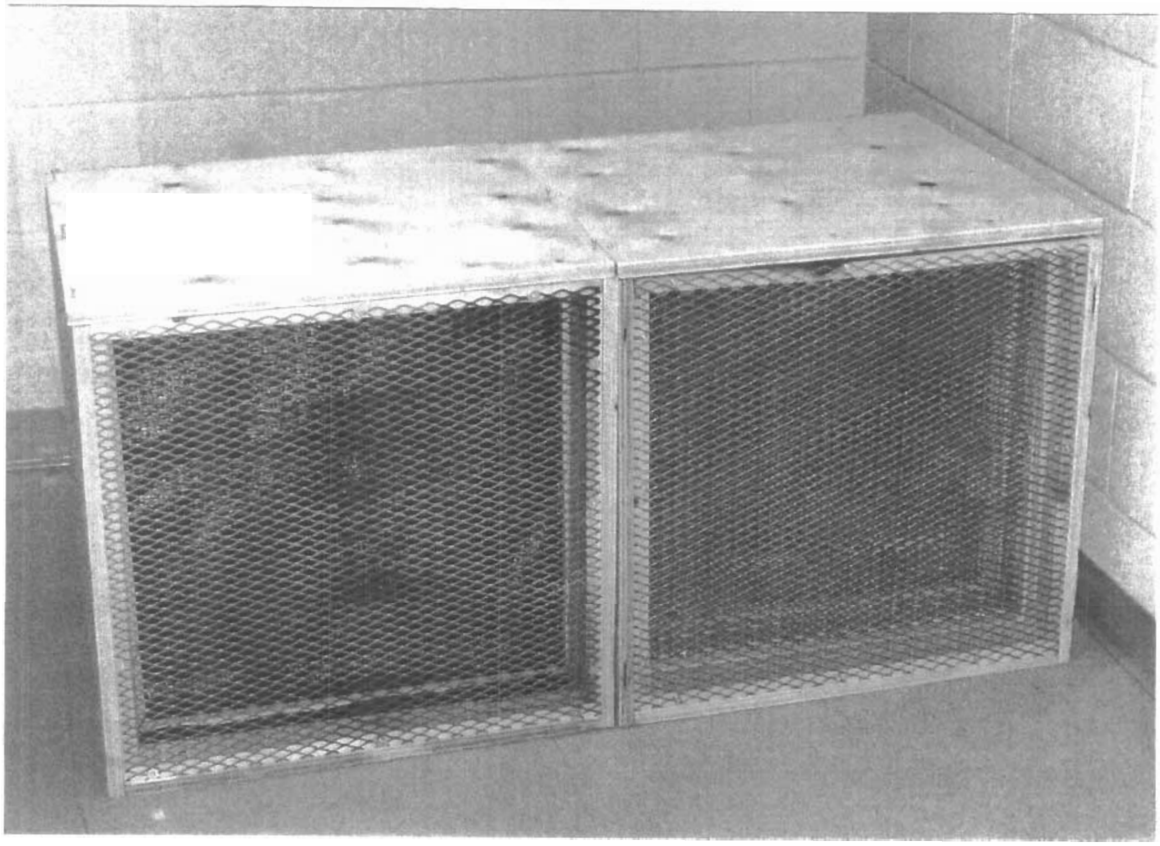
One of the concerns for these barriers is whether they will be able to handle the spring run off. As part of the on site trials in 2003 and 2004, filter materials will be analysed. By taking and analyzing samples for PCBs, after a nine month deployment on site, at different heights on the filters, the height of water passing through the system should be able to be determined. If water passes over the barrier this should also be evident. In addition a clean cell (an area filled with uncontaminated soil) will be placed beyond the barrier and analysis of this will also determine the efficiency of the unit. The barrier units are envisaged to be the gate in a funnel and gate setup. They would be securely bolted to the ground and would need to be level and have watertight surroundings. As discussed in section B above, how this is to be done will require more research and on site development work.



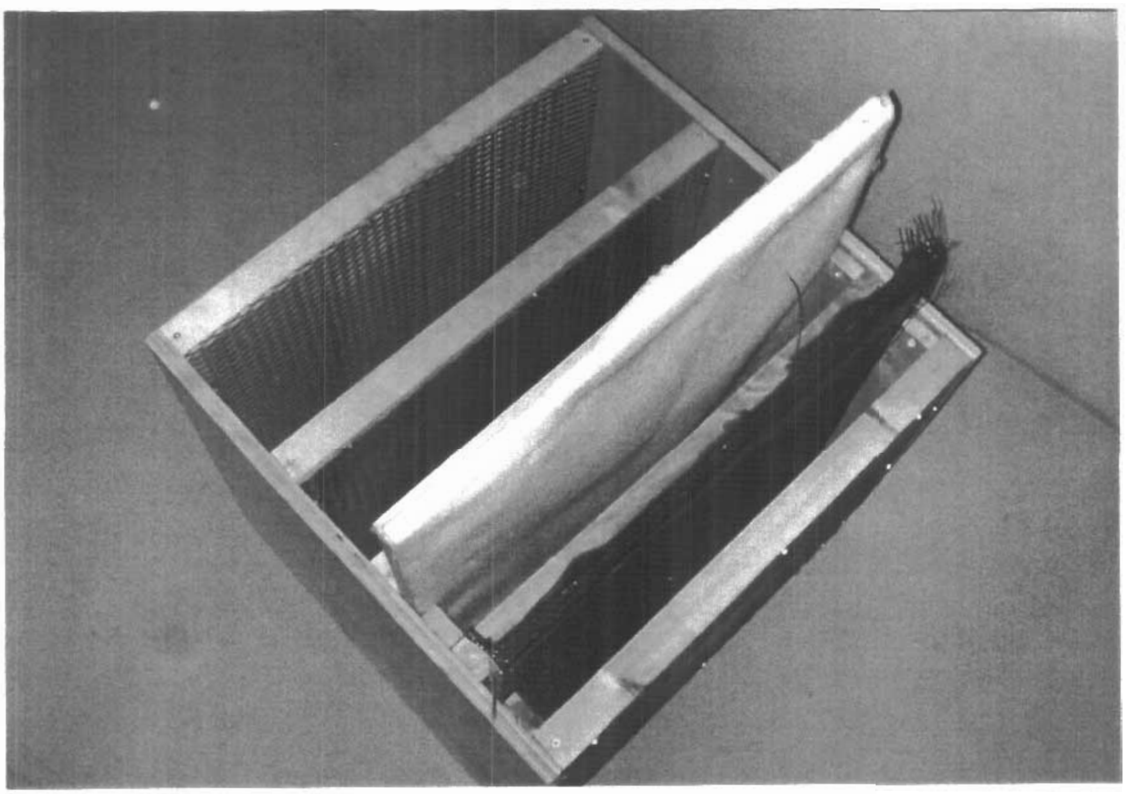
Photograph VI-1: The Equipment used for Filtration Experiments



Photograph VI-2: The Experimental Setup to Examine Leaching of PCBs from PCB Contaminated Soil and Filter Materials



Photograph VI-3: Two Units of the Wooden Prototype Barriers.



Photograph VI-4: One of the Wooden Barrier Units with Filters