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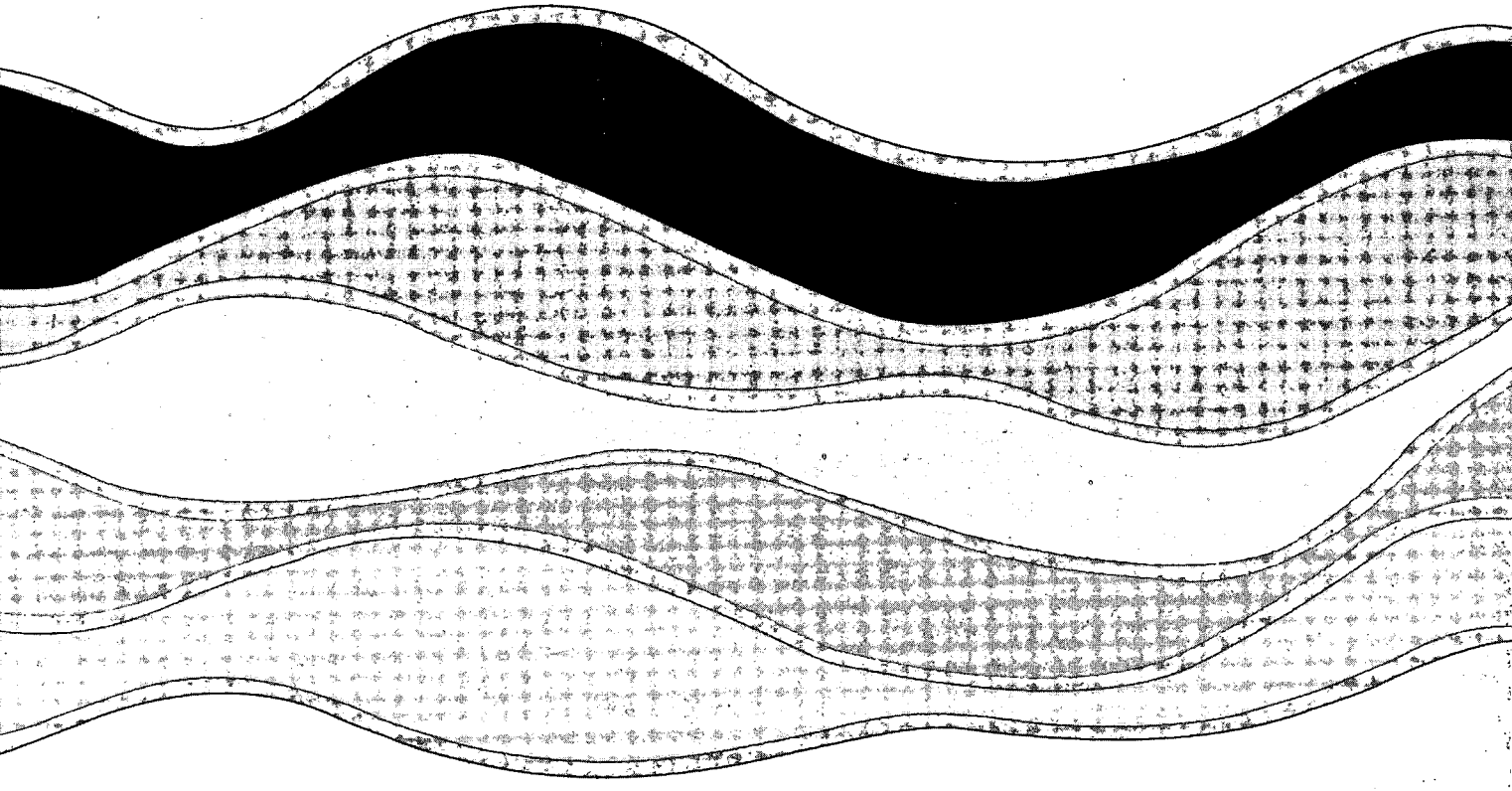

ECOTOXICOLOGICAL STUDY OF WATERS, SEDIMENT AND SUSPENDED SEDIMENTS IN THE ATHABASCA, PEACE AND SLAVE RIVERS

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MANAGEMENT PERSPECTIVE

This exploratory ecotoxicological study of the waters, sediments and suspended sediments in the Athabasca, Peace and Slave Rivers is part of a four year research project under the aegis of the federal Panel for Energy Research and Development. The long term goal of this ecotoxicological-bioassay study is to develop the knowledge base which can assist government and industry in the assessment of potential environmental impact of oil sands operations upon river systems, and to incorporate this knowledge base into a model which can be used to predict environmental sensitivity to various scenarios.

In this study a variety of bioassays were used to evaluate extraction/concentration procedures, to evaluate the sensitivity of the bioassays to pollutants specific to the area and to establish the degree to which waters and sediments have been impacted by the oil sands operations. Also, in order to try to better understand contaminant transport in rivers and streams, studies were undertaken to gain knowledge of the partitioning of contaminants between suspended particulates including bacteria and the dissolved phase.

In this report, information on the ecotoxicological responses of the various bioassays to the waters, sediments suspended sediments and their extracts or concentrates are described and discussed. Also, we report on the size classes of the predominant suspended particulates in these waters and their relative nutrient and microbial loads.

PERSPECTIVE GESTION

Cette étude préliminaire des eaux, des sédiments et des matières en suspension effectuée dans l'Athabasca, la rivière de la Paix et la rivière des Esclaves s'inscrit dans le cadre d'une recherche d'une durée de quatre ans, sous les auspices du Comité fédéral sur la recherche et le développement énergétiques. Il s'agit d'une étude à long terme sur des épreuves biologiques d'écotoxicité dont l'objet est double : élaborer une base de connaissances destinée à aider le gouvernement et l'industrie dans l'évaluation des répercussions de l'exploitation des sables bitumineux sur les réseaux fluviaux; incorporer cette base à un modèle utilisable pour prévoir la sensibilité de l'environnement dans diverses situations.

Au cours de cette étude, des modes d'extraction/concentration ont été évalués grâce à diverses épreuves biologiques, afin d'évaluer la sensibilité de ces épreuves en présence de polluants typiques de la région et de déterminer le niveau de contamination de l'eau et des sédiments dû à l'exploitation des sables bitumineux. En outre, dans le but de mieux comprendre le transport des polluants dans les cours d'eau, des études ont été entreprises sur le partage de ces substances entre les matières particulaires (y compris les bactéries) en suspension et les matières dissoutes.

Le présent texte comporte une discussion ainsi qu'unedescription de la réponse écotoxicologique des diverses épreuves en présence de ces eaux et des matières en suspension et sédiments qui s'y trouvent, ou de leurs extraits et concentrés. On indique aussi la granulométrie des principales matières particulaires en suspension dans ces eaux ainsi que les proportions de nutriments et de microbes que chaque fraction granulométrique renferme.

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ABSTRACT

This report describes an exploratory ecotoxicological study of the waters, sediments and suspended sediments in the Athabasca, Peace and Slave Rivers. During the study a variety of concentration and extraction procedures was evaluated in order to enhance the sensitivity of the various bioassays used to screen for toxicant/genotoxicant activity. As part of this project an intensive study was carried out on the bacterial and nutrient content associated with the various sized suspended particulates fractions. Based on ecotoxicological data collected from sediments, suspended sediments and water samples there appears to be an indication of an effect downstream of the Suncor and Syncrude oil sands plants, even though samples from above the plants indicated the presence of sufficient contaminants to trigger responses in various toxicant screening tests.

RÉSUMÉ

Ce rapport décrit une étude écotoxicologique préliminaire des eaux, des sédiments et des matières en suspension effectuée dans l'Athabaska, la rivière de la Paix et la rivière des Esclaves. Au cours de cette étude, divers modes de concentration et d'extraction ont fait l'objet d'une évaluation afin d'améliorer la sensibilité des diverses épreuves biologiques utilisées pour dépister les agents toxiques et génotoxiques. Dans le cadre de cette étude, des recherches poussées ont été réalisées sur les teneurs en bactéries et en nutriments des diverses fractions granulométriques des matières particulaires en suspension. D'après les données écotoxicologiques recueillies après l'étude d'échantillons de sédiments, de matières en suspension et d'eaux, il semblerait que des répercussions se fassent sentir en aval des usines d'exploitation des sables bitumineux de la Suncor et de la Syncrude. Toutefois, l'analyse d'échantillons prélevés en amont de ces usines a montré la présence d'une quantité de polluants assez importante pour entraîner une réponse positive à diverses épreuves de dépistage d'agents toxiques.

ECOTOXICOLOGICAL STUDY OF WATERS, SEDIMENTS AND SUSPENDED SEDIMENTS IN THE ATHABASCA, PEACE AND SLAVE RIVERS

INTRODUCTION

This ecotoxicological study of waters, sediments and suspended sediments in the Athabasca River and Peace-Athabasca Delta is part of a four year research project under the aegis of the federal Panel for Energy Research and Development.

The following project conception is excerpted from the PERD Project #57205 Task 5.7. "Aquatic impact assessment is a major concern of federal and provincial agencies, especially in areas where economic development occurs in the vicinity of sensitive ecosystems such as commercial or sports fishery, or designated natural preserve. Proper assessment requires the development of protocols which take into account all appropriate parameters, and lead to policy decisions which reflect realistic estimates of risk. While environmental assessment has historically focussed on a managed resource, such as a fishery, there is increasing emphasis being placed upon functional analysis of the entire ecosystem, including chronic effects displayed at lower trophic levels".

The Rivers Research Branch (RRB) of the National Water Research Institute (NWRI) proposed a four-year research project under the auspices of the federal Panel for Energy Research and Development (PERD). The long term goal of this project is to develop the knowledge base which can assist government and industry in the assessment of potential environmental impact of oil sands operations

upon river systems, and to incorporate the knowledge base into a model which can be used to predict environmental sensitivity to various development scenarios.

The contamination of aquatic systems by industrial wastes/hazardous wastes can be estimated by a variety of approaches. Two of the main ones are toxicity-based and chemistry-based. In the toxicity-based approach, toxicity tests directly measure toxic effects which can be either acute or chronic.

Toxicity is a generic measurement of a biological effect (e.g., death, mutagenicity, teratogenicity) associated with exposure to complex mixtures of chemicals in instances when the mechanisms of toxicity are not readily apparent and the specific causes of the effect are often unknown. The toxicity-based approach was developed for measuring and regulating the toxicity of complex effluents discharged to surface waters (US EPA, 1985). It has also been used to identify and characterize toxic wastes under the USA Superfund Acts (Green et al., 1988) to establish the scientific basis for assessing adverse ecological effects at hazardous waste sites (Parkhurst et al. 1989) and to delineate impact zones and prioritize monitoring and remedial activities (Dutka, 1988).

Rationale for using the toxicity-based approach to evaluate the impact of oil sands operations are:

(a) Water, sediment, air and soil quality criteria (if they exist) do not account for additive, synergistic or antagonistic interactions among toxic chemicals in a complex mixture;

(b) Toxicity tests measure the aggregate toxicity effect of all constituents in a complex mixture, including additive, synergistic and antagonistic effects;

(c) Analyses of complex chemical mixtures, especially for organics, can be more expensive than toxicity testing and may not include many toxic chemicals actually present;

(d) It is not always clear from chemical data which compounds are producing the toxic effect in complex hazardous waste mixtures, sediments, suspended sediments soils, or water samples; and

(e) The bioavailability of toxic chemicals is measured with bioassay tests and not with chemical analyses; therefore chemical data may over-or-under-estimate the toxic effects of single chemicals.

A variety of tests, procedures and criteria has been developed internationally to assess the ecological impact of domestic and industrial effluents/discharges. However, with the increasing awareness of the long term effects of chemicals discharged into aquatic systems, research efforts have been directed at short-term bioassay tests to alert monitoring agencies as well as dischargers of the presence of toxicants in effluents and the aquatic ecosystem. Application of these short term bioassays to environmental samples soon revealed that there was no single test which was responsive to all conditions. This realization led to the concept of using a battery of tests to ascertain the ecological impacts of effluents and discharges.

In this study, the following bioassays were used to evaluate extraction/concentration procedures, to evaluate the sensitivity of the bioassays and to establish the degree and extent to which the waters and sediments have been impacted by the oil sands operations: Algal ATP, ATP-TOX System, Microtox, Mutatox, SOS Chromotest, Toxi-Chromotest, Daphnia magna, Ceriodaphnia dubia, nematode, earthworm, seed germination and root elongation, Spirillum volutans, and ECHA dip stick.

The adsorption of contaminants onto suspended matter in aquatic systems is influenced by a variety of parameters such as particle size distribution, bacterial content, ionic charge, stream velocity, pH, etc.. To understand contaminant transport in rivers and streams, and to try to develop contaminant transport models, the knowledge of partitioning of contaminants between suspended particles including bacteria and the dissolved phase is essential. Therefore, to gain a better understanding of the importance of suspended particulates in relation to bacterial and nutrient loads, suspended particulate size distribution analyses were initiated using Athabasca river waters with their contained suspended particulate load.

In this report, information on the ecotoxicological responses of the various bioassays to the waters, sediments, suspended sediments and their extracts or concentrates are described and discussed. Also, we report on the size classes of the predominant suspended particulates in these waters and their relative nutrient and microbial loads.

METHODS

Samples and Sample Collection

Figures 1 and 2, and Table 1 locate the various sampling sites, in the Athabasca River valley, from which water, suspended sediments and sediments were collected, refrigerated or frozen and shipped to our laboratory in Burlington for processing. The first five sampling sites listed in Table 1, were specifically sampled for toxicants and these sites were chosen due to their lower content of sand in the sediment. Surface water samples in litre, 5 litre and 18 litre quantities were collected for coliphage, suspended particulates analyses and toxicant screening tests. Suspended sediments were collected at specific sites by means of Alfa-Laval centrifuges with the centrifuges being operated for periods varying from 2 to 4 hours during which 500 to 1000 litres of water were centrifuged. Approximately 100 - 150 grams of suspended sediments were collected from each centrifuge bowl. Bottom sediments were usually collected with Ekman dredges with the top 2-3 cm layer being harvested, until sufficient sediment was collected at each site.

Sediment and Water Extraction and Processing

Sediment size distribution and analytical procedures involved are described by Dalton (1989) and Duncan (1990) (Table 1). The routine Milli-Q water extraction procedure used with some sediments is described in detail in Dutka and Kwan (1988). Two other inter-related sediment-water-extracts were also evaluated for their toxicant content

in this study. In the first procedure a specific weight of sediment e.g. 100 gm was centrifuged at 10,000 rpm at 4°C for 20 minutes, and the supernatant (pore water) was carefully decanted for toxicity screening. In the second procedure, this dewatered sediment was weighed and Milli-Q water was added to the sediment in the ratio of 1 gm sediment to 1 mL Milli-Q water, and then, after thorough mixing with a clean stainless steel spatula it was vigorously hand shaken for one minute. The slurry was then centrifuged at 10,000 rpm at 4°C for 20 minutes and the supernatant was used for toxicity testing.

Sediments for organic extraction procedures were frozen on site. In the laboratory, frozen sediment samples were thawed and subsampled. An amount of wet sample equivalent to 10 g dry weight of suspended sediment or 10 g dry weight of bottom sediment was weighed and ground with combusted (450°C) anhydrous sodium sulfate to a dry consistency. This mixture was soxhlet extracted for 24 hours with 350 mL DCM (Dichloromethane). The DCM extract was concentrated and a solvent exchange carried out into 1 mL 100% DMSO. With the sole exception of the nematode test (10% DMSO) these extracts were diluted to 1% DMSO and used in toxicant screening bioassay tests.

Water samples were concentrated by two procedures. In one procedure, water samples were concentrated 10 times (10X) by flash evaporation at 45°C using a Buchi Rotovapor EL. In the other procedure, large volumes of water from each site were clarified by pressure filtration through a glass fibre filter (Gelman A/E) or by centrifugation through an Alfa-Laval continuous-flow centrifuge. Then, eighteen litres of this water were placed in a stainless steel pressure filtration vessel, and the pH was adjusted to 11-12 by addition of 10 N sodium hydroxide (20 mL). Following this, 600 mL DCM

were added, and the sample was extracted by stirring with a propeller-type stirrer for 15 minutes. Then after allowing the mixture to stand for 15 minutes the lower DCM layer was removed by pressurizing the filtration vessel with purified nitrogen and siphoning the DCM into a clean one litre bottle. A further portion of DCM (300 mL) was added to the filtration vessel and the extraction repeated. Then the pH of the water was adjusted to 2-3 by addition of 6 N hydrochloric acid (50 mL) and the water extracted with DCM (600 mL and 200 mL) as above.

The acid and base extracts were concentrated by separating the DCM layer in a separatory funnel, and passing them through combusted (450°C) anhydrous sodium sulfate, and reducing them to 5-10 mL aliquots on a rotary evaporator. The solutions were transferred to 15 mL graduated centrifuge tubes and the volume reduced in each to 1 mL under a stream of argon. Dimethyl sulfoxide (DMSO, 1 mL) was added and the volume was again reduced to 1 mL under argon. Removal of the last traces of DCM required heating of the samples and bubbling of the argon through the DMSO. Complete removal of DCM was verified by gas chromatographic analysis.

Coliphage Test

The four tube coliphage test was performed on waters collected at sites, Mile 16.3, Mile 32.5 Mile 69 (Peace River), Mile 73, Mile 133.3 and Mile 317.5 (Slave River) using the APHA (1985) procedure.

Toxicity Screening Test

Water samples were tested directly by the Daphnia magna (acute toxicity) and Ceriodaphnia dubia (chronic toxicity) tests. The other

bioassays were applied to water samples concentrated 10X by flash evaporation. Pore water and Milli-Q sediment extracts were tested directly by the "battery of tests" approach Dutka (1989). DMSO (100%) extracts of sediments were diluted with Milli-Q water and tested at 1% DMSO concentration.

The base/neutral fraction and acid fraction from extracted water samples were concentrated into 1mL 100% DMSO and were tested by the battery of tests approach at 1% DMSO concentration. Similarly the solvent extracted suspended sediment and bottom sediments were concentrated into 1mL 100% DMSO and were tested at a 1% DMSO concentration. These are designated as DCM-DMSO extracts in the text.

The Microtox test was performed using the luminescent bacterium Photobacterium phosphoreum and the procedure detailed in Methods for Microbiological and Toxicological Analysis of Water; Wastewater and Sediments (Dutka 1989). Spirillum volutans, a large bacterium with a rotating fascicle of flagella at each end, was used to test the samples, following a modification of the procedure developed in 1974 by Boudre and Krieg (Dutka and Kwan 1984). ATP-TOX System, a toxicity screening test based on the inhibition of bacterial growth and luciferase activity was applied to all samples (Xu and Dutka 1987). An algal-ATP toxicity screening test based on the inhibition of ATP production by the green alga Selenastrum capricornatum (Kwan, 1989) was also applied to the samples. The results are reported as a percentage of relative light units (RLU) produced by the tested sample, compared to the nonstressed control which is accepted as 100% output. A 48 hour Daphnia magna test, using ten organisms per sample and sample dilution was performed on all samples to assess acute toxicant activity (Dutka 1989). The seven day Ceriodaphnia dubia,

3-brood life cycle chronic toxicity test using four cladocerans per sample or sample dilution was used to test all samples (Rao 1988).

Toxi-chromotest, a rapid bacterial colorimetric assay based on the ability of toxicants to inhibit the de novo synthesis of an inducible enzyme, beta galactosidase in an E. coli. mutant was used to test water and sediment extracts (Orgenics 1985).

The Mutatox test based on the use of a dark mutant strain of Photobacterium phosphoreum M169 to screen for genotoxic agents was field tested in this study. This test is responsive to chemicals which are (a) DNA damaging agents (b) DNA intercalating agents (c) direct mutagens which either cause base substitution or are frame shift agents and (d) DNA synthesis inhibitors. Genotoxic chemicals will restore the light emitting stage of the strain and can be measured in a modified Beckman Microtox Model 2055 analyzer. The test procedures are similar to those followed in the Microtox test with incubation of M169 cells, cell media and sample being carried out at 20 - 24°C for 18 - 20 hrs. Light level is read after the 18-20 hr contact and compared to the negative control (Kwan et al. 1990).

The SOS chromotest, a test for genotoxicants, consists of colorimetric assays of microbial enzymatic activities after incubation of the bacterial tester strain (E. coli K12-PQ37) in the presence of various concentrations of water or sediment and water extracts. The intensity of the colour (blue) can be read usually or with a microplate reader (Xu, Dutka, Kwan 1987).

Four non routine toxicant screening tests were included in this study (a) a seed germination and root elongation test using prize head leaf lettuce seeds (Dutka 1989), (b) a 14 day earthworm (Eisenia) survival test (Dutka 1989), (c) the ECHA dip stick test (Dutka and

Gorrie 1989) and (d) a four day nematode toxicity assay using Panagrellus redivivus (Samoiloff 1990).

Suspended Particulates Size Fractionation

The five litre water samples for suspended particulate analyses were collected from three sites on the Athabasca River: Mile 16, Mile 34 and Mile 133.3. A modified cascade filtration procedure using 88, 64, 40, 20 and 10 micron filter sieves was used to collected the various sized particles in these water samples (Rao and Kwan 1990). Extreme care was taken to minimize particle disintegration and filter clogging. This involved the very gentle mixing of the sample during the filtration process and resuspension of the settled material from each filter surface by slow immersion of the filter sieve below the surface of the filtrate. This process enabled smaller entrapped particulates to pass through the filters. The suspended particulates remaining on each filter sieve were carefully resuspended in approximately 20 mL sterile distilled water to obtain total weight, bacterial, nitrogen and particulate organic carbon content.

Bacterial Density Determination in Suspended Particulates

A 1 mL sub-sample of each of the filtered particulate fractions was diluted to 10 mL with sterile low-response water and homogenized using a vortex mixer at the highest speed for 1 min. to facilitate uniform dispersal of bacteria from the particle aggregates (Marxen, 1988). Bacterial content was then determined using the acridine orange direct microscopic procedure with a phase contrast microscope (Rao et al. 1984).

Organic Carbon and Nitrogen in Suspended Particulates

Particulate organic carbon and nitrogen analysis were performed according to standard Water Quality Branch procedures (1979).

Suspended Particulate Weight

Total weight of each of the suspended particulate fractions was determined according to APHA standard methods (1985). Clean evaporating dishes were numbered and heated at 550°C ± 50°C for 3h. in a muffle furnace. After cooling, the dishes were dessicated, weighed and stored. A known volume of each of the filtered particulate fractions was transferred into each of the preweighed dishes and evaporated to dryness in a drying oven at 105°C to a constant weight. The increase in weight of the evaporating dish over that of the empty dish represents the total residue. Although these weights do not represent the true weight of the particulates, this determination serves to compare the relative distribution patterns of different sizes of suspended particulates in the Athabasca River.

Point Scoring and Ranking Scheme

The procedures detailed in Dutka (1988) with modifications described in Dutka et al. (1989) were used in this study to award points for specific data values and to rank the samples and sites.

Results and Discussion

Surface River Water

Surface river water samples were collected for bioassay screening from Miles 16.3, 32.5, 73, 133.3 on the Athabasca River and Mile 69 on the Peace R. and Mile 317.5 on the Slave R (Fig. 1, Table 2). All water samples, with the exception of the coliphage, Daphnia magna and Ceriodaphnia dubia tests, were tested at 10X concentrations. The Daphnia, Ceriodaphnia and coliphage tests were performed on natural water samples.

Results of bioassays which responded to contaminants in the water samples are shown in Table 2. The following bioassay tests indicated no toxicant/genotoxicant responses to the samples tested, Microtox, Mutatox, SOS Chromotest, Spirillum volutans, Ceriodaphnia dubia, seed germination and root elongation, earthworm and ECHA dip stick test.

Water samples collected upstream (Mile 16.3) and downstream of the oil sands (Mile 32.5) show only minimal responses to the toxicant screening bioassays. The water sample collected from Mile 32.5 showed the least toxic response with only the ATP-TOX System showing a response which was slightly above background noise levels. However, Mile 32.5 sample was the only water sample containing coliphage, which suggests there is some fecal contamination upstream of this site.

Water samples from the Slave River and Peace River produced the strongest responses in the toxicant screening bioassay tests and ranked first and second, based on our point ranking scheme. Samples from Miles 73 and 133.3 showed similar toxicant response patterns but

at a much lower level than samples from the Peace and Slave Rivers (Table 2).

Based on this set of bioassay data, obtained from the application of the battery of screening tests approach to Athabasca, Peace and Slave River water samples, the data suggest that the contaminant level of these waters is at a much lower level than two other rivers we have recently studied, the Yamaska (Dutka et al. 1989) and Thames (Dutka et al. 1990).

Extracted Water Samples

Eighteen litre samples of clarified water (river water from which most of the solids had been removed by either centrifugation or filtration) were collected from four sites on the Athabasca River (Miles 16.3, 34, 73, 133.3) and from one site each on the Peace and Slave Rivers for solvent extraction at pH 12 and pH 2. These base and acid extracts were tested by a shortened version of the "battery of tests" (Dutka 1988) due to the small final sample size (1 mL). Two of the bioassay tests (Microtox and Algal ATP) applied to the 1% DMSO extracts, were negative in all samples and thus are not reported with the results shown in Table 3.

From Table 3 it can be seen that the samples produced a variety of toxic responses in the bioassay tests. When reviewing these data in relationship to Table 2, it must be remembered that the tests are responding to toxicants concentrated from 180 mL of water while Table 2 data are derived from toxicants concentrated from 10 mL of water and from toxicants in natural unconcentrated water samples.

Acid extracted samples produced greater (more toxic) responses in the bioassays at two sites, Mile 16.3 and Slave River, while base

extracted samples produced greater responses at two sites also, Mile 73 and Mile 133.3. Mile 34 base and acid bioassay responses were similar in total points but showed a great difference in bioassay test response pattern, suggesting there are at least two major chemical groups in these waters.

One of the major differences between Table 2 and Table 3 data is the presence of responses in the genotoxicant tests (Table 3). Whether these responses are due to the greater concentration of the chemicals in the sample or due to the presence of solvent soluble chemicals is not known yet.

The Mutatox test is most responsive in the base extracted water samples with 73 ARCB producing the greatest number of revertants (3.7 times greater than the control). The SOS Chromotest appears to be equally responsive in both base and acid extracts with the highest induction factors being found in Mile 16 ARCA and Mile 69 PRCA samples.

In the Mutatox test any value greater than 3X is considered a positive confirmation for the presence of genotoxicants and in the SOS chromotest an induction factor of greater than 1.25 is considered an indication of the presence of genotoxic chemicals.

Miles 16.3 and 34, (Figure 2) which are upstream and downstream of the oil sands and the Suncor and Syncrude plants, seem to be similar in total toxicant load, a confirmation of the water samples tested at 1X and 10X concentrations (Table 2). Samples from Athabasca River Mile 133.3 and Peace River appear to contain the greatest total toxicant load and again are a partial confirmation of Table 2 observations.

Pore Water and Water Extracts of Sediment

In this study 3 types of water related sediment extracts were tested (1) pore water (P), (2) sediments which contained their pore water and were extracted 1 mL Milli-Q water to 1 gram wet weight of sediment (PS), and (3) sediments from which the pore water was removed and then were further extracted 1 gm sediment: 1 mL Milli-Q water (WPS). Samples for this study were collected at specific mileage points on the Athabasca River, with sample 16.3 being upstream of the oil sands plants and the other samples were downstream of the oil sands plants and one from the Slave River. These samples were collected from areas with low sand and high clay content (Table 1). The mile 16.3 sample was intended to be a control site for evaluating the effects, if any of the oil sands extracting plants on the Athabasca River. Table 4 summarizes the results obtained when the "battery of bioassay tests" approach was applied to these various water based sediment extracts.

The following bioassays did not show a toxic response to the three extracts tested; Algal ATP, Ceriodaphnia dubia, earthworm, ECHA dip stick, Microtox, Spot plate and Toxi-chromotest. Only four tests indicated the presence of a toxicant; ATP-TOX System, Daphnia magna, seed germination and root elongation and the Mutatox test for genotoxicity.

From Table 4 it can be seen that Mile 16.3 pore water (P) was the most toxic extract in the seed germination and root elongation test with only 45% of the seeds germinating and of those germinating, their root length was 44% shorter than the control's. No other extract or sample indicated a problem with root length inhibition.

These observations suggest that Mile 16.3 sample contained a water soluble chemical(s), in concentrations toxic to the plant material used in this bioassay.

Comparing P extract bioassay responses to PS extract responses it can be seen that with minor exceptions (seed germination Mile 73) pore water contains the greatest toxicant load. However, when P bioassay response are compared to WPS extracts, a totally different picture emerges. Here, it can be seen (Table 4) that in the ATP-TOX System test, P extracts are the more toxic extracts while in the Daphnia magna and Mutatox tests the WPS extracts provide the greatest responses.

These Milli-Q extracts indicate that even after the pore water is removed from the sediments, there are still some more firmly fixed water soluble chemicals which can be solubilized by the Milli-Q water (Kwan and Dutka 1987). Both PS and WPS extracts produced a greater response in the Mutatox test than did the P extracts. Only samples producing 3X responses or greater are considered to be positive for the presence of genotoxicants.

Reviewing the total point score and ranking for the three extracts, it can be seen that Miles 32.5 (Athabasca) and Slave River contained the greater chemical hazard potential with Miles 133.3, 73 and 16.3 following in decreasing order. However, if one only considers pore (P) water extracts, Miles 16.3 and 32.5 produced equivalent point scores and ranking. Mile 16.3 would have to be considered to contain the most potential chemical hazards, as the seed germination and root elongation test (for which we have not yet developed a point score format) was very positive in Mile 16.3 pore water, and this result is not reflected in the point score.

DMSO Extracts from Freeze-Dried Sediments

A novel approach in obtaining sediment extracts was applied to surface sediments collected from Miles 16.3, 32.5, 73, 133.3 and Slave River. The extracting procedure followed was basically that described by Kwan and Dutka (1990) using freeze-dried sediment and 100% DMSO, and all tests were performed on extracts diluted to 1% DMSO with Milli-Q water.

The following bioassays were negative in these 1% DMSO samples; Microtox, Mutatox, Algal ATP, Spirillum volutans and spot plate. One unexpected observation with these samples was the lack of response in the Microtox test coupled with the positive response in 4 of the 5 samples with the Toxi-chromotest, a reversal of past observations (Table 5).

The ATP-TOX System response seen in Table 5, were unusually strong and not typical of our other river study observations (Dutka et al. 1989, 1990). In this Table it can also be seen that the Daphnia magna test while positive was responding at low levels while two of the samples Miles 32.5 and 133.3, showed solid evidence of the presence of chemicals capable of producing chronic effects in the Ceriodaphnia test. These effects were not found in the water extracted sediments (Table 4). In these data (Table 5) we find an unusual pattern of toxic responses which are not typical of what we have seen before (Dutka et al. 1989, 1990). The data suggest the presence of specific (groups of) chemicals which only trigger responses in certain bioassays e.g. ATP-TOX System, Toxi-chromotest, Ceriodaphina dubia, and produce low level toxicant response in the Daphnia test. The pattern of responses suggests the presence of at

least three types or classes of chemical pollutants, one that arises before Athabasca River Mile 16.3 (Table 4) and another entering upstream of Athabasca River Mile 32.5 and a third entering in the vicinity of or upstream of the Slave River site.

From the point score and ranking of results (Tables 4 and 5), it would appear, based on the extraction procedures and bioassays used, that the sediments at Athabasca River Mile 32.5 are the most contaminated, with those collected at the Slave River site following closely behind. The results obtained from the Slave River sediments (Fig. 1) may reflect the combined downstream flow of pollutants from the drainage area of the Peace and Athabasca Rivers and Lake Athabasca.

DCM-DMSO Extracted Bottom Sediments

A total of nine bottom sediments were collected for DCM-DMSO extraction. Three of the sediments, Mildred Lake (MLBS), Beaver Creek reservoir (BCRBS) and Sedimentation pond (SPBS) were from lakes or ponds. In this study the toxicant screening test results were based on extracting 15-20 g dry wt of sediment and concentrating the extract into 1 mL, 100% DMSO. Bioassay results from previous studies (Table 5) were based on 100 g wet weight of sediment concentrated into 1 mL, 100% DMSO. Thus compared to our previous studies we are assessing the toxicant load in extracts representing a fifth or seventh of our routine sediment sample. Therefore, the implications of positive or negative results (toxicity/genotoxicity) must be considered when evaluating the data or comparing to any of our previous studies (Dutka et al. 1989, 1990).

All samples, based on the bioassay tests used, indicate the presence of toxicants/genotoxicants to varying degrees. As a group, the lake/pond sediments (SP, ML and BCR) with a 1,2 and 3 ranking contain a greater toxicant load than the river sediments (Table 6). Of the river sediments tested Slave River (Mile 317) and Mile 73 (Athabasca River) contain the greatest contaminant load and Miles 34 and 24 (Athabasca River) appear to contain the least.

Sediments from BCR (Beaver Creek Reservoir) produced the highest (most toxic) response in six tests; ATP-TOX System, Microtox, Toxi-chromotest, Nematode survival, Daphnia magna and nematode maturation (along with four other samples). In the various water and sediment extracts tested in this study the Microtox test was responsive in only a few samples. Of all the samples tested, sediment extracts from BCRBS, SPBS and MLBS produced the greatest response in the Microtox test, with BCRBS extract indicating the presence of the greatest amount of toxicants producing a response in the Microtox test.

The nematode toxicity assay (Panagrellus redivivus) produced an interesting set of data. In the toxicity response test (% survival) there were three definitely positive samples BCR, ML and SP, while in the maturation inhibition test, all samples showed a response with five samples completely inhibiting the maturation process in the surviving organisms. Samoiloff (1990) indicates that the completion of the J4 adult moult requires steroid and extensive utilization of genetic information. Therefore, inhibition of the moult suggests toxic effects at the genetic level. Interestingly the two microbial tests for genotoxic chemicals, Mutatox and SOS chromotest showed little or no responses in those samples. The Mutatox test was

negative in all the samples while the SOS chromotest indicated possible positive responses, just above background levels in three samples 25 ARBS, 34 ARBS and 73 ARBS. Sample 25 ARBS, in the nematode maturation test, inhibited all the test animals from reaching the adult stage, while in samples 34 ARBS and 73 ARBS approximately 16% of the animals were able to reach maturity. These SOS chromotest results tentatively confirm the nematode maturation test results.

The lack of response in the Mutatox test to these solvent extracted samples was surprising, especially as it can be seen in Table 4, that four of the sites (Miles 32.5, 73, 133.3 and Slave River) produced positive responses in the Mutatox test. These observations lead us to suspect that we are observing the presence of water soluble contaminants which have genotoxic activity and these contaminants are all downstream of the oil sands plants. The lack of positive response in the Mutatox and SOS chromotest may also be related to the small size of the predominantly sand sample extracted i.e. 15-20 g. and the insensitivity of the bioassays to possible trace amounts of genotoxic chemicals present in the 1 mL DMSO extract. However, since Table 5 sediment samples, which were predominantly silt and clay and were examined in 100 g aliguots, were also negative in the genotoxicant tests, more credence must be given to the presence of specific water soluble genotoxicants.

The bioassay C. dubia produced an interesting pattern of positive (toxic) responses, as seven of the nine samples produced a positive response and five of these at the 1% level (Table 6). In two samples 73 ARBS and ML BS, due to the testing of insufficient dilutions, it is probable that the toxic effect may have been noted in at least a 10 fold lower dilution (e.g. 0.1%). The two samples showing the least

response in the C. dubia test 34 ARBS and 24 ARBS also show similar patterns of responses in the other tests.

Sediment extracts from 34 ARBS (Table 6) indicate an equivalent or decreased concentration of toxicants compared to the two upstream site 24 ARBS and 25 ARBS which is contrary to our findings with the DMSO extracted sediment at Site Mile 32.5 (Table 5). Since the sediment composition is very similar at these three sites, 24 ARBS, 25 ARBS and 34 ARBS, (Table 1), there is not a great likelihood that there is a deposition of toxicants in these sediments and the results merely imply that the toxic chemicals are heterogeneously dispersed in this part of the Athabasca River due to the scavaging effects of the turbulent waters, and as yet we have not pinpointed toxicant input sources. However, sediments at Mile 32.5 (Table 5) which contain only 12% sand versus 98-99% sand at sites 24 ARBS, 25 ARBS and 34 ARBS, appear to have been collected from an area of deposition (edge of river) and this may account for the much higher concentration of toxicants found in this sample than in other upstream and downstream samples.

Based on our point allocation and ranking scheme the following river sediment extracts contain the greatest toxicant load in descending order 317SRBS, 73 ARBS, 25 ARBS, 69 PRBS, 34 ARBS and 24 ARBS.

Suspended Sediments

Suspended sediments were collected in August at eight sites (Table 7) using an Alfa-Laval centrifuge during a period of unusually high flow and suspended sediment concentration. Extracts were

prepared from 5 - 10 g dry wt. of suspended sediments for testing at the 1% DMSO concentration level by the battery of tests approach. All samples indicate the presence of toxicants/genotoxicants with samples from sites 34 ARSS, 73 ARSS and 69 PRSS indicating the presence of the greatest toxicant load and these extracts ranked 1 and 2. Based on these results, it would appear that there may be a downstream effect (excluding Peace River Site 69) from the area around the oil sands and the Suncor and Syncrude complexes which is partially obscured by the presence of upstream toxicants as seen at site 16 ARSS (Tables 7 , 5 and 4).

All samples (Table 7) produced a strong positive response in the D. magna acute toxicity test with samples from sites 16 ARSS, 133 ARSS and 317 SRSS showing the greatest responses and 25 ARSS the least. The test for chronic toxicity, C. dubia was positive in all extracts with the exception of site 25 ARSS. Sites 16 ARSS, 34 ARSS, 69 PRSS and 73 ARSS results indicated the presence of the greatest concentration of chemicals able to produce a toxicity response in the test animals. Samples 69 (Peace River) and 73 (Athabasca River) may have been able to produce a chronic toxicity effect (reproduction inhibition) at a dilution below 1% (1% = $\frac{1}{100}$ dilution of 1% DMSO extract) however, due to the small amount of sample extract available, dilutions below 1% were not tested.

The nematode survival test indicates that three of the extracts Miles 16, 133 and Slave River were toxic while all of the extracts inhibited to varying degrees, the maturation of the surviving larval forms. Site 317 SRSS extract produced the greatest inhibition of the maturation process.

Weak positive responses in the genotoxicant test (SOS chromotest), were found in only four extracts, 34 ARSS, 73 ARSS, 133.3 ARSS and 317 SRSS, and the positive responses were just above baseline levels. No samples were positive in the Mutatox test, a common finding with the Athabasca samples. The only samples which showed a positive response in this test were the water extracts from sediments (Table 4) which suggest that either the chemicals stimulating a response in the Mutatox test are water soluble or the solvent extracting procedures applied to sediments and suspended sediments inactivate potential genotoxic chemicals. The Toxi-chromotest was not overly responsive in these extracts (Table 7) with samples 69 PRSS, 133 ARSS and 317 SRSS producing low level positive (toxic) effects. The suspended sediment extracts were the first and only group of samples in this study to all produce positive effects in the Microtox test with sites 24 and 25 being the most toxic. In contrast, sites 24 and 25 produced one of the few not detected (ND) results that we have observed with the ATP-TOX System test. Invariably in previous studies, of all the bioassay tests used in the battery of tests approach, the ATP-TOX System is the single test that is most often positive i.e. indicates presence of toxicants. Site 34 extract produced the greatest inhibition effect in the ATP-TOX System while Sites 16, 73 and 133 had similar but slightly lower responses compared to Site 34.

Interestingly, Site 25 extract (Table 7) produced non detectable and the lowest responses in six of the bioassays and yet it also produced the second highest toxicant response in the Microtox test. There are at least two possible explanations for these observations. One possibility is that a chemical or class of chemicals which

trigger(s) specific reactive sites in the testing organisms, impact the Athabasca River immediately upstream of Site 25 ARSS. Another possibility is that we are observing the effects of contaminants upstream of site 16 ARSS which are being diluted/precipitated out by the time site 25 is reached. This latter probability tends to have more credibility due to the pattern of responses observed at Site 25 compared to sites 16 and 34 ARSS (Table 7). However, with the increased responses of site 34 extract in the battery of tests compared to sites 24 and 25, we believe there may be sources of contaminants impacting the river upstream of Site 34 and below or near sites 24 and 25.

Suspended Particulate Study

A summary of the suspended particulates analyses is shown in Table 8. One of the factors controlling the suspended particles' capacity for concentrating contaminants is the particle size (Harowitz 1984). It has been shown that fluvial transport of particles in Canadian waters is mainly composed of suspended materials in the 2 to 62 µ range (Blachford and Day, 1988). In this Athabasca River study the distribution analysis of different particle sizes (Table 8) indicate that more than 60% by weight of the suspended particulates were below 40 µm in size. The particles retained on the 20 µm filter sieve which represents 20-40 µm range appear to be the predominant size class in all of 3 sampling sites. (Site Mile 16, 5.2 mg/l, site Mile 34, 3.0 mg/l and site Mile 133.3, 14.3 mg/l). Average size of particulates greater than 40 µm constituted approximately 34% of the suspended particles. Bacterial density, particulate organic carbon

and nitrogen determinations of the different size classes of particulates from the 3 sites indicated that the 20 - 40 µm fraction generally contained greater concentrations of all tested parameters compared to the other fractions. The predominant sized class of particulates (20-40 µm) at site 16 contained 21 x 10^7/L bacteria, whereas the predominant sized class particulates at site 34 contained 13.7 x 10^7/L and site 133.3 contained 8 x 10^7/L. A similar trend was also observed with regard to the distribution of particulate organic carbon and nitrogen in the waters at these three sites.

The implications of these predominant size class of particulates harbouring increased levels of biological and chemical complexes are now being studied.

SUMMARY

In summation, the following observations were made during this study:

(1) River water samples tested in the unconcentrated form and concentrated 10X showed signs of low grade toxicity, with the Daphnia magna and ATP-TOX System tests being the most responsive;

(2) River water samples upstream of the oil sands plants (Mile 16) and downstream of these plants (Mile 34) showed similar ecotoxicological responses in the bioassays;

(3) In the study to evaluate the three water related sediment extracts (a) pore water (P); (b) sediments which contained their pore water and were extracted with Milli-Q water (PS); and (c) sediments from which pore water was removed and then extracted with Milli-Q water (WPS), it was found that WPS extracts with one

exception contained the greatest toxicant load with P extracts having the next greatest toxicant load;

(4) Studies on the direct extraction of toxicants by 100% DMSO from freeze-dried sediments indicated that sediment samples collected from Mile 32.5, downstream of the oil sands plants contained the greatest toxicant load. In comparison to the pore water and Milli-Q water extracts of sediments, it was noted that both procedures produced positive results in the ATP-TOX System and D. magna tests. However, some of the DMSO extracted sediments were also positive in the C. dubia and Toxi-chromotest tests while the pore water and Milli-Q extracts were positive in the Mutatox test;

(5) Data from DCM-DMSO extracted sediments (Table 6) indicated that more bioassays were positive for the presence of contaminants than were found by the two other procedures (pore and Milli-Q water combinations and 100% DMSO). With this extracting procedure river sediments from the Slave River (Mile 317) were found to contain the greatest toxicant load. This may be due primarily to the type of sediment collected, clayey, bank sediment from the Slave River versus sandy mid-channel sediments from the Athabasca River;

(6) Suspended sediment analyses indicated that samples collected from Mile 34 (below the oil sands plants) and Mile 73 had a slightly greater toxicant load than suspended sediments collected from Mile 16 (above the oil sands plants);

(7) Suspended particulate studies indicated that the 20-40 micron sized particulates were the predominante size class which carried the greatest bacterial and nutrient load.

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Table 1. Site Location, Sediment Description and Classification.

Site	Latitude	Longitude	Description and Shepard Classification			
Mile 16.3	56°54'36"	111°12'54"	Sand[A] 7.34% CLAYEY	Silt 53.41% SILT	clay	39.25%
Mile 32.5	57°06'30"	111°34'30"	Sand 12.87% CLAYEY	Silt 53.94% SILT	clay	33.19%
Mile 73	57°37'30"	111°27'36"	Sand 2.36% CLAYEY	Silt 50.14% SILT	clay	47.5%
Mile 133.3	58°20'24"	111°31'48"	Sand 7.98% CLAYEY	Silt 55.49% SILT	clay	36.53%
Mile 317.5	59°51'12"	111°35'30"	Sand 6.87% CLAYEY	Silt 57.66% SILT	clay	35.47%
AR[1]BS Mile 24	57°00'42"	111°28'12"	Sand[B] 99.22% SAND	Silt and clay	.78%	
ARBS Mile 25	57°01'12"	111°29'06"	Sand 98.68% SAND	Silt and clay	1.32%	
ARBS Mile 34	57°07'36"	111°36'06"	Sand 99.51% SAND	Silt and clay	.49%	
ARBS Mile 73	57°39'54"	111°25'36"	Sand 99.09 SAND	Silt and clay	.91	
PR[2]BS Mile 69	59°6'00"	112°26'36"	Sand 99.82 SAND	Silt and clay	.18%	
SR[3]BS Mile 317	59°57'12"	111°35'30"	Sand 4.33% CLAYEY	Silt 60.38% SILT	clay	35.29%
SP[4]BS	57°01'30"	111°29'48"	Sand 16.78% SILT	Silt 34.54% CLAY	clay	48.68%
ML[5]BS	57°03'12"	111°34'54"	Sand 3.6% CLAY	Silt 12.85%	clay	83.55%
BCR[6]BS[7]	56°58'48"	111°37'00"	Sand 71.54% CLAYEY	Silt 9.48% SAND	clay	18.98%

AR[1] = Athabasca River, PR[2] = Peace River, SR[3] = Slave River
SP[4] = Sedimentation Pond (Syncrude) ML[5] = Mildred Lake
BCR[6] = Beaver Creek Reservoir
BS[7] = Bottom Sediment
A = J. Dalton, 1989
B = G. Duncan, 1990

Table 2. Athabasca, Peace and Slave River Water Samples, 1989. Waters were concentrated 10X for most tests with exception of those marked*.

Site	ATP-TOX % Inhibition	Algal ATP % Inhibition	*Daphnia magna** EC as % of sample	Coliphage/* 100 mL	Toxi-chromotest % inhibition	Points	Rank
16.3	26	neg	EC_{25}	<5	neg	2	5
32.5	21	neg	neg	10	neg	2	5
73	42	neg	EC_{45}%	<5	neg	6	3
133.3	21	neg	EC_{45}%	<5	14.2	5	4
69[1]	43	24.2	80%	<5	neg	11	2
317.5[2]	43	neg	40%	<5	neg	12	1

Negative tests were, *Spirillum volutans*, Microtox, Mutatox, *Ceriodaphnia dubia*, seed germination and root elongation, ECHA dip stick and earthworm test.

69[1] = Peace River 317.5[2] = Slave River

Table 3. Athabasca, Peace and Slave River Water Samples, base and acid extraction, and tested at 1% DMSO concentration.

Site	Sample Type	ATP-TOX % Inhibition	Daphnia magna EC as 100% of sample[3]	Mutatox No. revertants X Control	SOS Chromotest Induction Factor	Toxi-Chromotest % Inhibition	Points
16	ARCB[1]	N.D.[4]	N.D.	2.9	1.33	6.4	4
16	ARCA[2]	16.6	EC_{70}	N.D.	1.51	N.D.	12
34	ARCB	N.D.	N.D.	3.3.	1.27	2.1	7
34	ARCA	31.8	EC_{20}	N.D.	1.30	7.5	8
73	ARCB	N.D.	N.D.	3.7	1.37	2.1	9
	ARCA	19.3	EC_{30}	1.4	1.25	4.6	5
133.3	ARCB	11.0	EC_{50}	3.0	1.36	3.7	15
	ARCA	19.1	EC_{90}	N.D.	1.19	N.D.	10
69[5]	PRCA	16.5	EC_{50}	N.D.	1.53	15.4	12
317[6]	SRCB	9.3	EC_{20}	N.D.	1.22	N.D.	3
	SRCA	16.7	EC_{40}	N.D.	1.36	5.9	7

1 = base extracted water
2 = acid extracted water
3 = insufficient sample for dilutions - EC_{90} = 90% of animals died in 100% sample.
4 = N.D., not detected
5 = Peace River
6 = Slave River

Table 4. Sediment Pore Water and Milli-Q Water extracts of sediments from which pore water was and was not removed. Athabasca and Slave Rivers 1989.

Site	Sample Type	ATP-TOX % Inhibition	*Daphnia magna* EC as % of sample	Seed % germination	% root length Inhibition	Mutatox No revertants X Control	Points by procedure	Rank by procedure
16.3	Pore	36	EC_{45}	45%	44%	0	6	1
	Milli-Q with pore	3.3	EC_{35}	82%	0%	2.2	3	4
	Milli-Q without pore	22	EC_{40}	82%	0%	1.7	3	3
32.5	Pore	43	EC_{45}	70%	0%	1.4	6	1
	Milli-Q with pore	10.9	EC_{45}	90%	0%	2.0	4	3
	Milli-Q without pore	11	87	91%	0%	3.0	10	2
73	Pore	48	EC_{35}	100%	0%	1.0	5	2
	Milli-Q with pore	15	EC_{25}	72%	0%	2.2	2	5
	Milli-Q without pore	19	82	73%	0%	4.5	10	2
133.3	Pore	39	EC_{30}	79%	0%	0	4	3
	Milli-Q with pore	15	EC_{25}	76%	0%	2.0	2	5
	Milli-Q without pore	33	97	76%	0%	3.2	12	1
317.5[1]	Pore	32	EC_{40}	67%	0%	1.0	5	2
	Milli-Q with pore	19	EC_{30}	72%	0%	2.7	3	4
	Milli-Q without pore	32	82	73%	0%	3.6	12	1

The following toxicant screening bioassay tests were negative: *Spirillum volutans*, Spot plate; Microtox, Algal ATP, Toxi-chromotest, *Ceriodaphnia dubia*, Earthworm, ECHA dip stick.

1 = Slave River

Table 5. DMSO Sediment Extract Tested at 1% DMSO Level. Athabasca and Slave River Study 1989.

Site	ATP-TOX % Inhibition	Toxi-chromotest % Inhibition	*Daphnia magna* EC as %/sample	*Ceriodaphnia dubia* % sample producing reproduction inhibition	Points	Rank
16.3	52.4	25	EC_{15}	N.D.	6	5
32.5	71.4	37.5	EC_{30}	50%	14	1
73	76.2	25	N.D.	N.D.	8	4
133	85.7	N.D.	EC_{20}	50%	9	3
317[1]	71.4	62.5	EC_{15}	N.D.	12	2

The following toxicant screening bioassays were negative; Microtox, Mutatox Algal ATP, Spot Plate, *Spirillum volutans* : ND = not detected

1 = Slave River

Table 6. Bioassay results from DCM-DMSO extracts of 15 - 20 g. dry wt aliquots of bottom sediments. Athabasca River study area - August 1989

Site & Sample type	ATP-TOX % Inhibition	Microtox EC_{50} % mL	Toxi-chromotest % Inhibition	Mutatox No. revertants X control	SOS Induction Factor	Nematode Percent Survival/ Maturation S M	C. dubia % sample producing reproduction inhibition	D. magna EC_{50} as % sample	Points	Rank
SP BS	25.6	0.13	7.1	1.6X	1.2	85.3 0	1%	40%	30	1
ML BS	N.D.	2.6	10.8	1.4X	1.2	62.1 0	1%	37%	28	3
BCR BS	50.1	0.6	25.9	1.2X	1.0	35.8 0	50%	33%[3]	29	2
24 ARBS	12.3	N.D.	8.5	N.D.	1.1	97.9 26.2	N.D.[1]	EC_{30}[2]	5	9
25 ARBS	10.6	12.7	14.1	1.5X	1.3	92.6 0	50%	100%	19	6
34 ARBS	3.3	N.D.	20.2	N.D.	1.3	94.7 15.7	N.D.	N.D.	7	8
73 ARBS	25.7	N.D.	14.4	N.D.	1.3	98.9 15.9	1%	87%	22	5
69 PRBS	44.1	N.D.	N.D.	1.4X	1.1	100 28.9	1%	EC_{30}	14	7
317 SRBS	23.1	19.8	12.1	1.3X	1.0	97.9 0	1%	70%	26	4

N.D.[1] = not detected

EC_{30}[2] = 30% of animals tested died in 1% DMSO extract

33%[3] = 50% of animals died in 33% of 1% DMSO extract

Table 7. Bioassay results from DCM-DMSO extracts of 5 - 10 g dry wt aliquots of suspended sediments. Athabasca, Peace and Slave River study. 1989.

Site & Sample type	ATP-TOX % Inhibition	Microtox EC_{50} % mL	Toxi-chromotest % Inhibition	Mutatox No. revertants X Control	SOS Induction Factor	Nematode Percent Survival/ Maturation S	M	*C. dubia* % sample producing reproduction inhibition	*D. magna* EC_{50} as % sample	Points	Rank
16 ARSS	39.1	13.1	7	N.D.	1.2	77.9	67.5	1%	50%	24	3
24 ARSS	N.D.	4.3	8.5	N.D.	1.2	100	76.0	10%	70%	20	5
25 ARSS	N.D.	7.1	N.D.	N.D.	1.2	100	76.0	N.D.	100%	12	7
34 ARSS	47.9	16.4	N.D.	N.D.	1.3	93.7	69.0	1%	64%	27	1
73 ARSS	39.9	12.5	3.9	N.D.	1.3	100	69.9	1%	78%	27	1
133.3 ARSS	38.5	18.0	18.0	1.3X	1.3	80	61.8	10%	50%	23	4
69 PRSS	34.1	25.1	17.1	N.D.	1.1	100	68.3	1%	62%	26	2
317 SRSS	29.5	23.6	13.4	N.D.	1.3	74.7	58.3	50%	50%	19	6

Suspended particulates data summary, Athabasca River 1989

Suspended Particulates Fractions (µm)	Distribution of Suspended Particulates (mg/l)	Bacteria (10^7/L)	POC[1] (mg/L)	PON[2] (mg/L)
Site: Mile 16				
>88	1.2	5.0	.0158	.0018
64-88	1.3	7.6	.0114	.0014
40-64	2.8	9.0	.0312	.0037
20-40	5.2	21.0	.0638	.0086
10-20	4.8	10.0	.0150	.0017
Site: Mile 34				
>88	1.2	6.6	.0076	.0008
64-88	1.3	7.2	.0071	.0026
40-64	1.8	9.0	.0095	.0018
20-40	3.0	13.7	.0231	.0035
10-20	3.0	5.4	.0121	.0017
Site: Mile 133.4				
>88	11.0	4.1	.010	.0041
64-88	11.0	6.5	.0061	.0017
40-64	2.2	10.0	.0081	.0038
20-40	14.3	8.0	.0153	.0016
10-20	3.0	6.5	.0126	.0013

POC[1] - particulate organic carbon
PON[2] - particulate organic nitrogen

FIGURE 1. Showing Main Sampling Points Athabasca, Peace and Slave Rivers. 1989 Study.

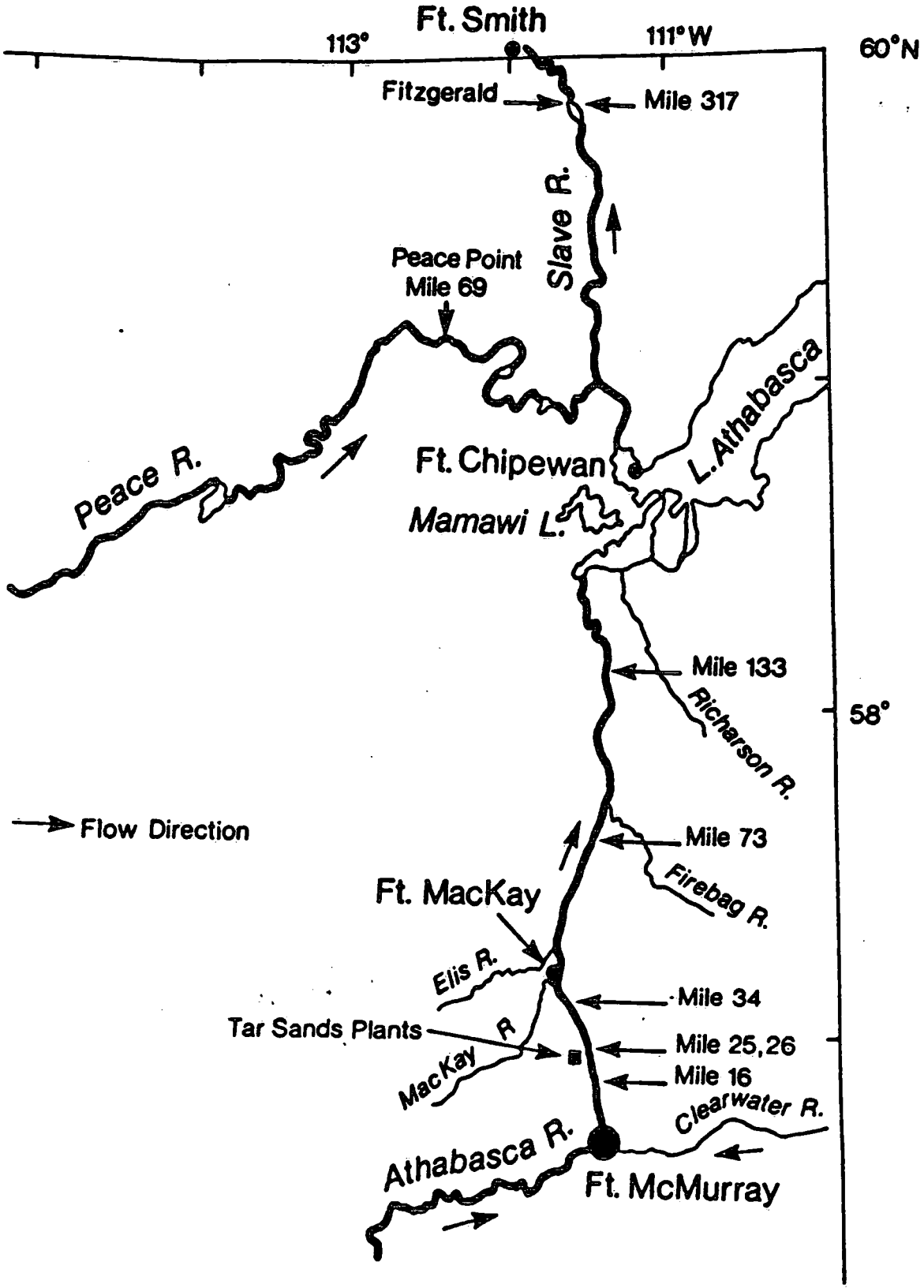
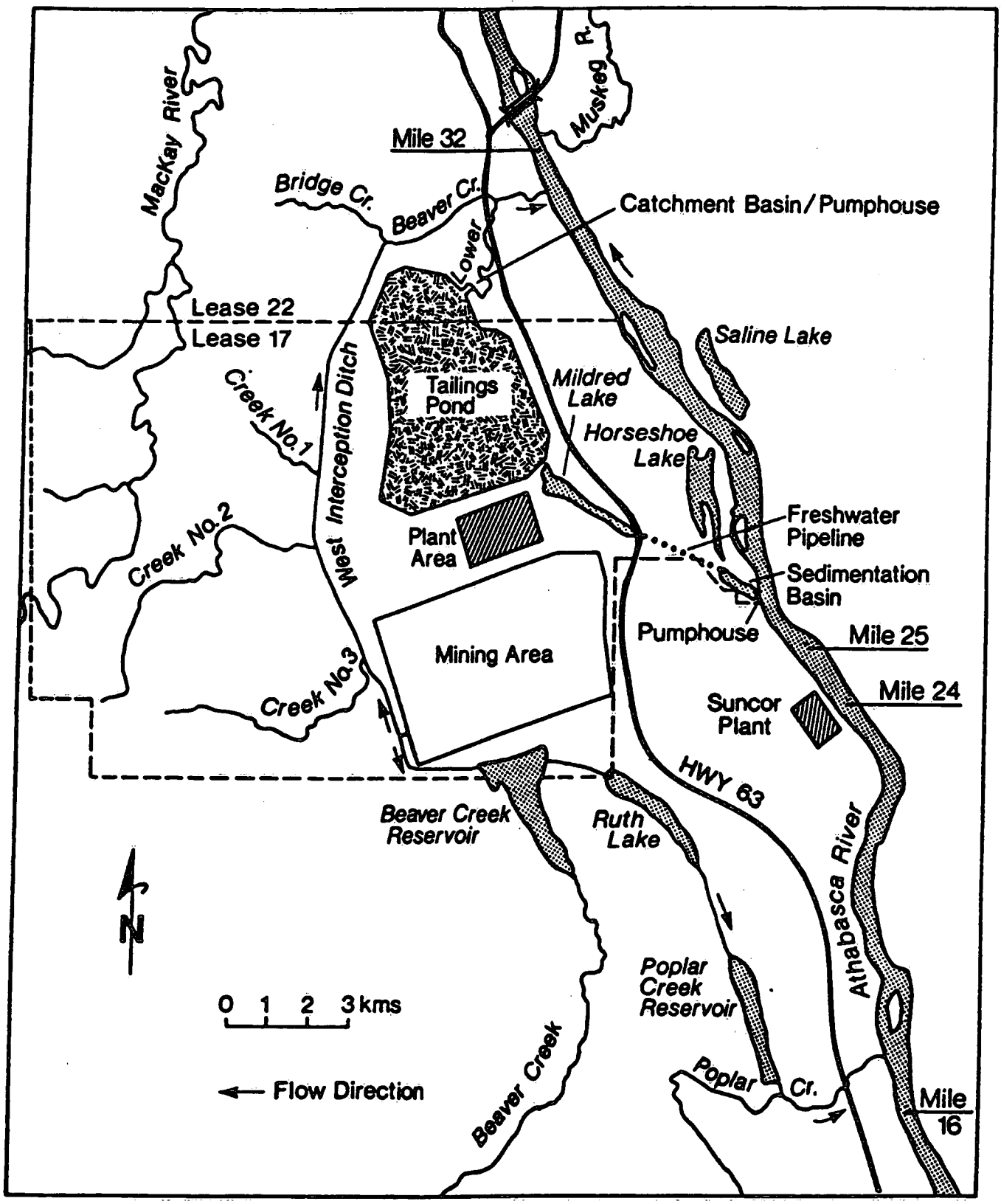
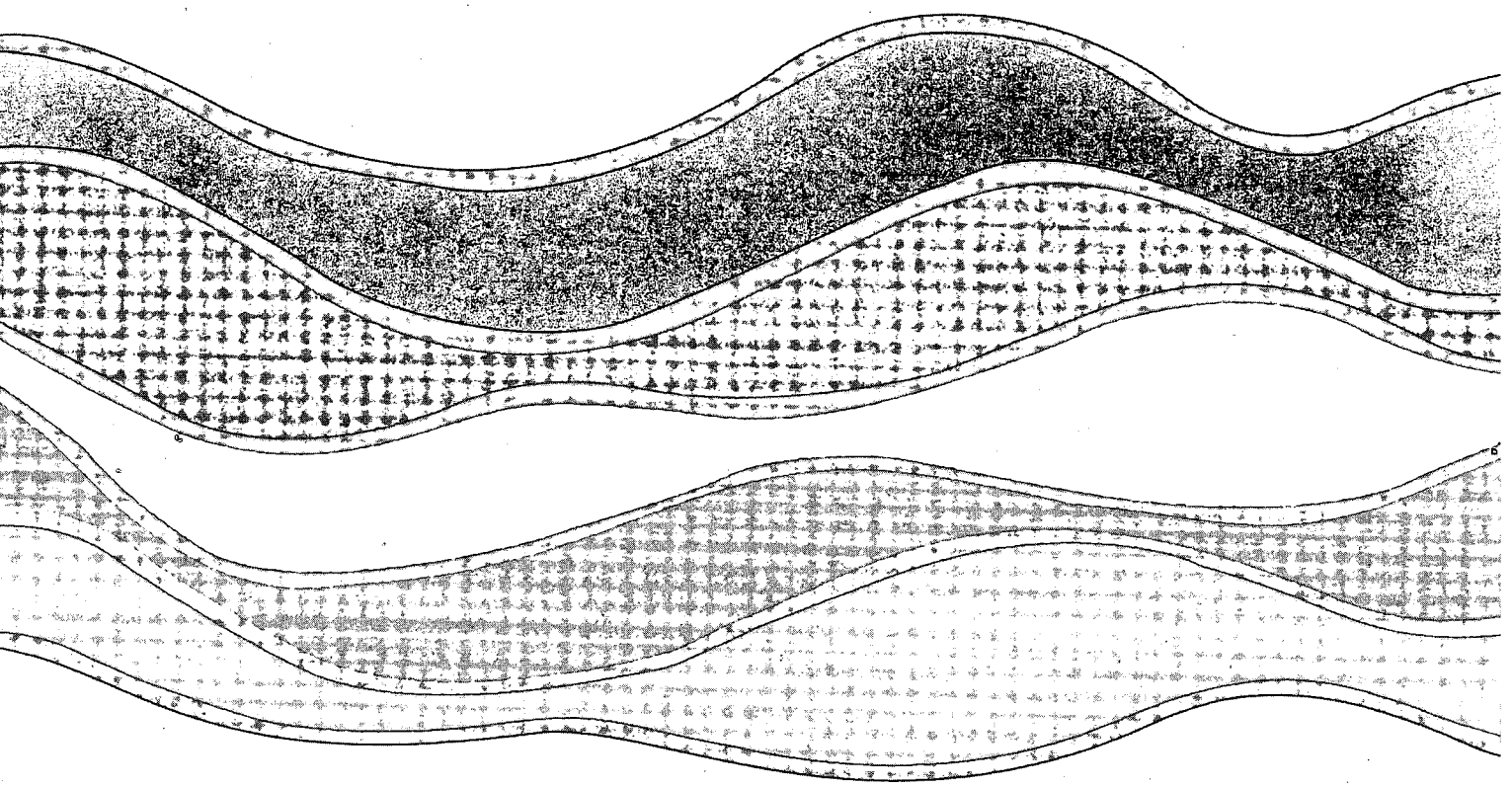

Ft. Smith
113°
111°W
60°N
Fitzgerald
Mile 317
Slave R.
Peace Point
Mile 69
Peace R.
Ft. Chipewan
L. Athabasca
Mamawi L.
Mile 133
Richarson R.
58°
Flow Direction
Mile 73
Firebag R.
Ft. MacKay
Elis R.
Mile 34
Tar Sands Plants
MacKay R.
Mile 25,26
Mile 16
Clearwater R.
Athabasca R.
Ft. McMurray

FIGURE 2. Details of the Oil Sands and Suncor Plant Area Sampling Sites.


MacKay River
Mile 32
Muskeg R.
Bridge Cr.
Beaver Cr.
Lower
Catchment Basin/Pumphouse
Lease 22
Lease 17
Saline Lake
Tailings Pond
Mildred Lake
Horseshoe Lake
Creek No.1
West Interception Ditch
Freshwater Pipeline
Plant Area
Creek No.2
Sedimentation Basin
Pumphouse
Mile 25
Mining Area
Creek No.3
Mile 24
Suncor Plant
HWY 63
Beaver Creek Reservoir
Ruth Lake
Athabasca River
N
Poplar Creek Reservoir
0 1 2 3 kms
Beaver Creek
Poplar Cr.
Flow Direction
Mile 16



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