TOXICITY OF LANDFILL LEACHATE AND SEASONAL PERFORMANCE OF WETLANDS

FINAL REPORT

prepared for: U.M.A. ENGINEERING LIMITED

prepared by: Margarete Kalin

April 14, 1992

TOXICITY OF LANDFILL LEACHATE AND SEASONAL PERFORMANCE OF WETLANDS

At the meeting held in Halifax with our client and the regulatory agencies on March 25 1992, several issues were raised which we agreed Boojum Research Limited would address.

One issue was the effluent characteristics described in the Memo of March 5, 1990, from A. Hennigar to W. Ernst both of Environmental Protection , C&P Atlantic region (see Appendix 1). Our comments on the organics are presented in Appendix 2.

Information was provided on bioassay/toxicity results carried out by Environment Canada, File 4863-3 4863-4 dated February 3rd and 28th l990 respectively (see Appendix 3).

The results are self-explanatory and are as expected. It is not surprising that the sample "swamp outflow" showed acute toxicity with the Microtox^{TM} test but was not toxic to fish, as Microtox^{TM} is very sensitive to organics. The samples reported in the Memo February 28 1990, indicate again, that making decisions on environmental protection based on bioassays is difficult. The sample collected above the landfill leachate site "Upstream , near Highway 101 Bridge" was toxic to rainbow trout and *Daphnia magna*, whereas the "Swamp outflow to river" was not toxic to *Daphnia magna*.

Given the chemical complexity of the landfill leachate effluent, and the difficulty in arriving at consistent monitoring parameters, a monitoring program should be considered for upstream and downstream sampling locations for a longer period. This would obtain a database against which the effluent criteria can be developed. For economic reasons the bioassay recommended would be the Microtox^{TM}.

Boojum Research Limited carried out work on water samples from the landfill site to ascertain the presence or absence of the relevant bacteria to remove ammonia. These water samples were submitted for the determination of inorganic constituents after filtration and acidification with ICP.

In Table 1, the results are presented from the samples collected in l992 and they are compared to one sample collected from the Environmental Control Branch in October l989. The elemental scan indicates, that the effluent improves significantly for most parameters comparing raw leachate to the effluent from the siltation pond. Assuming that the siltation pond effluent is the same as that described for the settling pond outlet in l989, no significant changes in the parameters reported have occurred between October l989 and 1992. Heavy metals are unlikely to be a significant problem, given the

Table 1: INORGANIC COMPOSITION

SAMPLE DATE	29-Jan-92	29-Jan-92	29-Jan-92	23-Oct-89
SAMPLE VOLUME	100	100	100	
ASSAYERS CODE	3650	3651	3652	
SAMPLING LOCATIO	UMA HWY101 Treat Raw leachate	UMA HWY101 Treat Laggon Effl.	UMA HWY101 Treat Siltation Effl.	UMA HWY101 Settling Pond Outlet
Processing code	FA	FA	FA	
** L A B **				
Temp. (C)	19	19	18.5	
pH	6.23	6.86	9.98	
Cond. (umhos/cm)	3900	2680	690	1740
Eh (mV)	-102	-175	40	
Acidity (mg/l)	2800	260		
Alkalinity (mg/l)	2640	1380	360	870
ELEMENTS Ag	< 1	< 1	< 1	
Al	< 1	< 1	< 1	0.44
As	< 1	< 1	< 1	0.41
B	4	2	< 1	
Ba	< 1	< 1	< 1	
Be	< 1	< 1	< 1	
Bi	< 1	< 1	< 1	
Ca	997	353	168	
Cd	< 1	< 1	< 1	< 0.01
Ce	< 1	< 1	< 1	
Co	< 1	< 1	< 1	
Cr	< 1	< 1	< 1	0.03
Cu	< 1	< 1	< 1	< 0.01
Fe	360	6	< 1	7.57
K	326	155	35	135
La	< 1	< 1	< 1	
Mg	191	84	5	48.6
Mn	29	6	< 1	2.55
Mo	< 1	< 1	< 1	
Na	741	451	99	
Nb	< 1	< 1	< 1	
Ni	< 1	< 1	< 1	0.05
P	2	< 1	< 1	
Pb	< 1	< 1	< 1	< 0.02
S	183	82	38	
Sb	< 1	< 1	< 1	
Se	< 1	< 1	< 1	
Si	12	4	2	
Sn	< 1	< 1	< 1	
Sr	4	1	< 1	
Te	< 1	< 1	< 1	
Th	< 2	< 1	< 1	
Ti	< 1	< 1	< 1	
U	< 2	< 1	< 1	
V	< 1	< 1	< 1	
W	< 1	< 1	< 1	
Y	< 1	< 1	< 1	
Zn	11	< 1	< 1	0.16
Zr	< 1	< 1	< 1	
Nitrate	< 0.1	< 0.1	< 0.1	
Ammonium	33	360	500	
Phosphate	110	7	7	

anticipated changes and improvements which are to be implemented for the treatment of the landfill leachate.

Regarding the analysis of the organic compounds submitted in the Memo of March 5, 1990 from the Environmental Control Branch (see Appendix 1), the following comments can be offered.

Two samples were analyzed by the regulatory agency, one labelled "Leachate outfall" and the other, "swamp outfall". The data on the compounds are summarized in Table 2. In the first column the chemical compound name is listed, followed by the common name. The next column to the right indicates the degree of possibility to which the compound is likely to be the one identified by name. The designation of N.F inthe next column was given to the compound if it was identified in the "Leachate outfall" sample but was no longer identified in the "swamp outfall" sample. One immediate observation is evident. Many of these complex organic substances were no longer identified as present where the effluent enters the river.

In order to objectively evaluate the concern expressed by Environment Canada about the toxicity of the leachate (partly substantiated by the bioassays) the 5th column in Table 2 records the presence/absence of the compounds identified in the Ontario Effluent Monitoring Priority Pollutants List (OEMPPL) and the EPPL list, The Michigan Critical

Table 2:
ORGANICS LIST FROM HWY 101 LEACHATE SITE

COMPOUND NAME	COMMON NAME	LEACH. OUTFA POSSIBILITY	SWAMP OUT. POSSIBILITY	ONT EPPL PRES/ABS	SOLUBILITY (Merk)
PHENOL	CARBOLIC ACID	70	N.F. **	PRESENT	water soluble
2-METHYL PHENOL	O-CRESOL	94	N.F.	PRESENT	in 40 pts water
3-METHYL PHENOL	M-CRESOL	93	N.F.	PRESENT	in 40 pts water
2-ETHYL PHENOL	PHLOROL	90	N.F.	ABSENT	insoluble
3-ETHYL PHENOL	PHLOROL- LIKE	92	N.F.	ABSENT	insoluble
3-PROPYLPHENOL	HYDROXY-PROPYL BENZENE	94	N.F.	ABSENT	slightly sol.***
N,N-DIETHYL-3-METHYL BENZENE	N,N-DIETHYL-M-TOLUMIDE DEET	91	95	ABSENT	INSOLUBLE
BENZENE ETHANOL	BENZENE METHANOL LIKE	57	N.F.	PRESENT	40g/L
4-TRIMETHYL CYCLOHEXANE METHAN	TERPINEOL LIKE	79	59	ABSENT	INSOLUBLE?
4-TRIMETHYL-3-CYCLOHEXANE-1-METHANOL	X TERPINEOL	36	59	ABSENT	INSOLUBLE?
2,2,4-TRIMETHYL-1,3-PENTANEDIOL		86	64	ABSENT	UNKNOWN
6-AMINOHEXANOIC ACID	NORLEUCINE LIKE	64	N.F.	ABSENT	11.5g/L (25C)
3-(-1 METHYL-2 PYROLIDIMYL)-PYRIDINE	NICOTINE	47	N.F.	PRESENT	MISCIBLE
1-(1,4-DIMETHYL-3-CYCLOHEXANE-1YL ETHANONE		75	N.F.	ABSENT	UNKNOWN
4-(4-HYDROXYPHENYL)-2-BUTANOL		92	N.F.	ABSENT	UNKNOWN
DIETHYL PHTHALATE	PLASTICIZER: DEP	79	79	ABSENT	INSOLUBLE
1,2-BENZENE DICARBOXYLIC ACID DIISOCTYL ESTER	DI-M-OCTYL PHTHALATE	N.F.	28	PRESENT	INSOLUBLE
BENZOTHIAZOLONE	(BENZOTHIAZOLINE?)	86	N.F.	ABSENT	SLIGHTLY SOL.*
M-BUTYL BENZENE SULFONAMIDE	SULFAMIDO-BENZOIC ACID LIK	47	44	ABSENT	INSOLUBLE
OCTADECENAMIDE *	OLEIC ACID + AMMONIA	63	N.F.	ABSENT	INSOLUBLE
4-(1,5-DIMETHYL-3-OXOHEXYL) -1-CYCLOHEXENE CARBOXYLIC ACID METHYLESTER		N.F.	64	ABSENT	UNKNOWN
HEXANEDIOIC ACID DIOETYL ESTER	OCTYL ADIPATE	N.F.	63	ABSENT	INSOLUBLE

* MAJOR COMPOUND FOUND IN LEACHATE - ENVIRONMENT CANADA
** N.F. = NOT FOUND
*** FOUND SIMILAR COMPOUND IN CRC HANDBOOK CHEMISTRY AND PHYSICS
1 PRESENT IN MICHIGAN CRITICAL MATERIALS REGISTER (1980)

Material Register (1980). The OEMPPL list is included as Appendix 4 for reference. Evidently, when the presence/absence of these compounds is evaluated, the toxicity information for many compounds will not be available. A compound's absence from these registers, however, does not suggest that the compound is not toxic, but that it is not a well-known and documented carcinogen or toxic substance. In order to determine if the presence of the toxic compounds in the leachate effluent is realistic, the Merk index was consulted and solubilities are reported in the last column of Table 2. Many of the compounds are insoluble in water and some solubilities are unknown. In Appendix 2, our comments on the organics also includes the information from the Merk index for ease of reference.

In general, given the origin and use of these compounds, it is not surprising to find them in landfill leachate. Many compounds are products which are expected to find their way to a waste dump, as for example, their use in perfumes, insect repellents or disinfectants.

Based on this assessment of the organics in the effluent, it is strongly recommended that the original criteria of removing ammonia from the effluent remain the important performance criteria for effluent treatment system. The rationale for this recommendation is that it would be extremely difficult to arrive at a technical basis which substantiates the environmental degradation of the Sackville river, based the presence of the organic compounds identified to date, as the environmental fate of many compounds is not known. In order to provide the best possible assurance to the regulatory agencies, a limited database of organics in landfill leachates may be developed through a monitoring program at the swamp outflow and the siltation pond effluent.

Additionally, the question of the winter performance of a wetland was raised at the March 25th meeting in Halifax and it was agreed that the literature would be consulted with specific reference to the seasonality of ammonia removal from effluents.

In Appendix 5, the details of the most recent literature is extracted, with quotations and figures representing the relevant seasonal data, from two major references in the field.

In summary, the literature on the seasonal performance of the wetlands is inconsistent. It cannot be documented conclusively that the wetlands do not work at the lower temperatures of the winter months, as many other factors, such a loading rate, concentrations of ammonia, retention time, dissolved organic carbon and vegetation type are all cited as important factors.

A pragmatic evaluation of the literature suggests that it is realistic to expect lower removal rates during the winter.

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Pb	< 1	< 1	< 1	< 0.02
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Sr	4	1	< 1	
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Th	< 2	< 1	< 1	
Ti	< 1	< 1	< 1	
U	< 2	< 1	< 1	
V	< 1	< 1	< 1	
W	< 1	< 1	< 1	
Y	< 1	< 1	< 1	
Zn	11	< 1	< 1	0.16
Zr	< 1	< 1	< 1	
Nitrate	< 0.1	< 0.1	< 0.1	
Ammonium	33	360	500	
Phosphate	110	7	7	

ENVIRONMENT CANADA MEMORANDUM

TO:

William R. Ernst
Head, Pesticides and Ecological
Investigations Section, C&A
Environmental Protection, C&P Atlantic

FROM:
Peter A. Hennigar
Head, Organic Chemistry Section,
Laboratory Division (BIO),
Environmental Control Branch
Environmental Protection, C&P Atlantic

Security-Classification	
Our File	
Your File	
Date	March 5, 1990

SUBJECT: ANALYTICAL RESULTS - MOUNT UNIACKE LANDFILL

The results of analyses of water samples related to Mount Uniacke Landfill leachates have been summarized in the appended tables.

The identification of organic compounds in these samples was obtained by GC-mass spectrometric screening. The results have been "corrected" for control sample and reagent blank contaminants.

In part, the analytical method incorporates a solvent partition step which permits the extraction of most base-neutral organic compounds, as well as, many weakly acidic organics such as phenols. Organic compounds of greater acidity e.g. carboxylic acids, however, may not have been isolated by the procedure employed. In addition, the method does not provide for the isolation and identification of many light-weight molecular volatiles, e.g. benzene, toluene, halogenated methanes, etc. This identification of these classes of compounds, therefore, is method dependent and this is reflected in the analytical results.

The purpose of the GC-MS analysis was to identify as many organics in these samples as possible. Target compounds were not specified and identification of unknowns, therefore, was carried out using a computer based search technique. The search technique compares the mass spectrum of an unknown to a data base library of mass spectra. The NBS data base library used in this case contains 42,000 compounds. The search technique employs a probability-based matching algorithm which assigns a confidence value to a match between an unknown spectrum and one or more library spectra. The probability value for each compound thus identified has been included in the table of results. The accuracy of identification by this technique depends on several factors:

. . . / 2

1) the type of instrument and experimental conditions used to collect unknown spectra and to collect reference spectra.
2) quality of the spectra in the data base.
3) the selection of background correction spectra.
4) purity of the unknown spectra.
5) strategy parameters used for the algorithm search. The search routine, therefore, should not be considered as providing conclusive identification. The results obtained must be considered tentative. The highest confidence in identification by MS can only be obtained with reference spectra obtained on the same conditions. Nevertheless, the identifications provided in the result tables may be viewed a useful guide. In general, a probability of 85% or greater may be considered a near perfect match and below 50% as an unlikely match.

Reference standards were not available for the GC-MS analysis and therefore no attempt was made to quantify the individual compounds in any sample. Concentrations of individual compounds probably are in the range of 1 to 100 µg/l with most concentrations being in the lower end of this range. Concentrations in the leachate outfall were highest while concentrations of the same compounds in the swamp outfall tended to be lower presumably due to a dilution effect.

It should be noted that only compounds of "sufficient" concentration (and high instrument signal (to noise ratio) were selected for matching. Many compounds of low concentration were observed, particularly in the leachate outfall, but their signal to noise ratios were such that satisfactory spectral searching was precluded.

If consideration is to be given to further work in this area, I would suggest

1) larger sample volumes be used for analyses
2) the analysis of lower molecular weight volatiles be included
3) separate analysis of the acidic fraction of leachate samples be done, and
4) where possible the identification of unknowns be confirmed with authentic reference standards.

P. Hennigar

PH/dg

cc: H. Samant
K. Doe
G. Julien

MASS SPECTROMETRIC ANALYSIS: Mount Uniacke Landfill Site, N.S.

Leachate Outfall

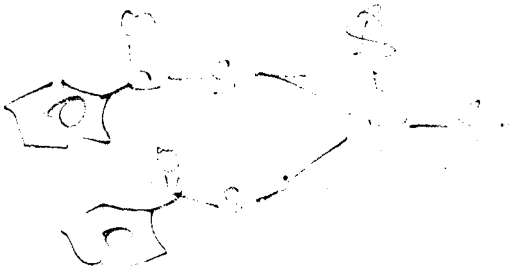
pH = 8

No.	Compound Name	Possibility	Comments
1.	Phenol	70	
2.	2-Methyl Phenol	94	O-Cresol
3.	3-Methyl Phenol	93	M-Cresol
4.	Benzene ethanol	57	Good match
5.	4-trimethyl cyclohexane methanol	79	
6.	2,2,4-trimethyl-1,3-pentanediol	86	
7.	2-ethyl phenol	90	Partially resolved compounds
8.	3-ethyl phenol	92	
9.	Unknown	-	
10.	4-trimethyl-3-cyclohexene-methanol	36	x terpineol
11.	6-aminohexanoic acid	64	
12.	3-propylphenol	94	
13.	3-(-1 methyl-2-pyrolidimyl)-pyridine	47	nicotine
14.	1-(1,4-dimethyl-3-cyclohexen-1-yl ethanone	75	
15.	4-(4-hydroxyphenyl)-2-butanol	92	
16.	N,N-diethyl-3-methyl benzene	91	N,N-diethyl-m-tolumide; DEET; OFF
17.	diethylphthalate	79	plastizer
18.	benzothlazolone	86	poor match
19.	Unknown	-	
20.	m-Butyl Benzene Sulfonamide	47	
21.	Unknown	-	
22.	Octadecenamide	63	major component in leachate
23.	Unknown	-	

benzothiazole

benzothiazolone

[illegible]



MASS SPECTROMETRIC ANALYSIS: Mount Uniacke Landfill Site, N.S.

Swamp Outfall

pH = 7

No.	Compound Name	Prob-ability	Comments
1.	4-trimethyl cyclohexane methanol*	59	
2.	2,2,4-trimethyl-1,3-pentanediol*	64	
3.	4-trimethyl-3-cyclohexene-1-methanol*	59	
4.	Unknown	-	
5.	Unknown*	-	1-(1,4-dmethyl-3-cyclohexen-1-yl ethanane (in leachate outfall)
6.	N,N-diethyl-3-methyl benzamide*	95	DEET
7.	diethyl phthalate*	79	plastizer
8.	Unknown*	-	
9.	N-Butyl Benzene Sulfonamide*	44	
10.	4-(1,5-dimethyl-3-oxohexyl)-1-cyclohexene carboxylic acid, methylester	64	
11.	Unknown		
12.	Unknown		
13.	Hexanedioic Acid, dioetyl ester	63	octyl adipate
14.	1,2-Benzene Dicarboxylic acid, diisoctyl ester	28	Di-m-octyl phthalate
15.	Unknown		

* Compounds also found in leachate outfall

424-5

The attached documents were inadvertently omitted from a letter dated February 21 to Mort Jackson from E. Norrena, Environment Canada and N. Bellefontaine, Fisheries and Oceans. Please accept my apologies.

John D. Clarke

John D. Clarke, P.Eng.
February 25/92

- Toxicity ~ Organics → Program
~ Metal
~ Seasonality!
~ Winter ammonia

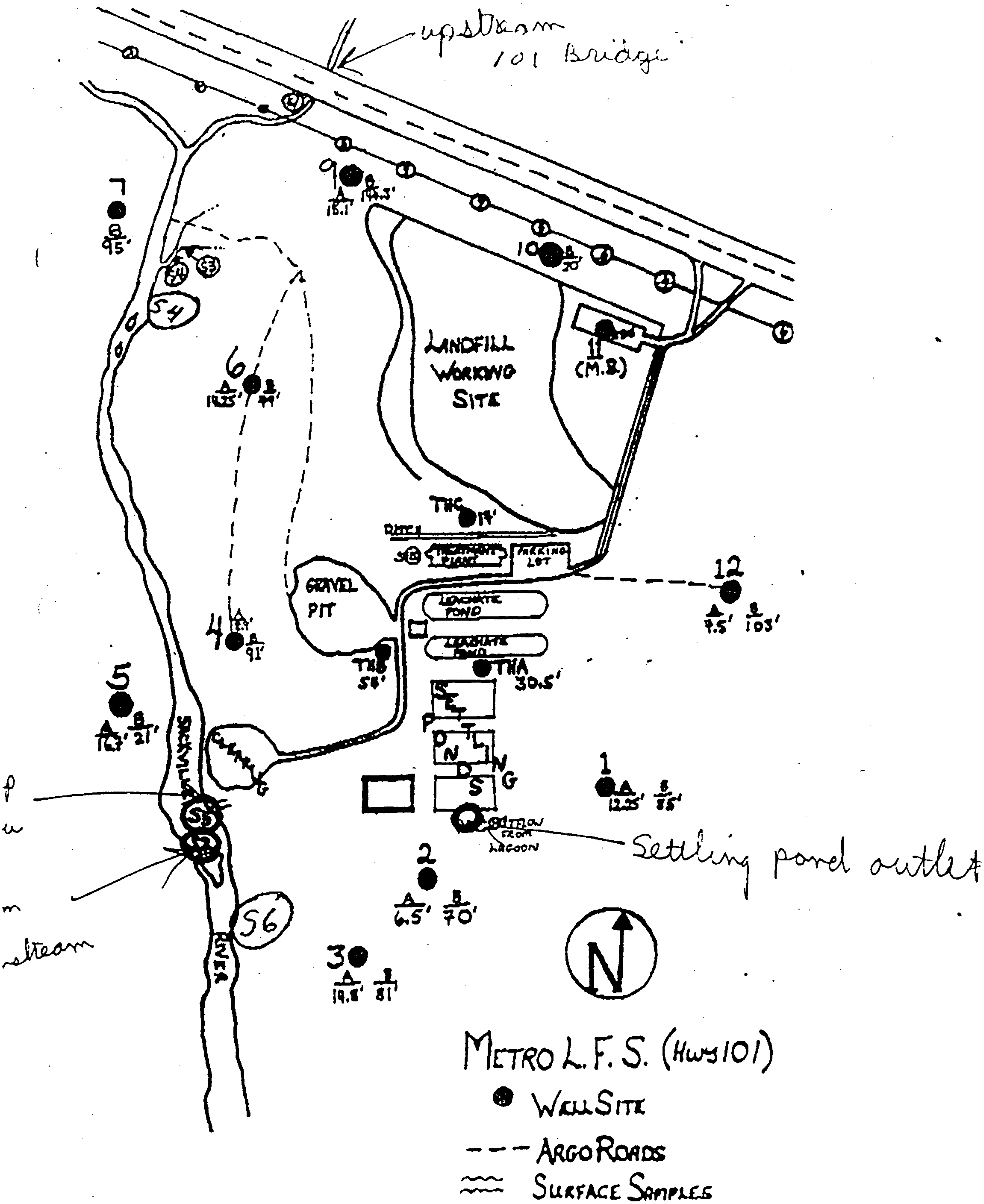
Limited ~ information

Rainfall → Retention times

ETRIC ANALYSIS: Highway 101 Landfill Site, N.S.

ownstream

Compound Name	Probability	Comments
ic acid, dioctyl ester	12	
e dicarboxylic, duso otylester	-	di-m-octyl phthalate



METRO L.F.S. (Hwy 101)

PHENOL: carbolic acid.

Obtained from coal tar, or made by fusing sodium benzenesulfonate with sodium hydroxide, or by heating monochlorobenzene with sodium hydroxide under pressure. Crystals are colourless, with characteristic odour. Poisonous and caustic. Prone to redden on exposure to air and light. It is liquified by mixing with 8% water. One gram dissolves in 15 mL water. LD50 (rats) 530 mg/kg. Ingestion of even small amounts may cause nausea, vomiting, circulatory collapse, tachypnea, paralysis, convulsions, coma, greenish or smoky-coloured urine etc. Average fatal dose is 15 g, but ingestion of as little as 1 g has been known to cause death. Fatal poisoning may also occur by skin absorption following application to large areas.

USE: As a general disinfectant, either in solution or mixed with slaked lime, for toilets, stables, etc.; for the manufacture of colourless or light-coloured resins, and as reagent for chemical analysis.

M-CRESOL: 3-methyl phenol.

Prepared from toluene. Colourless or yellowish liquid; phenolic odour. Soluble in about 40 parts of water, in solutions of fixed alkali hydroxides; miscible with alcohol. LD50 (rats) 2.02 g/kg.

USE: In disinfectants and fumigants; in photographic developers, explosives.

O-CRESOL: 2-methyl phenol.

Prepared from m-toluic acid. Crystals or liquid becoming dark with age and exposure to light and air; phenolic odour. Soluble in about 40 parts water in solutions with fixed alkali hydroxides; miscible with alcohol. LD50 (orally, rats) 1.35 g/kg.

USE: As a disinfectant like phenol; also as a solvent.

PHLOROL: 2-ethyl phenol, probably similar to 3-ethyl phenol.

Prepared by heating ethylene and phenol with phosphoric acid at 200 C. It is a colourless liquid with a phenol odour. Practically insoluble in water; freely soluble in alcohol, benzene, and acetic acid. Toxicology: action similar to, but less severe than, phenol.

3-Propyl-phenol. probably similar to both methyl and ethyl phenols.

DEET: N,N-dimethyl-3-methylbenzamide

Prepared from m-toluoyl chloride and diethylamine in benzene or ether. Freely soluble in alcohol, practically insoluble in water. Sparingly soluble in petroleum ether. LD50 (orally, rats) 2 g/kg.

USE: Insect repellant. Irritant to eyes, mucus membranes, but not to skin. Ingestion can cause CNS disturbances.

BENZENE ETHANOL: similar to benzene methanol or Benzene alcohol.

Produced on a large scale by the action of sodium or potassium carbonate on benzyl chloride. Liquid. Faint aromatic odour. Sharp burning taste. One gram dissolves in about 25 mL water. Misc. with abs. and 94% alcohol, ether, or chloroform. LD50 orally in rats - 3.1 g/kg. Pharmaceutic aid (bacteriostatic). Has been used for relief from pruritis.

USE: Manufacturing of other benzyl compounds. It is a solvent for gelatin, casein (when hot), solvent for cellulose acetate, shellac. Used in perfumery and in flavouring (mostly in form of its aliphatic esters). In microscopy as embedding material.

X-TERPINEOL: 4-trimethyl-3-cyclohexene-methanol, possibly similar to 4-trimethyl cyclohexane methanol.

Isolated from natural oils such as long leaf pine oil. Boiling point is at 81°C.

USE: Perfumes; denaturing fats for soap manufacture. Therapeutic use as antisceptic.

2,2,4 Trimethyl-1,3-pentanediol - not found

NORLEUCINE: 2-aminohexanoic acid; may be similar to 6-aminohexanoic acid.

An amino acid classified as non-essential with respect to its growth effects in rats. Sparingly soluble in alcohol; soluble in acids. Soluble in water at 11.5 g/L at 25 C.

NICOTINE: 3-(1-methyl-2pyrolidinyl) pyridine.

From the dried leaves of Nicotiana tabacum and N. rustica. Commercial nicotine is entirely a byproduct of the tobacco industry. Colourless to pale yellow, oily liquid; very hygroscopic; turns brown on exposure to air or light. Acrid burning taste. Develops the odour of pyridine. Forms salts with almost any acid and double salts with many metals and acids. Miscible with water below 60 C. Very soluble in alcohol, ether etc. LD50 in mice 0.3/kg intravenous; 230 mg/kg orally.

USE: As an insecticide; fumigant. Highly toxic. Base is readily absorbed through mucus membranes and intact skin.

1-(1,4-dimethyl-3-cyclohexene-1-yl ethanone - not found

4-(4-Hydroxyphenyl)-2-butanol - not found

PHTHALIC ACID, ethyl ester

Colourless, practically odourless, oily liquid, bitter, disagreeable taste. Insoluble in water, miscible in alcohol. LD50 (intraperitoneal, rats) 5.06 g/kg.

USE: Ethyl phthalate used in manufacture of celluloid; solvent for cellulose acetate in manufacturing of varnishes and dopes; fixative for perfumes. Irritating to mucus membranes, and in high concentrations, narcotic.

DIOCTYL PHTHALATE; Octoil

Used in vacuum pumps. Solubility 0.14 g/L at 37°C.

Benzothlazolone - not found

P-SULFAMIDO-BENZOIC ACID; M-Butyl benzene sulfonamide is probably similar, having just an extra butyl group in the m position.

May be obtained from crude saccharin. Has some inhibitory effect on carbonic anhydrase. Practically insoluble in water. Butyl group on molecule will make it more insoluble. Sodium salt has a solubility in water of 20 g/100 mL.

4-(1,5-dimethyl-3-oxohexyl)-1-cyclohexene carboxylic acid, methylester - not found

OLEIC ACID; Octadecenoic acid; similar to Octadecenamide

Obtained by the hydrolysis of various animal and vegetable fats and oils. Prepared from olive oil. Pure oleic acid is a colourless, or nearly colourless liquid. On exposure to air, especially when impure, it oxidizes and acquires a yellow to brown color and rancid odour. Practically insoluble in water (amide will make it more insoluble). LD50 (intravenously, mice) 230 mg/kg. According to our chemist, oleic acid in the presence of ammonia, can readily form the ammonium salt and the amide form.

USE: preparation of soft soap, and other oleates; in polishing compounds; waterproofing textiles; oiling wool; thickening lubricating oils. Mildly irritating to skin and mucus membranes.

ADIPIC ACID; Hexanedioic acid. diethyl ester group on C4 centre.

Found in beet juice. Prepared from cyclohexanone, or from cyclohexane. Freely soluble in methanol, ethanol, and acetone. Ethyl ester is insoluble in water.

USE: Manufacture of artificial resins, plastics (nylon), urethan foams. Used as an intermediate in lubricating oil additives.

DIOCTYL PTHALATE; Octoil

Used in vacuum pumps. Solubiltiy 0.14 g/L at 37°C.

2,2,4 Trimethyl-1,3-pentanediol - not found
1-(1,4-dimethyl-3-cyclohexene)-1-yl ethanone - not found
4-(4-hydroxyphenyl)-2-butanol - not found
4-(1,5-dimethyl-3-oxohexyl)-1-cyclohexane carboxylic acid, methylester - not found

ENVIRONMENT CANADA MEMORANDUM

282957

TO:
J. D. Clarke, A/Chief
Industrial and Air Programs Division
Contaminants and Assessments Branch
Environmental Protection, C&P Atlantic

FROM:
Suzanne Wade
Senior Bioassay Technologist
Aquatic Toxicology Section
Laboratory Division (BIO)
Environmental Control Branch

Security-Classification

FEB 3 3 32 PM '92
ENVIRONMENT CANADA

Our File
4863-3

Your File

Date
February 3, 1992

SUBJECT: Toxicity Results - Highway 101 Landfill Site, N.S.

On 16 December 1991, R. Gaudet collected a sample of "swamp outflow" from Highway 101 Landfill Site, N.S.

On 17 December 1991, 96-hour static toxicity tests were begun on the sample using fingerling rainbow trout and Atlantic salmon as the test organisms. In addition, a 48-hour static toxicity test was begun using the freshwater crustacean Daphnia magna. The sample was also tested using the Microtox Toxicity Assessment System, which determines the decrease in luminescence of the marine bacterium, Photobacterium phosphoreum, in response to a toxicant.

The sample was not acutely lethal to either of the test fish or to Daphnia magna neonates. However, the sample was acutely toxic to the marine bacterium, yielding a 15-minute IC50 value of 59.7% (95% confidence limits: 23.3 - 153.4%).

No sample was taken for chemical analysis, so the cause of toxicity to the marine bacterium could not be determined.

A copy of the Toxicity Reports are attached, which provide additional information about the tests.

S. Wade
S. Wade

SJW/jeh

Attachments (4)

cc: K. Doe
R. Gaudet
D. Aggett
R. Parker
H. Windsor, NSDOE

MICROTOX DATA REPORT

FILE NAME: 91SWAMP.015

REPORT DATE: 12-16-1991
TIME: 00:00:44

Sample Description:

"Highway 101 Landfill, swamp outflow, collected by B. Gaudet on 16 Dec 91, Lot # M105, performed by S. Wade."

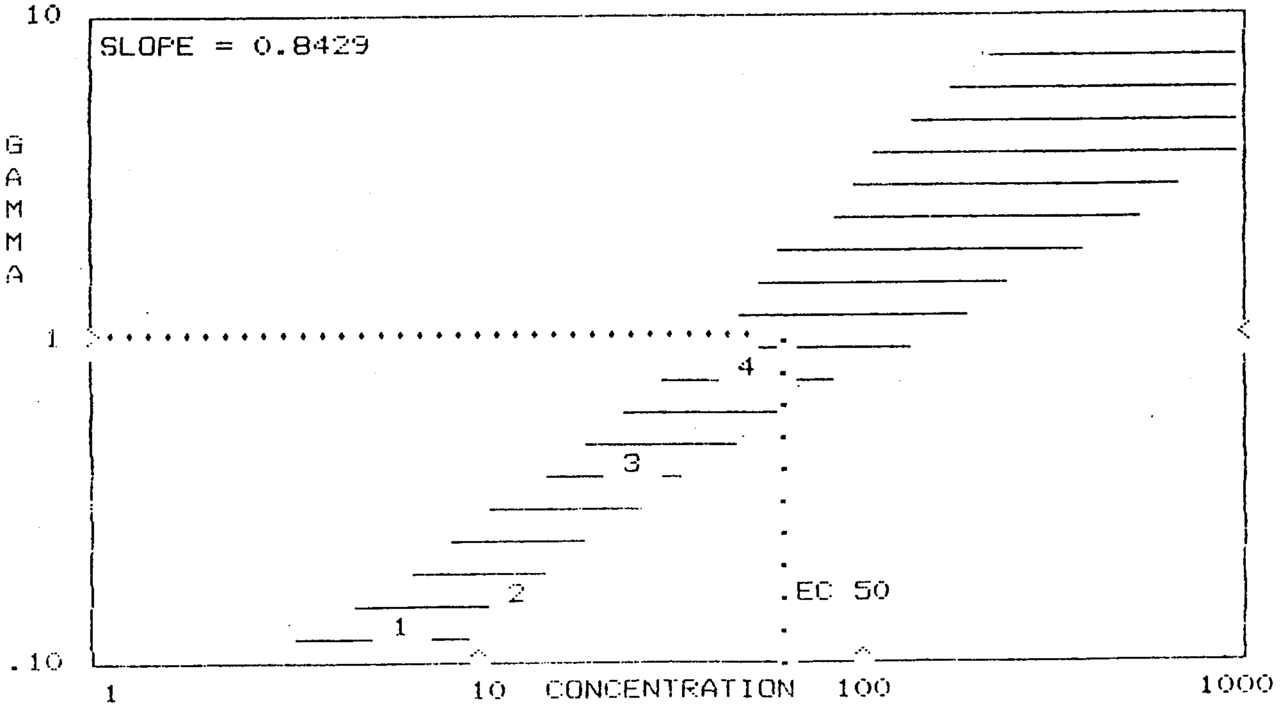
Procedure: STANDARD
Initial Concentration : 45 %
Assay Time: 15 minutes

Ionic Adjustment: MOAS
Dilution Factor : 2
Concentration Units: %

DIL.#	IO/IT	CONC.	GAMMA
1	89/ 61	5.6250	0.15584
2	89/ 59	11.2500	0.19503
3	83/ 46	22.5000	0.42942
4	89/ 39	45.0000	0.80786

BLANK BO/BT = 77/ 61

BLANK RATIO = 0.7922



EC 50 = 59.74 % (95% CONFIDENCE RANGE: 23.27 TO 153.38)

TOXICITY UNITS = 1.7 (95% CONFIDENCE RANGE IS 0.7 TO 4.3)

Initial T= 9°C DO= 8.6 pH= 7.8
S = 0 ‰

AQUATIC TOXICOLOGY LAB

EP, ATLANTIC REGION - TOXICITY REPORT

MATERIAL TESTED: Highway 101 Landfill Site, N.S.
Swamp Outflow

COLLECTED: 16 Dec. /91 1130 BY: R. Gaudet

SAMPLE NO. 92RP002 LOCATOR CODE: SPECNS01

TEST CONDITIONS:

Vol 40 L Duration 96 hr Type x static
___ cont. flow
Replacement rate N/A (mL/min)
Aeration rate 250 (mL/min)

Control Water Dechlorinated Dartmouth Municipal
pH x ambient
___ adjusted
Started 17 Dec./91 1200

Test Organism S. salar (Atlantic Salmon) #/Tank 5 Source Cobequid Hatchery 19 Sept./91 Tank #9

Length x ± S.D. (range) cm 6.5 ± 0.2 (6.3 - 6.8) n = 5

Weight x ± S.D. (range) g 2.0 ± 0.4 (1.5 - 2.6) n = 5 g/L 0.2

RESULTS:

Conc. (%)	T (C) Range	DO(mg/l) Range	pH Range	Cond. (umhos/cm)	# Mort/ # exp	LT50 (hr)	REMARKS
100	14-14.5	9.3-10.0	7.6-8.1	510	0/10	>96	
Control	14-14.5	10.0-10.7	7.3-7.9	50	0/10	>96	

96-hour LC50 >100% 95% Conf. Limits ____

Comments: ____

Performed By: S. Wade Verified By: Kenneth [illegible] Date: 4 Feb, 92

AQUATIC TOXICOLOGY LAB

EP, ATLANTIC REGION - TOXICITY REPORT

MATERIAL TESTED: Highway 101 Landfill Site N.S.
Swamp Outflow

COLLECTED: 16 Dec./91 1130 **BY:** R. Gaudet

SAMPLE NO. 92RP002 **LOCATOR CODE:** SPECNS01

TEST CONDITIONS:

Vol 20 L

Duration 96 hr

Type x static
__ cont. flow

Replacement rate N/A (mL/min)

Aeration rate 125 (mL/min)

Control Water Dechlorinated Dartmouth Municipal

pH x ambient
__ adjusted

Started 17 Dec./91 1200

Test Organism O. mykiss (rainbow trout)

#/Tank 10

Source Rainbow Springs 26 Nov./91 Tank #12

Length x ± S.D. (range) cm 4.3 ± 0.4 (3.8 - 5.0) n = 10

Weight x ± S.D. (range) g 0.8 ± 0.2 (0.4 - 1.2) n = 10 g/L 0.4

RESULTS:

Conc. (%)	T (C) Range	DO(mg/l) Range	pH Range	Cond. (umhos/cm)	# Mort/ # exp	LT50 (hr)	REMARKS
100	14-14.5	8.9-10.0	7.6-8.0	500	0/10	>96	
50	14-14.5	8.9-10.3	7.6-8.0	300	0/10	>96	
25	14-14.5	8.9-10.5	7.6-7.8	190	0/10	>96	
12.5	14-14.5	9.5-10.5	7.5-7.7	120	0/10	>96	
6.25	14-14.5	8.3-10.6	7.3-7.4	80	0/10	>96	
Control	14-14.5	9.2-10.6	7.1-7.4	50	0/10	>96	

96-hour LC50 ______ 95% Conf. Limits ______

Comments: Not Acutely Lethal

Performed By: S. Wade Verified By: Kenneth G. Doe Date: 4 Feb /92

DAPHNIA BIOASSAY REPORT

ENVIRONMENT CANADA, ATLANTIC REGION

MATERIAL TESTED: Highway 101 Landfill, N.S.
Swamp Outfall

COLLECTED: 16 Dec./91 1130 BY: R. Gaudet

SAMPLE NO. 92RP002 LOCATOR CODE: SPECNS01

TEST CONDITIONS:

Test organism Daphnia magna Vol 150 mls Duration 48 hrs. No./Vessel 10

Type static, no aeration Photoperiod 16L/8D Test temp. 20 ± 2°C

Control/dilution water Reconstitued water - 100 mg/L hardness (EPA recipe)

Young (≤ 24 hrs old) from 27 Nov./91 #2
100 mg/L EPA

pH ambient x
adjusted

TEST STARTED: 17 Dec./91 TIME: 0930 TEST TERMINATED: 19 Dec./91 TIME: 0930

RESULTS:

Test conc %	INITIAL			24 HOURS				48 HOURS				Cond.
	T (°C)	DO (mg/L)	pH	# dead/ # exp	T (°C)	DO (mg/L)	pH	# dead/ # exp	T (°C)	DO (mg/L)	pH	0 hrs.
100	19	9.4	7.7	0/10				0/10	20	7.4	8.1	540
50	20	9.2	7.8	0/10				0/10	20	8.4	8.1	460
25	20	9.1	7.9	0/10				0/10	20	8.6	8.1	420
12.5	20	9.0	8.0	0/10				0/10	20	8.6	8.1	380
6.25	20.5	9.0	8.0	0/10				0/10	20	8.7	8.0	370
Control	20.5	8.9	8.0	0/11				0/11	20	9.0	8.1	360

Initial T = 14 DO = 9.3 pH = 7.5 S = 0°/oo (17 Dec./91)

I = Immobile
S= Sluggish young

48 hr LC50: >100% 95% C.L. --

Remarks/Comments: Hardness = 120 mg/L as CaCO
Not Acutely Lethal

ENVIRONMENT CANADA MEMORANDUM

TO:
William R. Ernst
Head, Pesticides and Ecological
Investigations Section
Environmental Contaminants Branch
EP, C&P, Atlantic Region

FROM:
Kenneth G. Doe, Head
Aquatic Toxicology Section
Laboratory Division
Environmental Control Branch
EP, C&P, Atlantic Region

Security-Classification	
Our File	4663-4. 4863-3
Your File	
Date	February 28, 1990

SUBJECT: BIOASSAY RESULTS - HIGHWAY 101 LANDFILL SITE, NOVA SCOTIA

On October 23, 1989, Gary Julien (EP) and S. O'Neil (DFO) collected grab samples of leachate from the Highway 101 Landfill Site, N.S., and samples from upstream and downstream of the point of discharge into the Sackville River as follows:

1. "Settling Pond outlet" (corresponds to lab number 89GJ414)
2. "Swamp outflow to river" (corresponds to lab number 89GJ415)
3. "Island, 100m downstream" (corresponds to lab number 89GJ416)
4. "Upstream, near Highway 101 Bridge" (corresponds to lab number 89GJ413)

On October 24, 1989, 96-hour static acute lethal toxicity tests were started on each of these samples using both fingerling rainbow trout (Oncorhynchus mykiss) and speckled trout (Salvelinus fontinalis) as the test organisms. The test procedure followed as closely as practical the "Standard Procedure for Testing the Acute Lethality of Liquid Effluents" (EPS-1-WP-80-1). In addition, 48-hour static acute lethal toxicity tests were started October 25, 1989 on each of these samples, using the freshwater crustacean Daphnia magna as the test organism. The Daphnia magna tests followed the Environment Canada "Acute Lethality Test using Daphnia sp." (Final Draft; April 1989; TS-12) as closely as practical.

The results of the toxicity tests are summarized in Table 1: The "Settling pond outlet" sample was toxic to all three species tested. The "Swamp outflow to river" sample was toxic to both species of trout exposed to the undiluted sample, but both species survived at 56% concentration. This sample was not toxic to Daphnia magna. The "Island, 100m downstream" sample was not toxic to any of the test species, while the "Upstream, near Highway 101 Bridge" sample was not toxic to speckled trout but was toxic to rainbow trout and Daphnia magna.

..../2

The results of chemical analyses conducted on these samples are summarized in Table 2. These results indicate that the "Settling pond outlet" contained 60 mg/L of ammonia-nitrogen, which at the pH of this sample would be sufficient to account for the observed mortality in all three species (Trussell 1972; Russo and Thomann 1978). Similarly, the "Swamp outflow to river" sample contained enough ammonia (21.7 mg/L) to be toxic to the two trout species, but not enough to be toxic to Daphnia magna. Therefore, ammonia was identified as the primary cause of the observed toxicity of these samples.

The "Upstream, near Highway 101 Bridge" sample was soft (hardness = 18 mg/L as $CaCO_3$) and had an acidic pH of approximately 5. Studies in our laboratory indicate that under these conditions, the level of aluminum found in the sample (0.67 mg/L) would be toxic to rainbow trout if it was in the dissolved form (EP, Atlantic Region, unpublished data). It thus appears that aluminum, combined with the low pH and hardness of the sample, may have been the cause of its observed toxicity to rainbow trout. The low pH and low hardness of the sample would be sufficient to account for the Daphnia magna mortalities. The "Island, 100m downstream" sample was not toxic to any of the test species despite having similar hardness and aluminium values to the "Upstream, near Highway 101 Bridge" sample. The downstream sample had a higher pH than the upstream one (6.4-7.0 versus 5 in the upstream sample), and unpublished studies in our laboratory indicate that this would have lowered the toxicity of the aluminium present in this sample, thus accounting for its lack of toxicity.

A review of the scientific literature on the toxicity of landfill leachates reveals that other authors have also found ammonia to be an important component of the leachates (Cameron and Koch, 1980; Van Collie et al, 1989). Other important parameters identified in these studies, such as cyanide and tannins, were not measured in the present study but should be considered for future monitoring at this site. It would also be useful to measure dissolved aluminium (as well as total) in future. In addition, I suggest that this study should be repeated during conditions of low river flow, to obtain an indication of the risk posed by this leachate under low-flow conditions.

One copy of each Bioassay Report is attached, which provide additional information about the tests. Please pass these results on to Shane O'Neil of DFO, and if either you or Shane have any questions concerning these results, please contact me (426-3284) or Suzanne Wade (426-8491).

Kenneth G. Doe

K. G. Doe

KGD/SJW/dg

Attachments

cc: H. Samant
S. Wade
P. Hennigar
B. Horne
G. Julien
H. Windsor, NSDOE

Table 1: **Summary of Toxicity Test Results on Samples Collected at or near the Highway 101 Landfill Site**

MATERIAL TESTED	RAINBOW TROUT 96-hr. LC50	SPECKLED TROUT 96-hr. LC50	<u>DAPHNIA</u> <u>MAGNA</u> 48-hr. LC50
Settling pond outlet	24% (C.L.* = 18-32%)	42% (C.L. = 32-56%)	75% (C.L. = 56-100%)
Swamp outflow to river	75% (C.L. = 56-100%)	74% (C.L. = 56-100%)	NAL **
Island, 100m downstream	NAL	NAL	NAL
Upstream, Highway 101 Bridge	<100%	NAL	75% (C.L. = 56-100%)

* C.L. = 95% Confidence Limits
** NAL = Not Acutely Lethal

<u>50%</u> at <u>24%</u> effluent

Table 2: Summary of Results of Chemical Analyses on Samples Collected at or near the Highway 101 Landfill Site. L = Less Than; G = Greater Than.

√ S5

Parameter *	Settling Pond Outlet	Swamp Outflow to River	Upstream Highway 101 Bridge	Island, 100m Downstream
Ammonia-N	60.0	21.7	L0.14	0.3
Sulfide	L0.16	L0.16	L0.16	L0.16
Hardness	610	220	18	16
Conductivity	1.74	0.745	0.101	0.0991
Turbidity	17.0	2.5	0.65	1.4
Alkalinity	870	410	"low pH"	2.6
BOD	G760	120	L10	L10
Total Solids	2000	580	190	75
Magnesium	48.6	19.1	1.4	1.32
Sulphate	60.7	2.2	18.6	15.8
Arsenic	0.41	0.27	L0.05	L0.05
Cadmium	L0.01	L0.01	L0.01	L0.01
Copper	L0.01	L0.01	L0.01	L0.01
Iron	7.57	2.96	0.49	0.68
Lead	L0.02	L0.02	L0.02	L0.02
Zinc	0.16	0.01	0.03	0.02
Total Carbon	660	140	11.2	12.0
Nickel	0.05	0.01	L0.01	L0.01
Manganese	2.55	1.32	0.41	0.40
Chloride	182	71.2	14.9	23.4
Aluminum	0.44	0.17	0.67	0.95
Fluoride	L0.25	L0.25	L0.25	L0.25
Potassium	135	45.7	L0.01	L0.01
Chromium	0.03	L0.01	L0.01	L0.01

* NB: All values expressed in mg/L except Conductivity (mmho/cm) and Turbidity (JTU).

REFERENCES CITED:

1. Cameron, R.D., and F.A. Koch. 1980. Toxicity of landfill leachates. Journal of the Water Pollution Control Federation. 52(4): 760-769.

2. Russo, R.C., and R.V. Thomann. 1978. Ammonia and nitrite toxicity to fishes. Pages 75-82. In: Proceedings of the First and Second USA-USSR Symposia on the Effects of Pollutants upon Aquatic Ecosystems. Volume II. US Environmental Protection Agency. EPA-600/3-78-076. PB 287 219. August, 1978.

3. Trussell, R.P. 1972. The percent un-ionized ammonia in aqueous ammonia solutions at different pH levels and temperatures. J. Fish. Res. Bd. Canada. 29: 1505-1507.

4. Van Collie, R., N. Bermingham, C. Blaise, R. Vezeau, and J. S. S. Lakshminarayana. 1989. Integrated ecotoxicological evaluation of effluents from dump sites. Pages 161-191. In: J.O. Nriagu and J. S. S. Lakshminarayana (Editors). Aquatic Toxicology and Water Quality Management. John Wiley and Sons. ISBN 0-471-61551-X.

Table 5. THE ONTARIO EFFLUENT MONITORING PRIORITY POLLUTANTS LIST

CHEMICAL NAME	CHEMICAL ABSTRACT NUMBER	TOXICOLOGY ENVIR. FATE	USE RELEASE	EPA PPL	LAB CAP	MUNICIPAL SECTOR	INDUSTRIAL SECTORS	PETROLEUM REFINING	PULP AND PAPER	ORGANIC CHEMICALS	INORGANIC CHEMICALS	IRON & STEEL	ELECTRIC POWER	INDUSTRIAL MINERALS	MINING & REFINING
Dimethyl disulphide	624920	P-III	B		N	8									
2,4-Dimethylphenol	105679	P-I	B	X	Y	4	X	1	3			2			
4,6-Dinitro-o-cresol	534521	P-I	B	X	Y		X	1							
2,4-Dinitrophenol	51285	P-I	B	X	Y	4	X	1							
2,4-Dinitrotoluene	121142	P-I	B	X	Y	4	X	1		6					
2,6-Dinitrotoluene	606202	P-I	B	X	Y	4	X	1		6					
1,4-Dioxane	123911	S-I	B		P	22	X			18,22,42	18	18			
Diphenylamine	122394	P-II	B		P		X			22,44	22				
Diphenyl ether	101848	P-III	B		Y	4	X			8					
Ethylene dibromide	106934	P-I	B		Y		X	1							
Eugenol	97530	P-III	B		N		X		3						
Fluoranthene	206440	P-II	B	X	Y	4	X	1, 6	3,5	6		2, 5			
Fluorene	86737	P-III	B	X	Y	4	X	6	5	6		2, 5			
Formaldehyde	50000	S-I	B		N		X			33,44					
Hexachlorobenzene	118741	P-I	B	X	Y	4, 6	X	1, 6	3	6, 7					
Hexachlorobutadiene (HCBD)	87683	P-I	B	X	Y	4, 6	X	1, 6		6, 7					
Hexachlorocyclopentadiene	77474	P-I	B	X	Y	4	X		3						
Hexachloroethane	67721	P-I	B	X	Y	4, 6	X	1, 6		6, 7					
Hydrazine	302012	S-I	B		N		X	44	18,44	44	44	18,44	44	44	18,44
Hydroxycyclohexane	108930	P-III	B		N		X		3						
2-Hydroxybiphenyl	90437	S-III	B		N	8									
4-Hydroxybiphenyl	92693	P-III	B		N	8									
Indeno(1,2,3-cd)pyrene	193395	P-III	B	X	Y	4	X	1	5	6		2, 5			
Indole	120729	P-III	B		Y	8,43,48	X					2			
Isopimaric acid	5835267	P-III	B		P		X		3						
Lead	7439921	P-I	B	X	Y	4	X	1	3, 5	7		5			
Levopimaric acid	79549	P-III	B		P		X		3						
Limonene	138863	P-III	B		N		X		3	8					
Mercapto benzothiazole	149304	P-III	B		N	8	X		8						
Mercury	7439976	P-I	B	X	Y	4	X	1	3	7					
Methylene chloride	75092	P-II	B	X	Y	4	X	1	3	6					
Methyl ethyl ketone	78933	P-III	B		Y		X		3						
n-Methylformamide	123397	P-III	B		N		X		3						
1-Methylnaphthalene	90120	P-III	B		Y	8	X	1	8	8	50	2			
2-Methylnaphthalene	91576	P-III	B		Y	8	X	1	8	8	50	2			
Methyl styrene	250013154	P-III	B		?		X			8					
Molybdenum	7439987	P-III	B		Y	4	X	1	3						
Naphthalene	91203	P-I	B	X	Y	4	X	1, 6	3, 5	6, 8		2, 5			
1-Naphthylamine	134327	P-I	B		N	4									
2-Naphthylamine	91598	P-I	B		N	4									
Neoabietic acid	471772	P-III	B		P		X		3						
Nickel	7440020	P-I	B	X	Y	4	X	1	3, 5	7		5			

Table 5. THE ONTARIO EFFLUENT MONITORING PRIORITY POLLUTANTS LIST

CHEMICAL NAME	CHEMICAL ABSTRACT NUMBER	TOXICOLOGY ENVIR. FATE	USE RELEASE	EPA PPL	LAB CAP	MUNICIPAL SECTOR	INDUSTRIAL SECTORS	PETROLEUM REFINING	PULP AND PAPER	ORGANIC CHEMICALS	INORGANIC CHEMICALS	IRON & STEEL	ELECTRIC POWER	INDUSTRIAL MINERALS	MINING & REFINING
Chorinated dibenzofurans *	n/a	P-III	B		Y	4									
Chorinated dibenzo-p-dioxins *	n/a	P-III	B		Y	4									
Chlorobenzene	108907	P-I	B	X	Y	4	X	1		6, 7					
Chlorodehydroabietic acid	57055386	P-III	B		?		X		46						
Chlorodibromomethane	124481	P-III	B	X	Y	4	X	1	3	7		2			
Chloroform	67663	P-I	B	X	Y	4	X	1, 6	3, 5	6, 7		2, 5			
Chloromethane	74873	P-III	B	X	Y	4	X	1							
bis(2-chloroethyl)ether	111444	P-I	B	X	Y	4	X	1							
bis(2-chloroisopropyl)ether	108601	P-III	B	X	Y	4	X	1		47					
bis(chloromethyl)ether	542881	P-I	B	X	N		X	1							
4-Chloro-3-methylphenol	59507	P-III	B	X	Y	4	X	1	3						
1-Chloronaphthalene	90131	P-I	B		Y	22									
2-Chloronaphthalene	91587	P-III	B	X	Y	4	X	1							
2-Chlorophenol	95578	P-I	B	X	Y	4	X	1							
4-Chlorophenylphenyl ether	7005723	P-I	B	X	Y	4	X	1							
Chromium	7440473	P-I	B	X	Y	4	X	1	3, 5	7		5			
Chrysene	218019	P-II	B	X	Y	4, 5	X	1, 6	5	6		2, 5			
Cobalt	7440484	P-I	B		Y	4	X	1	3	7					
Copper	7440508	P-I	B	X	Y	4	X	1	3	7		5			
* m-Cresol	108394	P-III	B		Y	4, 8	Y		8			2			
* o-Cresol	95487	P-III	B		Y	4, 8	X		3,8			2			
p-Cresol	106445	P-III	B		Y	4, 8	X		8			2			
Cyanide	57125	P-I	B	X	Y		X		3			5			
Dibenzo(a,h)anthracene	53703	P-I	B	X	Y	4	X	1		6		5			
2,6 Di-t-butyl-4 methylphenol	128370	P-III	B		N	8	X	47	8	8,47					
Di-n-butylphthalate	84742	P-I	B	X	P	4	X	1	3	8		2			
1,2 Dichlorobenzene	95501	P-I	B	X	Y	4	X	1,6		6, 7, 8					
1,3 Dichlorobenzene	541731	P-I	B	X	Y	4	X	1		6, 7, 8					
1,4 Dichlorobenzene	106467	P-I	B	X	Y	4, 5	X	1,6	5	6, 7, 8		5			
3,3' Dichlorobenzidine	91941	S-I	B	X	P	23	X			18,44			21		25
1,1-Dichloroethane	75343	P-I	B	X	?	4	X	1,6		6,7		5			
1,2-Dichloroethane	107062	P-I	B	- X	Y	4	X	1		6, 7					
trans-1,2 Dichloroethylene	156605	P-I	A		Y	4,12,23,24 32	X	25,32,33		25		12,25			25
1,2-cis-Dichloroethylene	156592	P-III	B		Y		X	1							
1,1-Dichloroethylene	75354	P-I	B	X	Y		X	1		6, 7		2			
2,4-Dichlorophenol	120832	P-I	B	X	Y	4	X	1	3	6					
2,6-Dichlorophenol	87650	P-III	B		?		X			6					
1,2 Dichloropropane	78875	P-I	B	X	Y	4	X	1		6, 7					
cis-1,3-Dichloropropylene	10061015	P-III	B		Y		X	1							
trans-1,3-Dichloropropylene	10061026	P-III	B		Y		X	1							
bis(2 ethylhexyl)phthalate	111817	P-I	B	X	P		X		3						

Table 5. THE ONTARIO EFFLUENT MONITORING PRIORITY POLLUTANTS LIST

CHEMICAL NAME	CHEMICAL ABSTRACT NUMBER	TOXICOLOGY ENVIR. FATE	USE RELEASE	EPA PPL	LAB CAP	MUNICIPAL SECTOR	INDUSTRIAL SECTORS	PETROLEUM REFINING	PULP AND PAPER	ORGANIC CHEMICALS	INORGANIC CHEMICALS	IRON & STEEL	ELECTRIC POWER	INDUSTRIAL MINERALS	MINING & REFINING
Abietic Acid	514103	P-III	B		P	43	X		3.43						
Acenaphthene	83329	P-III	B	X	Y	4	X	1, 6	5	6		2, 5			
Acenaphthene, 5-nitro	602879	S-I	B		Y		X			44					
Acenaphthylene	208968	P-III	B	X	Y	4	X	1, 6	5	6		5			
Acridine	260946	P-III	B		P		X					2			
Acrolein	107028	P-I	B	X	Y	4	X	1		6					
Acrylonitrile	107131	P-I	B	X	Y	[illegible]	X	1		6					
4-Allyl-1,2-dimethoxy benzene	93152	P-III	B		N		X		3						
Aluminum	7429905	P-III	B		Y		X	1		7					
4-Aminoazobenzene	60093	S-I	B		N		X			22,44					
Aniline	62533	P-I	B		N	22,29	X			22,30,44					
Anthracene	120127	P-I	B	X	Y	4	X	1, 6	5	6		2, 5			
Antimony	7440360	P-I	B	X	Y	4	X	1							
PCB 1016	12674112	P-III	B	X	Y	4									
PCB 1221	11104282	P-III	B	X	Y	4									
PCB 1232	11141165	P-III	B	X	Y	4									
PCB 1242	53469219	P-III	B	X	Y	4									
PCB 1248	12672296	P-III	B	X	Y	4									
PCB 1254	11097691	P-III	B	X	Y	4									
PCB 1260	11096825	P-III	B	X	Y	4									
Arsenic	7440382	P-I	B	X	Y		X	1	3			5			
Benzaldehyde	100527	P-III	B		N	43	X		3						
Benz(a)anthracene	56553	P-I	B	X	Y	4	X	6	5	6		2,5			
Benzene	71432	P-I	B	X	Y	4	X	1	3, 5	6, 7		2,5			
Benzeneacetonitrile	140294	P-III	B		N		X					2			
Benzidine	92875	S-I	B	X	N	20,25,26	X	20				20	21		20
Benzo(b)fluoranthene	205992	P-II	B	X	Y	4	X	1, 6	5			2			
Benzo(k)fluoranthene	207089	P-II	B	X	Y	4	X	1	5	6		2,5			
Benzo(g,h,i)perylene	191242	P-III	B	X	Y	4	X	1, 6	5	6		2,5			
Benzo(a)pyrene	50328	P-I	B	X	Y	4	X	1, 6	5	6		2,5			
*Benzyl alcohol	100516	P-I	B		N	22,29	X	22	22	22					22
Beryllium	7440417	P-I	B	~~X~~	Y	4	X	1							
Biphenyl	92524	P-I	B		P	4									
Bromoform	75252	P-I	B	X	Y	4	X	1		6, 7					
Bromomethane	74839	P-I	B	X	Y	4									
4-Bromophenyl phenyl ether	101553	P-I	B	X	Y	4	X	1							
1,3-Butadiene	106990	P-III	B		Y		X					2			
Butanal	123728	P-III	B		N		X		3						
Butylbenzylphthalate	85687	P-I	B	X	P	4	X	1							
Cadmium	7440439	P-I	B	X	Y	4	X	1	3	7		5			
Camphene	79925	P-III	B		Y		X		3						
Carbon tetrachloride	56235	P-I	B	X	Y	4	X	1	3	6, 7					

Table 5. THE ONTARIO EFFLUENT MONITORING PRIORITY POLLUTANTS LIST

CHEMICAL NAME	CHEMICAL ABSTRACT NUMBER	TOXICOLOGY ENVIR. FATE	USE RELEASE	EPA PPL	LAB CAP	MUNICIPAL SECTOR	INDUSTRIAL SECTORS	PETROLEUM REFINING	PULP AND PAPER	ORGANIC CHEMICALS	INORGANIC CHEMICALS	IRON & STEEL	ELECTRIC POWER	INDUSTRIAL MINERALS	MINING & REFINING
Trichlorofluoromethane	75694	P-III	B	X	Y	4	X	1							
Trichloroguaiacol	61966367	P-III	B		Y		X		46						
2,3,4-Trichlorophenol	15950660	P-I	B		Y		X		3						
2,3,5-Trichlorophenol	933788	P-III	B		Y		X	1		6					
2,4,5-Trichlorophenol	95954	S-I	B		?		X		3,20,22,25	6,20,22	22				
2,4,6-Trichlorophenol	88062	P-I	B	X	Y		X	1	3	6					
3,4,5-Trichlorophenol	609198	P-III	B		Y		X	1							
2,4,5-Trichlorotoluene	6639301	P-III	B		Y		X			7					
Triethyl lead	n/a	P-III	B		P		X	1							
Trimethylbenzenes	25551137	P-III	B		N		X	1							
Trimethylnaphthalene	2717422	P-III	B		Y		X			8, 42,49		2			
Vanadium	7440622	P-III	B		Y		X	1							
Vinyl bromide	593602	P-I	B		Y	4									
Vinyl chloride	75014	P-I	B	X	Y	4	X	1, 6							
o-Xylene	95476	P-I	B		Y	4	X	1, 6	3, 5			2, 5			
m-Xylene	108383	P-I	B		N	4	X	1, 6	3, 5			2, 5			
p-Xylene	106423	P-I	B		N	4	X	1, 6	3, 5			2, 5			
Zinc	7440666	P-I	B	X	Y	4	X	1	3, 5	7		5			

*Represents tetra-, penta-, hexa-, and octa- congeners.

Table 5. THE ONTARIO EFFLUENT MONITORING PRIORITY POLLUTANTS LIST

CHEMICAL NAME	CHEMICAL ABSTRACT NUMBER	TOXICOLOGY ENVIR. FATE	USE RELEASE	EPA PPL	LAB CAP	MUNICIPAL SECTOR	INDUSTRIAL SECTORS	PETROLEUM REFINING	PULP AND PAPER	ORGANIC CHEMICALS	INORGANIC CHEMICALS	IRON & STEEL	ELECTRIC POWER	INDUSTRIAL MINERALS	MINING & REFINING
1-Nitronaphthalene	86577	P-III	B		P		X			8					
2-Nitronaphthalene	581895	P-III	B		P		X			8					
4-Nitrophenol	100027	P-I	B	X	Y	4	X	1	3						
n-Nitrosodimethylamine	62759	P-I	B	X	P	4									
n-Nitrosodi-n-propylamine	621647	P-III	B	X	P	4	X	1							
n-Nitrosodiphenylamine	86306	P-I	B	X	Y	4	X	1	3						
Octachlorostyrene	29082744	P-I	B		Y	6	X	1,6		6, 7					
Oleic Acid	112801	P-III	B		P		X		3						
Pentachlorobenzene	608935	P-III	B		Y	6	X	1		6, 7					
Pentachlorophenol	87865	P-I	B	X	Y	4	X	1, 6	3	6					
Perylene	198550	P-III	B		Y		X					2			
Phenanthrene	85018	P-III	B	X	Y							2			
Phenol	108952	P-I	B	X	Y	4	X	1, 6	3, 5	6		2, 5			
Pimaric acid	127275	P-III	B		P		X		3						
Pyrene	129000	P-II	B	X	Y	4	X	1, 6	5	6		2, 5			
Selenium	7782492	P-I	B	X	Y	4	X	1							
Silver	7440224	P-I	B	X	Y	4	X	1							
Styrene	100425	P-I	B		Y	4	X	1	3	6		2, 5			
Tetrachloroacetone	31422614	P-III	B		?		X		3						
1,1,3,3-Tetrachloroacetone	632213	P-III	B		?		X		46						
1,2,3,4-Tetrachlorobenzene	634662	P-III	B		Y		X	1		6, 7, 8					
1,2,3,5-Tetrachlorobenzene	634902	P-III	B		Y		X	1		6,7,8					
1,2,4,5-Tetrachlorobenzene	95943	P-III	B		Y		X	6		6, 7, 8					
2,3,7,8-Tetrachlorodibenzo-p-dioxin	1746016	P-III	B	X	Y	4									
1,1,2,2-Tetrachloroethane	79345	P-I	A	X	Y	4, 12,23, 24,25,26,28 31,36	X	1,25,33	27,32	25,45		12,25 2	34		25
Tetrachloroethylene	127184	P-I	B	X	Y	4, 6	X	1	3, 5	6, 7					
Tetrachloroguaiacol	2539175	P-III	B		P		X		3						
2,3,4,5-Tetrachlorophenol	4901513	P-III	B		Y		X	1	3	6					
2,3,4,6-Tetrachlorophenol	58902	P-III	B		Y		X	1		6					
2,3,5,6-Tetrachlorophenol	935955	P-III	B		Y		X	1	3	6					
Tetraethyl lead	78002	P-III	B		P		X	1							
Thallium	7440280	P-I	B	X	Y	4	X	1							
Thiourea	62566	S-I	B		?		X		44	18,44			44		44
Toluene	108883	P-I	B	X	Y	4	X	1	3, 5	6, 7		2, 5			
Tributyl phosphate	126738	P-III	B		N		X		3	42,43,48	48	48			
1,1,3 Trichloroacetone	921039	P-III	B		?		X		46						
1,2,3 Trichlorobenzene	87616	P-I	B		Y		X			6, 7, 8					
1,2,4-Trichlorobenzene	120821	P-III	B	X	Y	4	X	1		6, 7, 8					
1,1,2-Trichloroethane	79005	P-I	B	X	Y	4	X	1		6, 7					
Trichloroethylene	79016	P-I	B	X	Y	4	X	1	3	6, 7		2			

Quick review of Nitrification/Denitrification rates during winter. Review taken from Cooper and Findlater (Constructed wetlands in water pollution control) and Hammer (Constructed wetlands for wastewater treatment).

Willadsen C.T., O. Riger-Kusk, and B. Ovist. 1990. Removal of nutritive salts from two Danish root zone systems. IN: Cooper P.F. and B.C. Findlater (eds). Constructed wetlands in water pollution control. IAWPRC Pergamon Press, Oxford

(Hjembaek Root Zone System):
"Nitrification is a temperature-dependent process (Standford et al. 1975). The increased outlet concentrations of NH3/NH4 from November and December may be due to temperatures of 3-4 C, respectively, in the discharge water.... Since the temperature of the discharge water in January and February 1989 was 6 and 5 C, respectively, it is doubtful, however, whether the difference in temperature alone explains the difference in the outlet concentration." see (FIGURE 1).

Bahlo K.E., and F.G. Wach. 1990. Purification of domestic sewage with and without faeces by vertical intermittent filtration in reed and rush beds. IN: Cooper P.F. and B.C. Findlater (eds). Constructed wetlands in water pollution control. IAWPRC Pergamon Press, Oxford

Bahlo and Wach describe a reed bed system in lower Saxony (FRG). With a detention period of 27 days, their system was able to support extensive mineralization of N. "Although ammonia concentration of the effluents was comparatively high, the elimination of ammonia in the reed bed reached about 70% on average. It is remarkable that in the winter months clear nitrification took place, which became nearly complete in the summer (June 1989). The extended nitrification was also expressed in a significant decrease of the pH-values of the reed bed effluents." (FIGURE 2).

Christian J.N.W. 1990. Reed bed treatment systems: experimental gravel beds at Gravesend - The southern water experience. IN: Cooper P.F. and B.C. Findlater (eds). Constructed wetlands in water pollution control. IAWPRC Pergamon Press, Oxford

Southern Part of England:
"The removal of ammonia, either by conversion to nitrate or subsequent denitrification has been disappointing (as observed in most U.K. reed beds). As the reed beds mature ammonia removal may improve." Since data show virtually no ammonia removal at any time of year, singling out the winter as bad is not possible (FIGURE 3).

van Oostrom A.J. and R.N. Cooper. 1990. Meat processing effluent treatment in surface-flow and gravel-bed constructed wastewater wetlands. IN: Cooper P.F. and B.C. Findlater (eds). Constructed wetlands in water pollution control. IAWPRC Pergamon Press, Oxford

Pilot scale surface flow gravel bed in North Island, New Zealand:
"The concentration of nitrogen in the influent ranged between 93 and 167 mg/L and was generally 15 to 30 mg/L in the effluent. On average there was no significant difference between wetland effluents (Glyceria vs. Schoenoplectus vs. control). However taking into account the differences in evapotranspiration and nitrogen loading rates, the planted wetlands had higher mass nitrogen removal rates." Nitrogen removal by wetlands was extremely variable, but on average, increased removal rates occurred at higher loading rates. Total one year removal rates were 0.1 g/sq. m/day. No mention made of seasonality, although removal rates look lower in winter than in summer (note Nov-Dec 1988; FIGURE 4).

Davies T.H., and B.T. Hart. 1990. Reed bed treatment of wastewaters in a pilot-scale facility. IN: Cooper P.F. and B.C. Findlater (eds). Constructed wetlands in water pollution control. IAWPRC Pergamon Press, Oxford

Southern Australia:
"Ammonia nitrogen removal was quite good in the first summer, but then reduced rapidly to a low value in winter, but improved significantly in the spring. The combined nitrite and nitrate levels were consistently low at all times suggesting that any conversion of ammonia to this form by nitrification is rapidly converted to nitrogen gas by denitrification, i.e. the nitrification step is the limiting one in the ultimate removal of nitrogen compounds by denitrification." (FIGURE 5)

Gersberg R.M., S.R. Lyon, R. Brenner, and B.V. Elkins. 1989. Integrated wastewater treatment using artificial wetlands: A gravel marsh case study. IN: Hammer D.A. (ed.) Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea MI.

Southern California:
"The capability of wetlands to remove nitrogen through denitrification is well established. Denitrification is an anaerobic respiration whereby nitrate or nitrite is used as the terminal electron acceptor for oxidation of organic compounds, and is ultimately reduced to the gaseous end products N_2O or N_2.; The process is the most successful procedure for removal of nitrate from secondary effluents and agricultural return flows."

"Our studies of artificial wetlands at Santee have demonstrated sustained high rates of denitrification (>95% removal) at secondary wastewater application rates as high as 102 cm/day when methanol was added as an electron donor to drive denitrification."

"When nitrogen is in the form of ammonia (as in primary wastewaters), biological nitrogen removal can be accomplished by sequential nitrification -denitrification, whereby the ammonia is first oxidized aerobically to nitrate by nitrifying bacteria, which is then denitrified to N2 gas in anaerobic microenvironments. Artificial wetlands with permeable soils can sustain relatively rates of sequential nitrification-denitrification due to the alternating aerobic anaerobic conditions formed at the soil rhizosphere interfaces. At primary wastewater applications of about 5 cm/d (5 mL/sq. cm/d) total nitrogen removals above 80% were observed in both bulrush and reed artificial wetland beds."

"Under conditions where dissolved organic carbon is not limiting, the factor most limiting nitrogen removal appears to be the supply of O_2 necessary to sustain nitrification. In this regard, an oxidized rhizosphere where nitrification, can proceed, is an important factor. Capacity for ammonia removal by vegetated versus unvegetated artificial wetland beds is shown in figure 2." (FIGURE 6).

"We measured a 94% removal for bulrush wetlands, 78% for reeds, and 28% for cattails as compared with only 11% for unvegetated beds. Clearly sequential nitrification-denitrification was impeded in the unvegetated bed. This and other evidence suggest that nitrifying bacteria can be directly stimulated by oxidizing abilities of the plant rhizome. Hence aquatic plants perform a function analogous to a compressor supplying air to an activated sludge tank." No mention was made of seasonality which is clearly shown in FIGURE 6.

Watson J.T., S.C. Reed, R.H. Kadlec, R.L. Knight, and A.E. Whitehouse. 1989. Performance expectations and loading rates for constructed wetlands. IN: Hammer D.A. (ed.) Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea MI.

"Nitrogen is removed in surface and subsurface flow wetlands by similar mechanisms. Total nitrogen removals up to 79% are reported at nitrogen loading rates of up to 44 kg N/ha/d. Although uptake of nitrogen occurs, only a minor fraction can be removed by plants. At Listowel, harvested plant material accounted for less than 10% of the nitrogen removed by the system. Plant uptake at Santee, California was 12-16%."

"Nitrogen is most effectively removed by nitrification/ denitrification. Ammonia is oxidized to nitrate by nitrifying bacteria in aerobic zones, and nitrates are converted to free nitrogen in the anoxic zones by denitrifying bacteria. In subsurface flow systems, oxygen required by the nitrifiers is supplied by leakage from plant roots. The depth of the bed and the type of plant used can make a significant difference. At Santee, with the same bed depth for all channels, the bulrush (Scirpus) system removed 94% of applied nitrogen, while reeds, cattails and unvegetated beds achieved 78%, 28%, and 11%, respectively. The root zone of the bulrushes and reeds extended to >60cm and 76 cm respectively, while most of the root biomass of the cattails was confined to the top 30 cm of substrate. Thus, bed depth in subsurface flow systems should be matched to potential root penetration depth for selected vegetation. Nitrification will not occur in any flow beneath the root zone."

"Nitrification was incomplete in the surface flow system at Listowel during periods of anoxia. In summer, this was caused by high oxygen demand for organic decomposition. Oxygen mass transfer limits nitrification in attached growth systems. This problem can be minimized by recirculation, which dilutes ammonia concentrations and increases the dissolved oxygen concentrations in the wetlands influent."

"At Listowel, oxygen transfer in winter was limited by the ice cover, so low oxygen levels and low temperatures limited nitrification. In trickling filter and rotating biological contactor systems, significant levels of nitrification by attached growth organisms require a temperature of 5-7 C. This may be a significant process limitation for surface flow wetlands in cold climates if year round nitrification is required."

"Nitrification cannot be completed without adequate alkalinity. Approximately 7 mg alkalinity is required for oxidation of 1 mg of ammonia nitrogen. Alkalinity losses due to nitrification are partially offset by alkalinity produced by reduction of nitrate and sulphate. If additional alkalinity is needed, it can be supplemented with a limestone substrate. Other factors important to the nitrification process are (1) minimizing carbonaceous oxygen demand so slower-growing nitrifiers can compete with heterotrophic organisms; (2) maintaining pH within the optimum range of 7 to 8; (3) establishing adequate retention time (at least 5 days based on available data); (4) limiting toxics (certain heavy metals and organic compounds inhibit nitrifiers)."

"Fortunately, denitrification readily occurs in wetlands systems when sufficient dissolved carbon is present. Nitrate removal efficiency of greater than 95% is realistic. Denitrification occurs in reduced zones of the substrate and litter layer."

Steiner G.R., and R.J. Freeman Jr. 1989. Configuration and substrate design considerations for constructed wetlands wastewater treatment. IN: Hammer D.A. (ed.) Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea MI.

"Climate can influence system type because and SSF (subsurface flow) cell will be less affected by cold temperatures and freezing than an SF (surface flow) cell. Plant cover and litter will insulate the surface of an SSF cell, reducing freezing effects. In an SF cell, ice eliminates surface reaeration and overlying snow restricts solar radiation, affecting photosynthesis and related biological processes. An SF cell requires higher berms so that water depth can be increased in winter to compensate for detention volume lost to ice cover."

Brix H. and H.-H. Shierup. 1989. Management of domestic and municipal wastewaters. Danish Experience with sewage treatment in constructed wetlands. IN: Hammer D.A. (ed.) Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea MI.

"Performance for TP and TN was poor during the initial year, but seemed to improve thereafter.... However, there was no improvement from the second to the third year. The principal form of N in the influent was ammonia..., and the same was true of the effluent. During the second and third years, some NO_3 occurred in the effluent indicating that nitrification occurred in the bed, but the rate was too low to be of quantitative significance for removal of N in the bed."

The Danish effluent standard for TN in large sewage plants is 8 mg/L. This criterion cannot be fulfilled by reed beds because effluent concentrations for TN are typically 20-30 mg/L. Nitrification seems to be the critical process." (FIGURE 7)

"Hydraulic loading rate is particularly important regarding performance for N and P. Only systems with loading rates below 2 cm/day, have removal efficiencies better than 50%. These removal rates can be ascribed to the generally low hydraulic conductivities of reed bed soils. If the loading rate is increased beyond 2 cm/day, a major proportion of the sewage runs off on the surface. If this occurs, no correlation between organic loading rate and removal efficiency was observed."

James B.B. and R. Bogaert. 1989. Wastewater treatment/disposal in a combined marsh and forest system provides for wildlife habitat and recreational use. IN: Hammer D.A. (ed.) Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea MI.

Martinez, CA (Near San Francisco):
They have seasonality data, but do not mention much about it, other than to say that the algae in the summer and the trees in the fall are the largest consumers of the nitrogen. FIGURE 8 and 9.

(Stanford G, S. Dzienia, R.A. Vander Pol. 1975. Effect of temperature on denitrification rate in soils. Soil Sci. Soc. Amer. Proc. 39: 867-870.)

Water level references: Kadlec R.H., D.E. Hammer, and M.A. Girts. 1990. A total evaporative constructed wetland treatment system. IN: Cooper P.F. and B.C. Findlater (eds). Constructed wetlands in water pollution control. IAWPRC Pergamon Press, Oxford

Allen H.H., G.J. Pierce, and R. van Wormer. 1989. Considerations and techniques for vegetation establishment in constructed wetlands. IN: Hammer D.A. (ed.) Constructed Wetlands for Wastewater Treatment: Municipal, Industrial and Agricultural. Lewis Publishers, Chelsea MI.

Figure 1:

Figures 1a, 1b, and 2 show a picture of the analysis results for ammonium and total nitrogen.

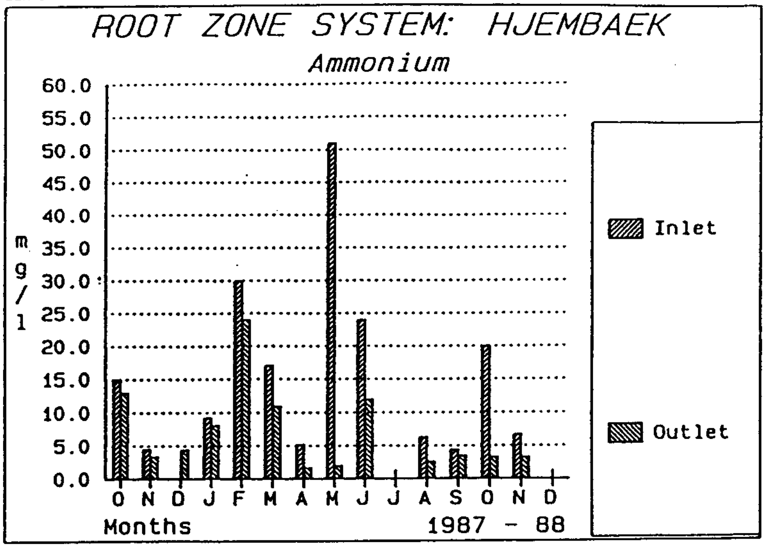


Fig. 1a. Ammonium concentration at inlet and outlet - Hjembaek 1987-88.

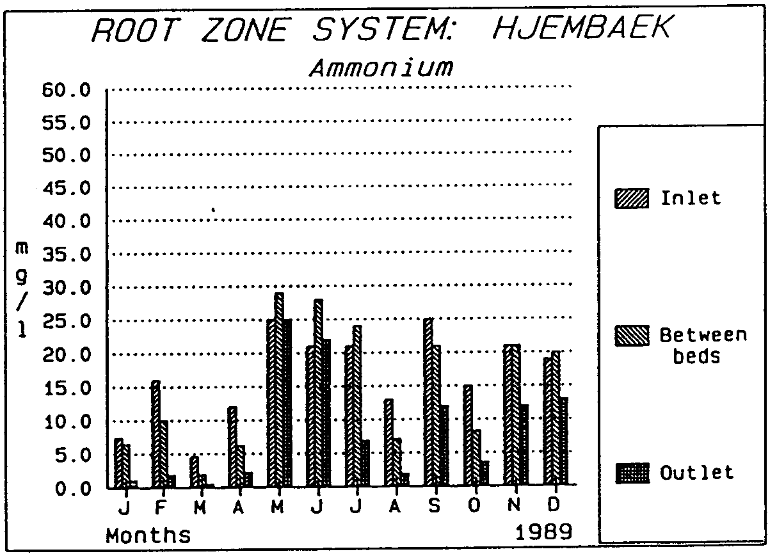


Fig. 1b. Ammonium concentration at inlet, between beds, and outlet - Hjembaek 1989.

Figure 2:

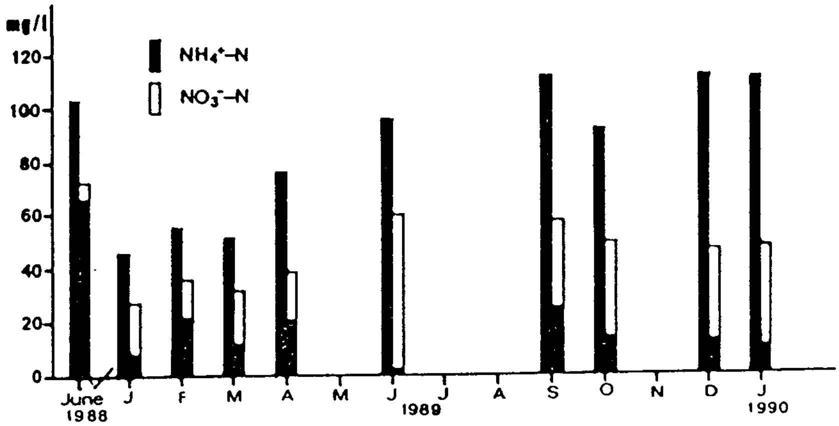


Fig. 2. Elimination of ammonia and nitrate; left bars: septic tank effluent, right bars: effluent of reed bed

Figure 3:

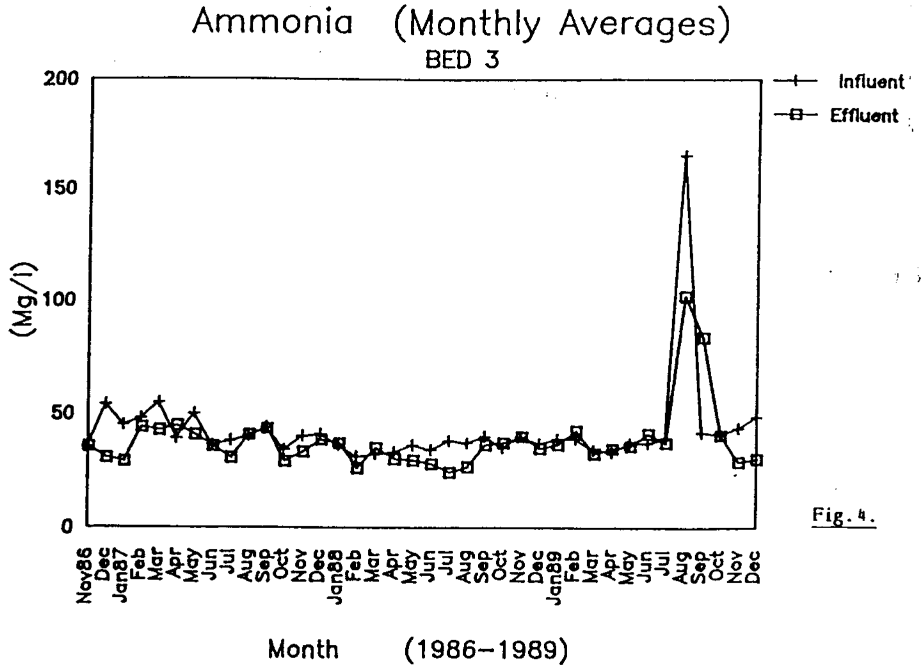

Ammonia (Monthly Averages)
BED 3

Fig. 4.

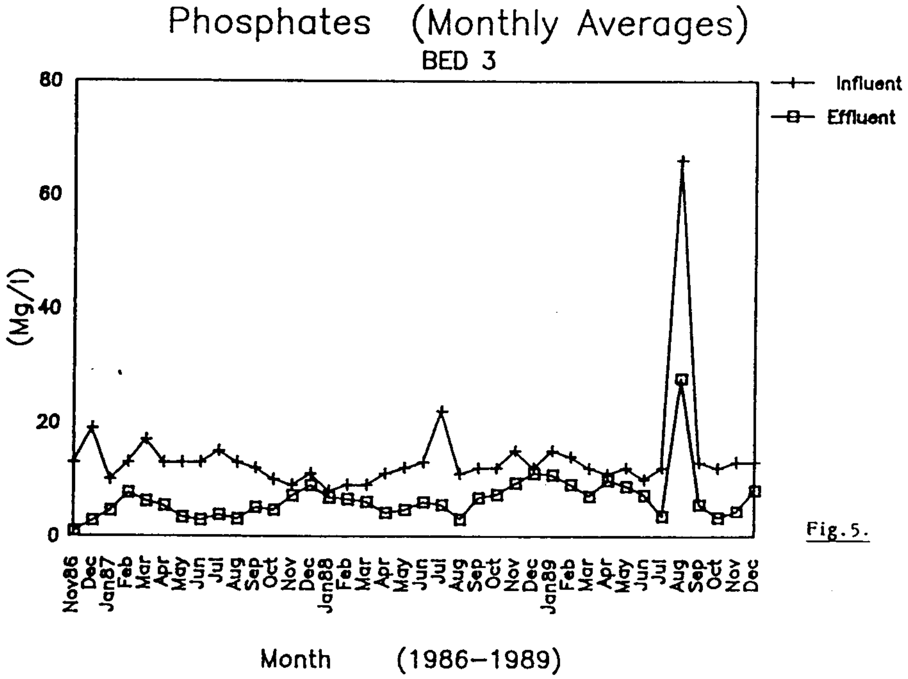

Phosphates (Monthly Averages)
BED 3

Fig. 5.

Figure 4:

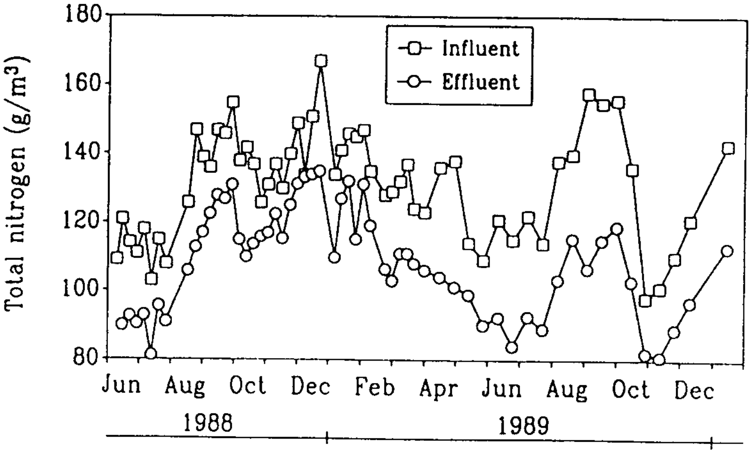


Fig. 7. Total nitrogen concentrations in the influent and effluent of the *Glyceria* wetland.

Figure 5:

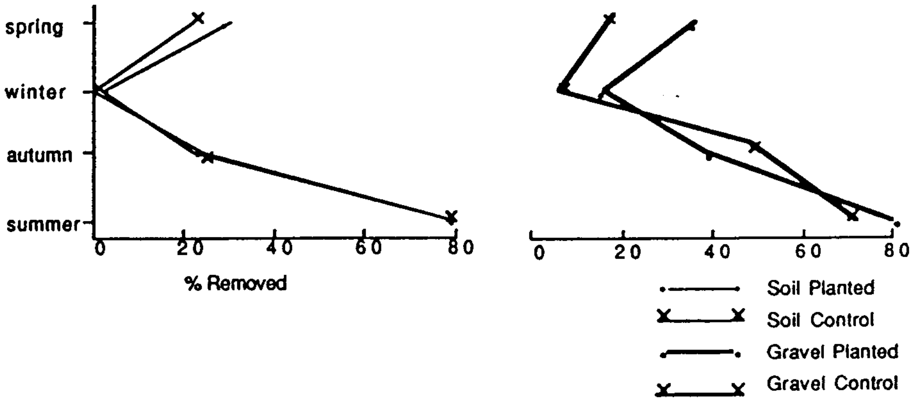


Fig 3 Ammonia N % Removal by Seasons

Figure 6:

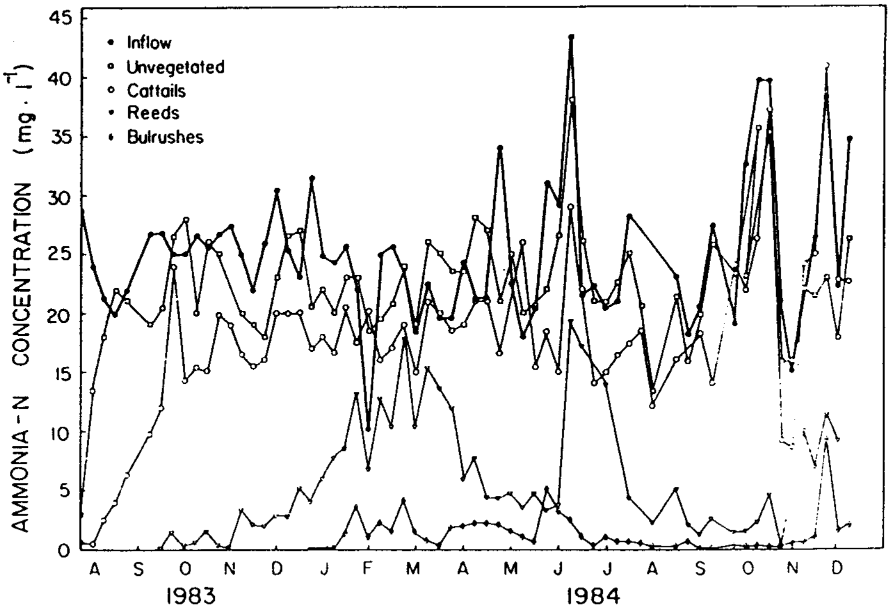


Figure 2. Level of ammonia nitrogen in the inflow and effluent of the vegetated and unvegetated beds, at a primary wastewater application rate of 5 cm/day.

Figure 7:

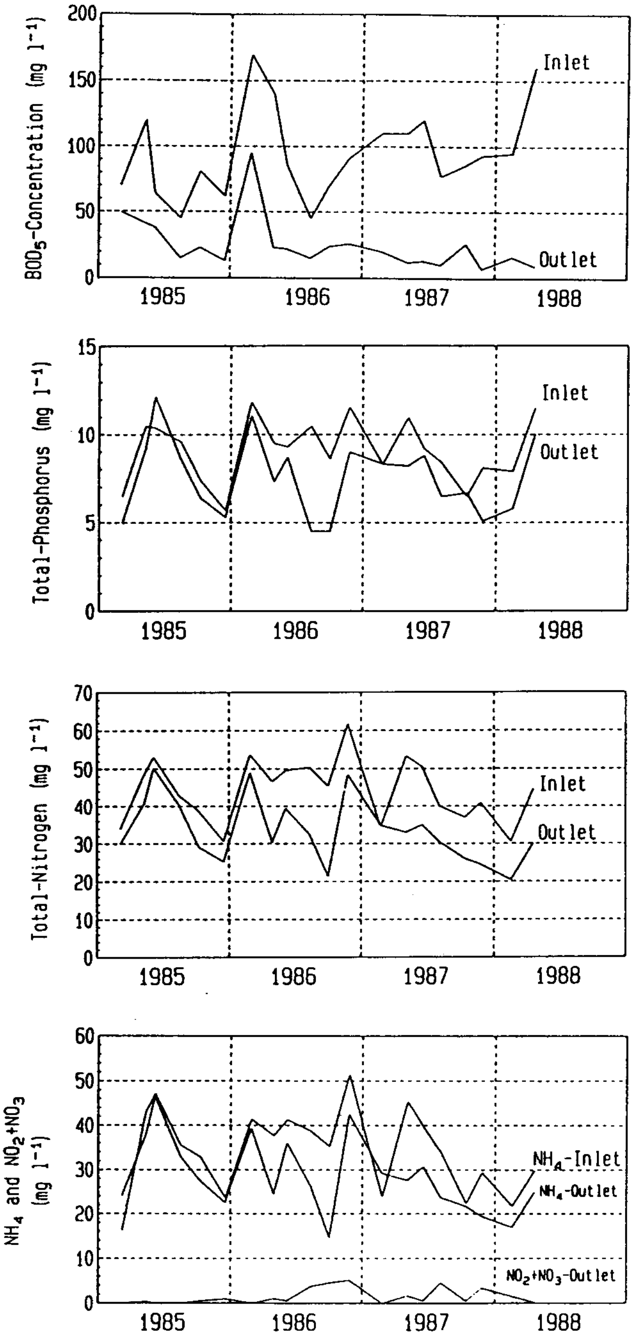


Figure 2. Seasonal variations in inlet and outlet concentrations (mg/L) of (a) BOD$_5$, (b) total phosphorus, (c) total nitrogen, and (d) NH$_4$ and NO$_2$ + NO$_3$ in the constructed reed bed at Kalo (site 14). (Inlet concentrations of NO$_2$ + NO$_3$ were <0.5 mg/L).

Figure 8:

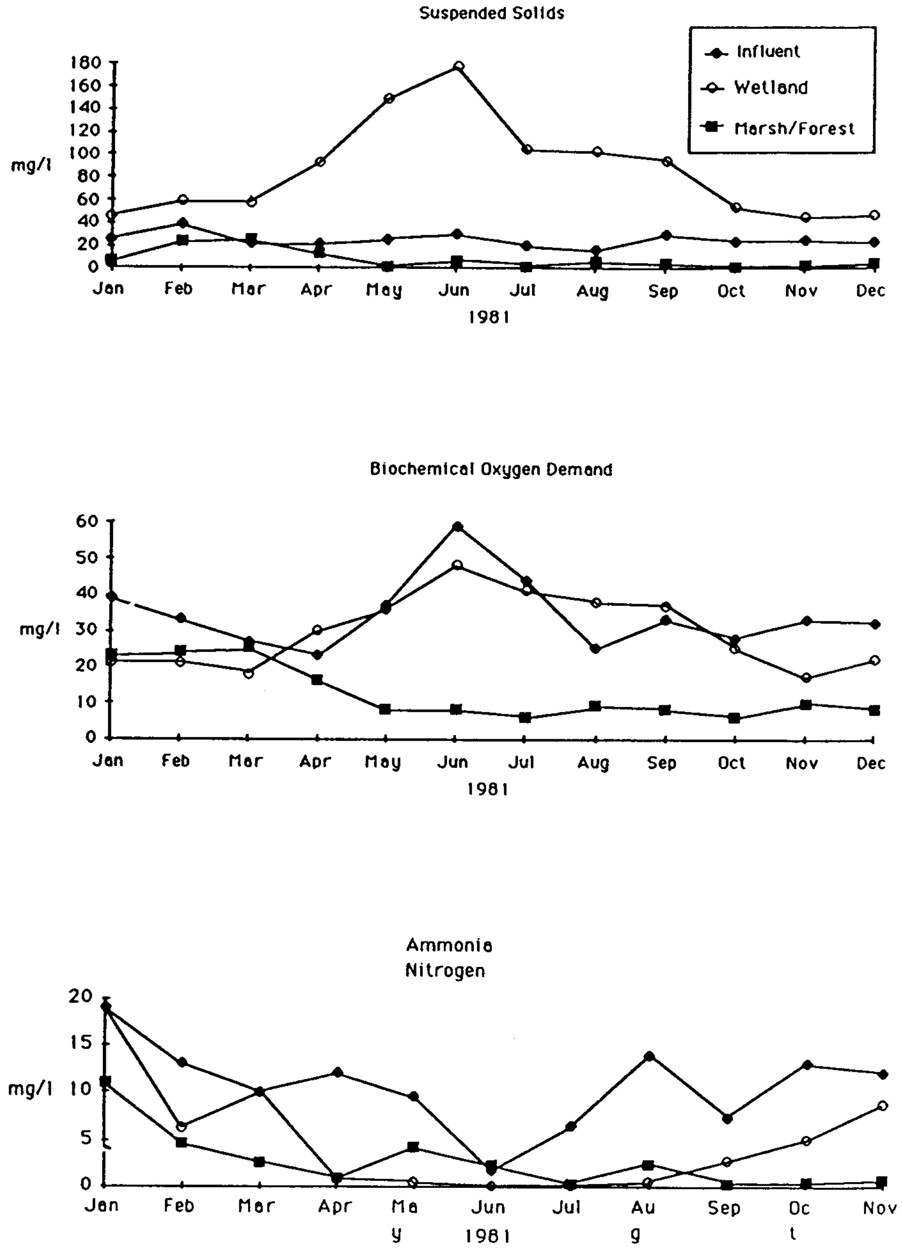


Figure 2. Suspended solids, BOD_5, and ammonia nitrogen in the wetlands and marsh/forest influent and discharges.

Figure 9:

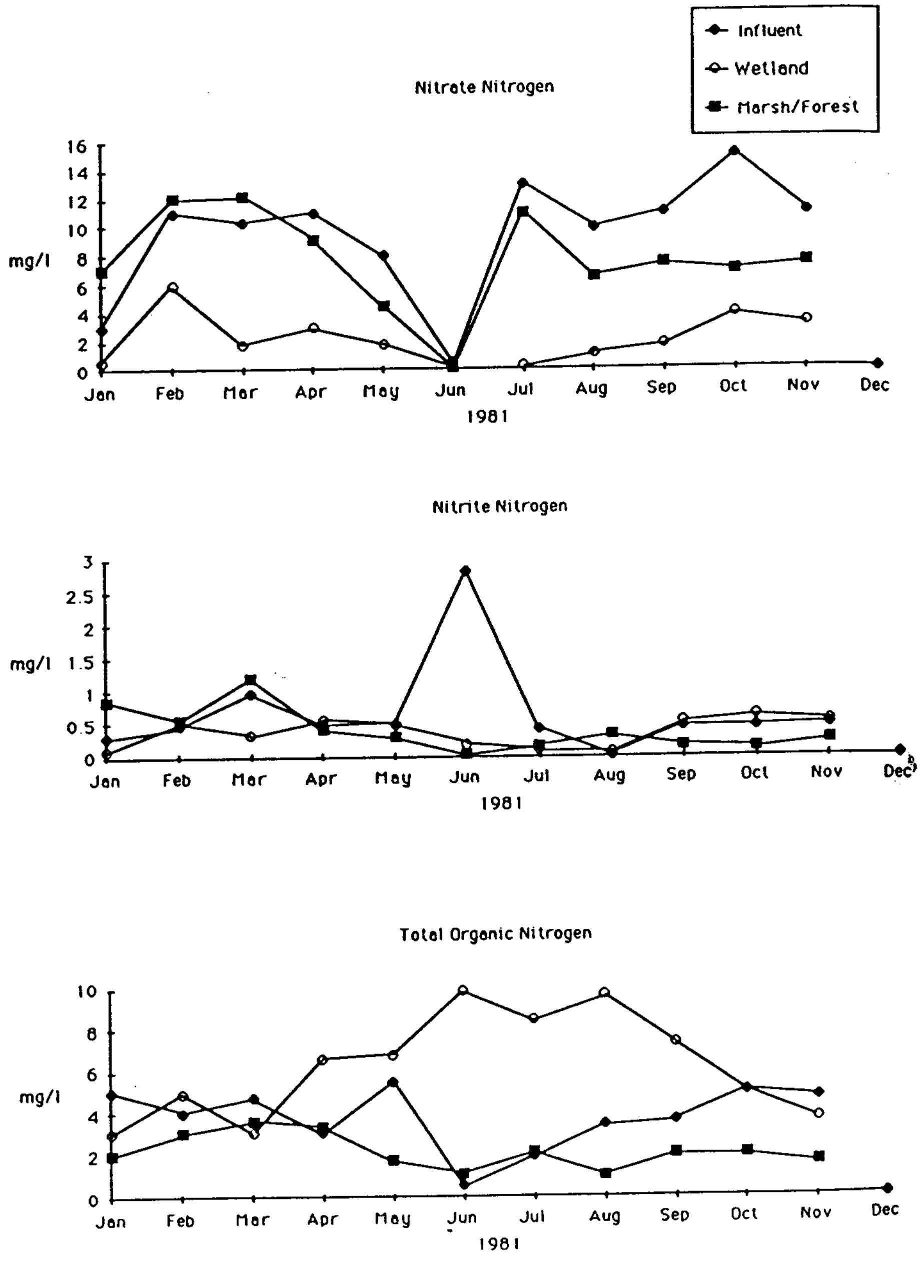


Figure 3. Nitrate, nitrite, and total organic nitrogen in the wetlands and marsh/forest influent and discharges.

Figure 1:

Figures 1a, 1b, and 2 show a picture of the analysis results for ammonium and total nitrogen.

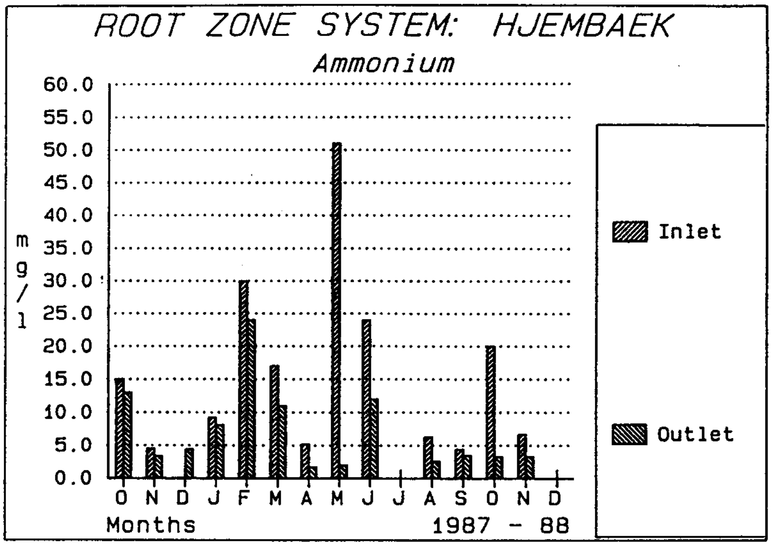


Fig. 1a. Ammonium concentration at inlet and outlet - Hjembaek 1987-88.

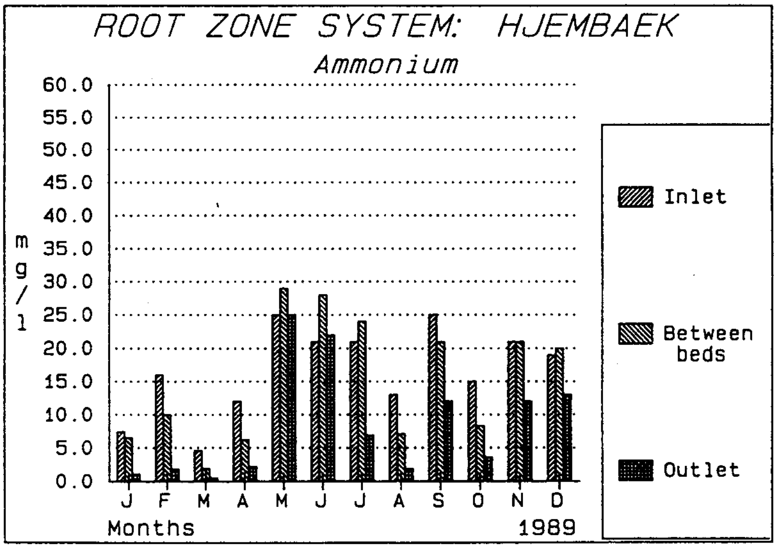


Fig. 1b. Ammonium concentration at inlet, between beds, and outlet - Hjembaek 1989.

Figure 2:

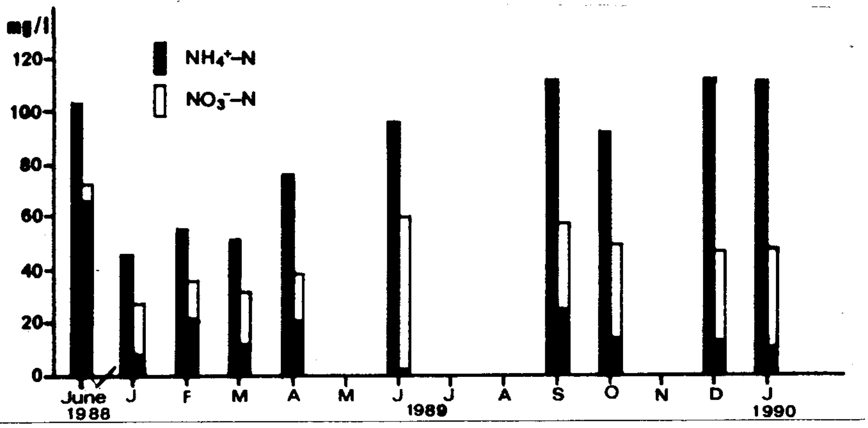
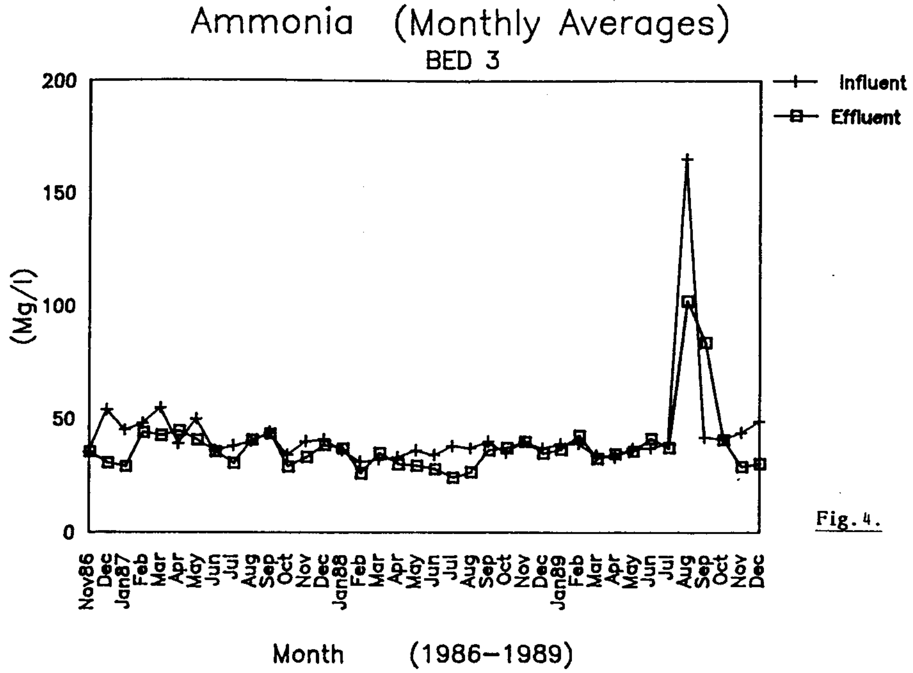


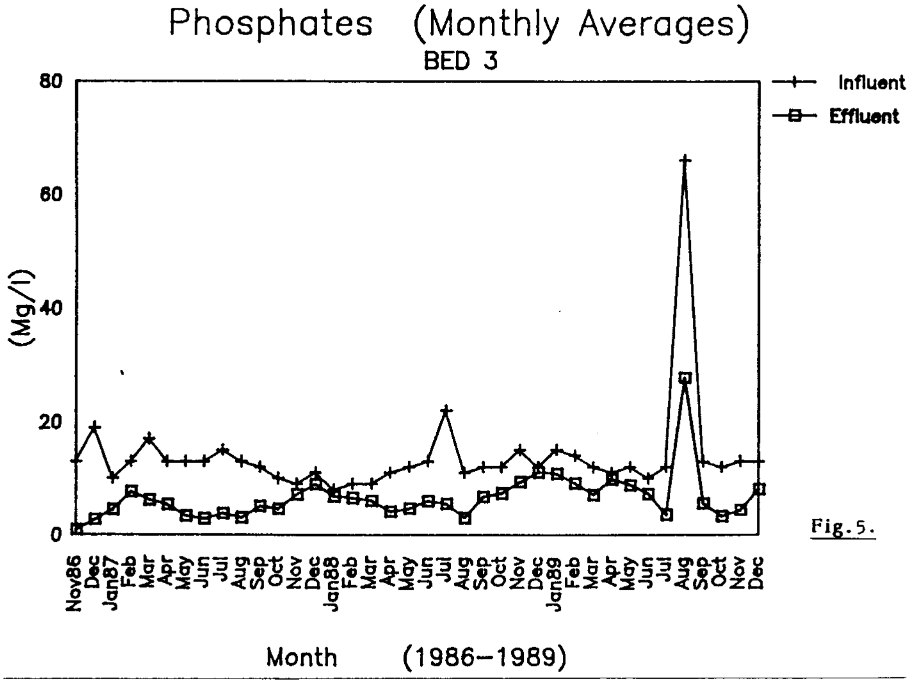
Fig. 2. Elimination of ammonia and nitrate; left bars: septic tank effluent, right bars: effluent of reed bed

Figure 3:


Ammonia (Monthly Averages)

BED 3

Fig. 4.


Phosphates (Monthly Averages)

BED 3

Fig. 5.

Figure 4:

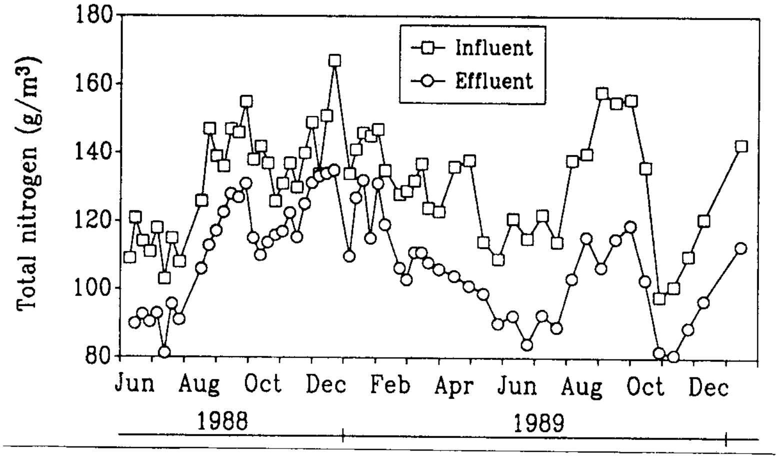


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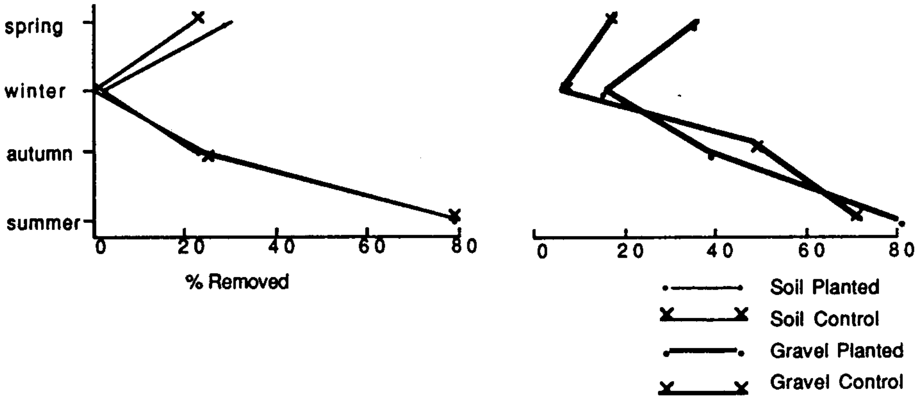
Fig 3 Ammonia N % Removal by Seasons



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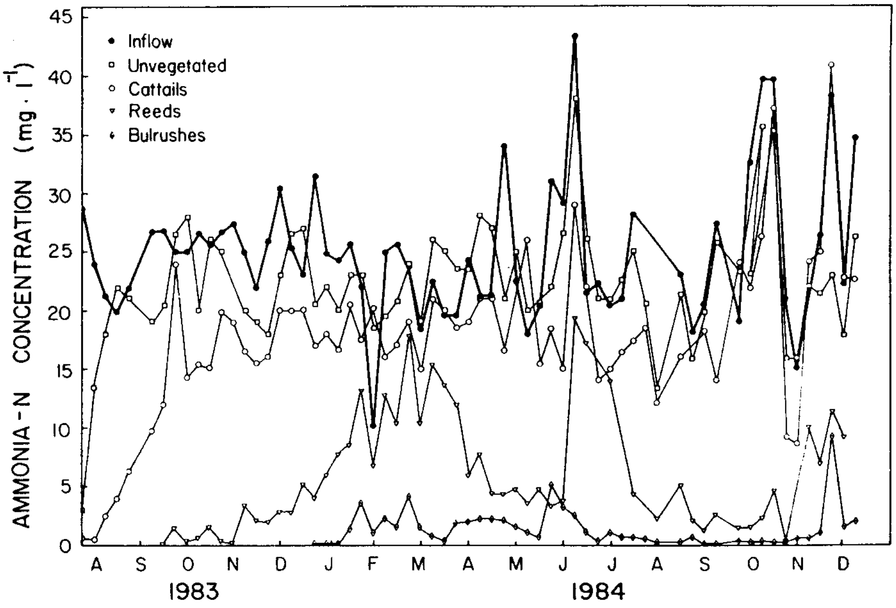

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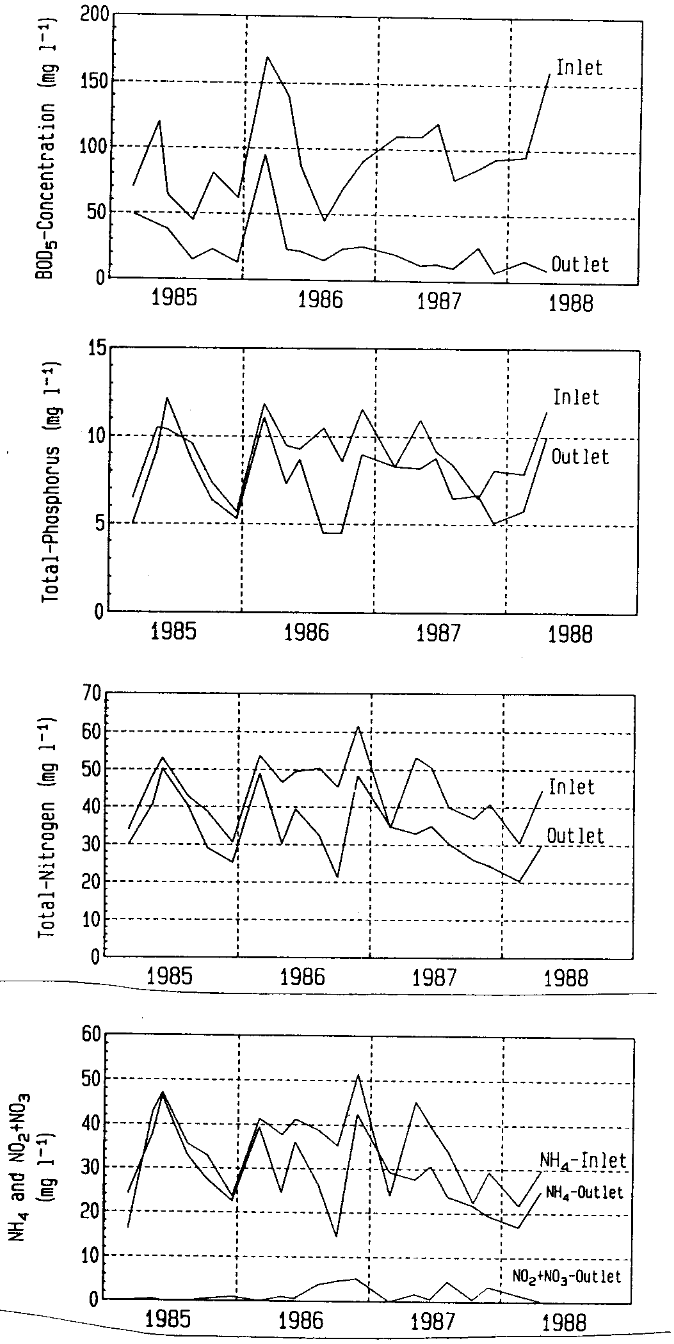

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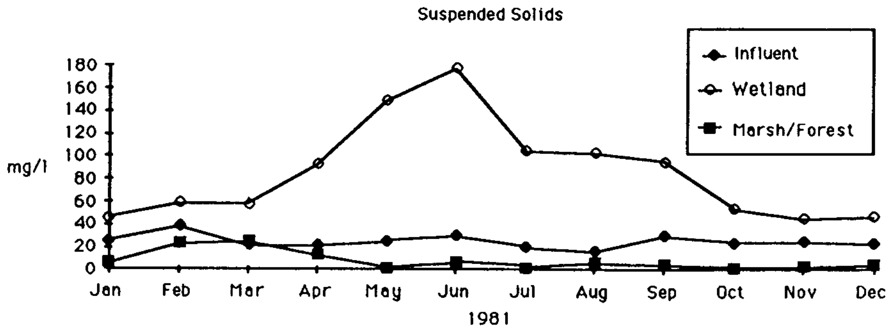

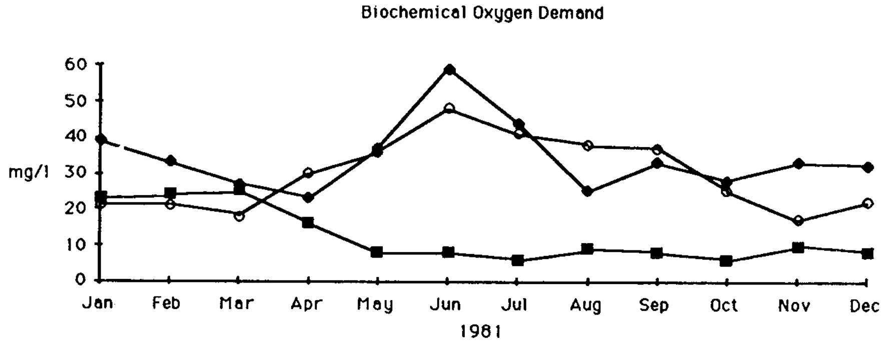

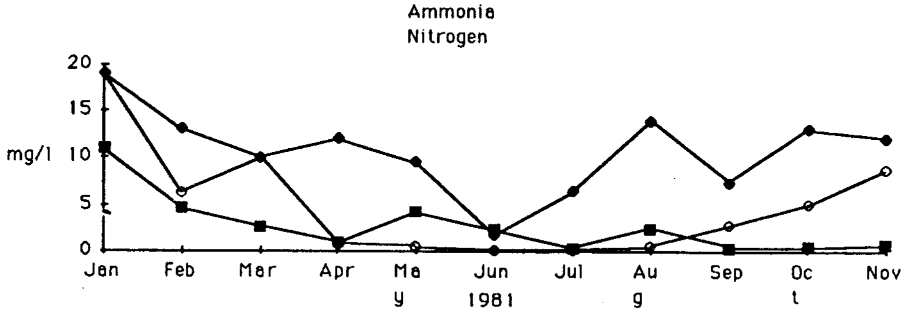

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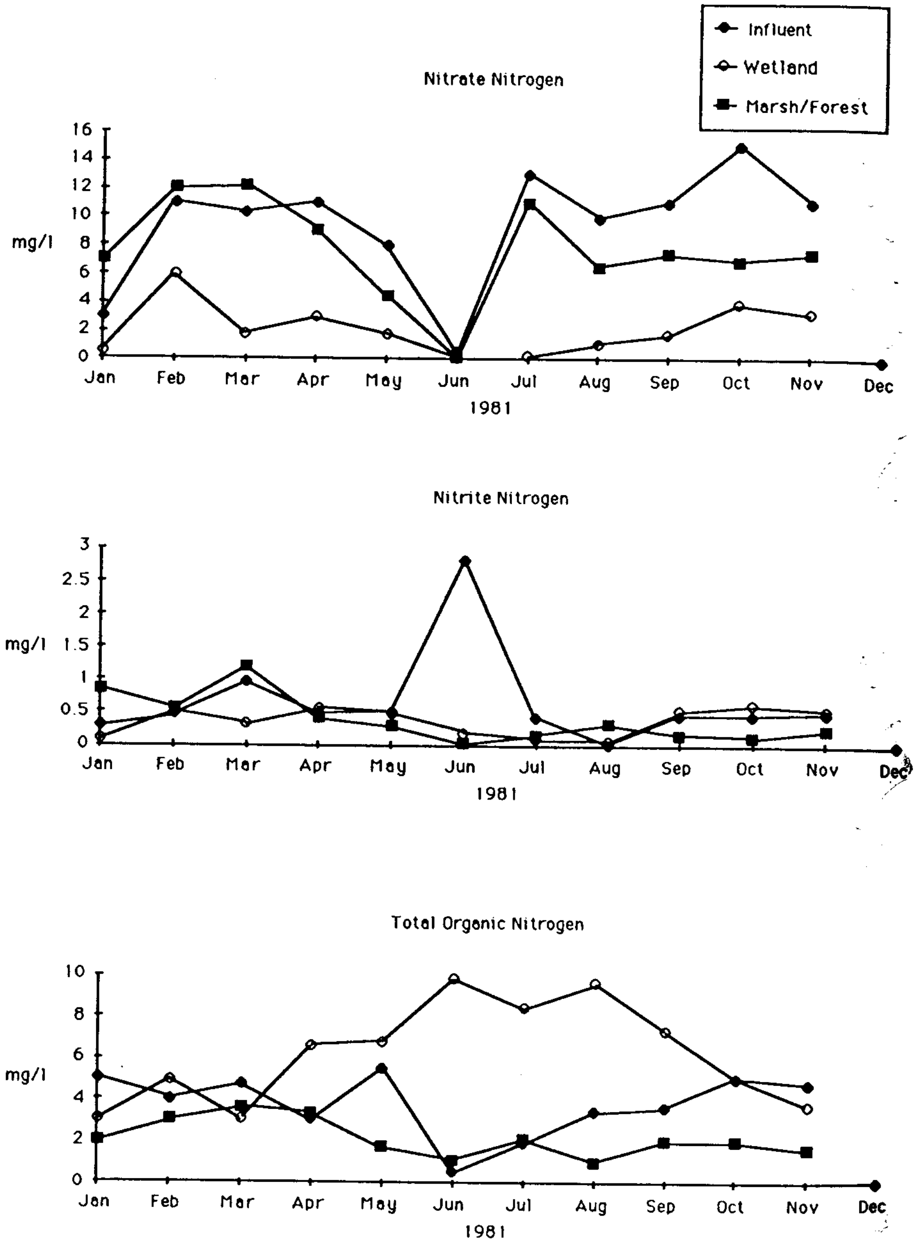

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