NIVA – REPORT

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Report No.: 0-79024

Sub-No.: I

Serial No.: 1603

Limited distribution:

Report title:

Highway pollution in a Nordic climate
VA-3/84

Date: 13. mars 1984

Project No: 0-79024

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Topic group: Highway pollution

Geographical area: Oslo

Number of pages (incl. app.) 83

Contractor: The Norwegian Road Research Laboratory

Contractors ref. (or NTNF - No): E. Hansen

Abstract:

The Norwegian Public Roads Administration decided in 1979 to finance a 3 year programme aimed at characterizing the nature and fate of pollutants from highways, especially related to drinking water resources. A section of the highway (E6) north of Oslo was prepared to study the pollution transport from a highway. In another part of the programme the impact on a small lake close to the highway (E18) south of Oslo was studied. The results indicate that in most cases the impact from the highway on groundwater or surface water resourses will be very small and should not affect the use of the resources for drinking water purpose.

4 keywords, Norwegian	
1.	Motorveg
2.	Forurensning
3.	Drikkevann
4.	Nordisk klima
	VA-3/84

4 keywords, English	
1.	Highway
2.	Pollution
3.	Drinking water
4.	Nordic climate

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ISBN 82-577-0763-5

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OSLO

0-79024

Highway pollution in a Nordic climate

Oslo, February 1984

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F O R E W O R D

In 1979 the Public Roads Administration in Norway decided to finance a 3 year research programme aimed at characterizing the nature and fate of pollutants from highways and their effects on adjacent drinking water resources.

The Norwegian Institute for Water Research (NIVA) in cooperation with the Norwegian Road Research Laboratory made out a plan for the research programme (VA 6/79, "Vannforurensning fra veg Programforslag"). The plan was sent to the folloving institutions and firms in Norway for comments:

National Institute for Public Health (Statens institutt for folkehelse), Norwegian State Pollution Control Authority (Statens forurensningstilsyn), Geological Survey of Norway (Norges geologiske undersøkelse) and Taugbøl and Øverland A/S.

Relevant departments of the Norwegian Public Roads Administration were also conferred. The research programme was implementet in 1980.

Prelimenary research results were presented on a conference in Oslo in 1981, where several institutions in Norway were represented.

The aim of the conference was to revise the research programme an ensure the best use of the funds in future work.

As a result of the conference, a survey of a former surface drinking water resource, close to a highway, was included in the project.

Several people and institutions have been involved in fulfilling this research programme. The authors and the Norwegian Road Research Laboratory wish to thank them all.

Oslo, February 1984

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ABSTRACT

The Norwegian Public Roads Administration decided in 1979 to finance a 3 year programme aimed at characterizing the nature and fate of pollutants from highways, especially related to drinking water resources.

A section of the main highway (E6), 50 km north of Oslo was prepared to study the pollution transport system from the highway to potential drinking water resources. The study included measurements of runoff quality and quantity, dust transport to surroundings, accumulation of pollutants in the snow, traffic density and meteorological parameters, drainage system function etc. The characterization of pollutants included studies of sedimentation characteristics, heavy metal content and content of organic micropollutants, especially PAH (Polyaromatic hydrocarbons).

Runoff water was also characterized by biological methods. The methods included toxicity tests on salmon, algae, bacteria and fungi as well as studies on the hatching of salmon eggs in the sedimented part of the runoff. Ames test was used to look at the mutagenic effect of the water, and a sample was inoculated with earth from the road ditch to study the biodegradability of PAH's by this bacteriaflora.

In another part of the programme a small lake close to the main highway (E18), 20 km south of Oslo, was studied with regard to water quality. The contribution of pollutants from the surrounding area, from the local atmosphere, and directly from the pavement was studied and related to the quality of the lake water and the outflowing water. PAH's, heavy metals, and several other quality parameteres were evaluated in this respect. Studies of lead, cadmium, zink, and PAH in sediments were included.

Adsorption experiments with regard to the adsorption of PAH's in different earth types were included.

The results indicate that a great portion of the pollutants are produced in the winter periode and transported as dust to the near surroundings where they are accumulated in the snow or deposited on the ground. Most of the pollutants (eg. lead) are deposited in signifi-

cant amounts within 25 m from the road, while some of the components (e.g. PAH) spread in massive amounts to a distance of 50 to 100 m. In snow areas, the pollutants are released in the snow melting periods, especially in March and April.

The results suggest that an essential part of the potentially toxic organic (and inorganic) pollutants are strongly adsorbed to the particulate matter and that the acute toxicity of the runoff water to the aquatic organisms studied is moderate.

The results show that the lake water is very little affected by the highway pollution, the lake acting as a sink most of the year for important pollutants.

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1. INTRODUCTION

Norway is known for its high quality drinking water resources and a lot of effort is spent to protect them for future use.

In some areas highways are passing through the catchment area of drinking water resources and the question is whether this means a conflict or not, and what eventually should be done to prevent the conflict.

The purpose of this program is to make up a general basis for the judgement of this question in each individual case.

In figure 1 are shown some of the pollution transport systems that have been studied in the program. Also have been included the impact on a lake close to a highway.

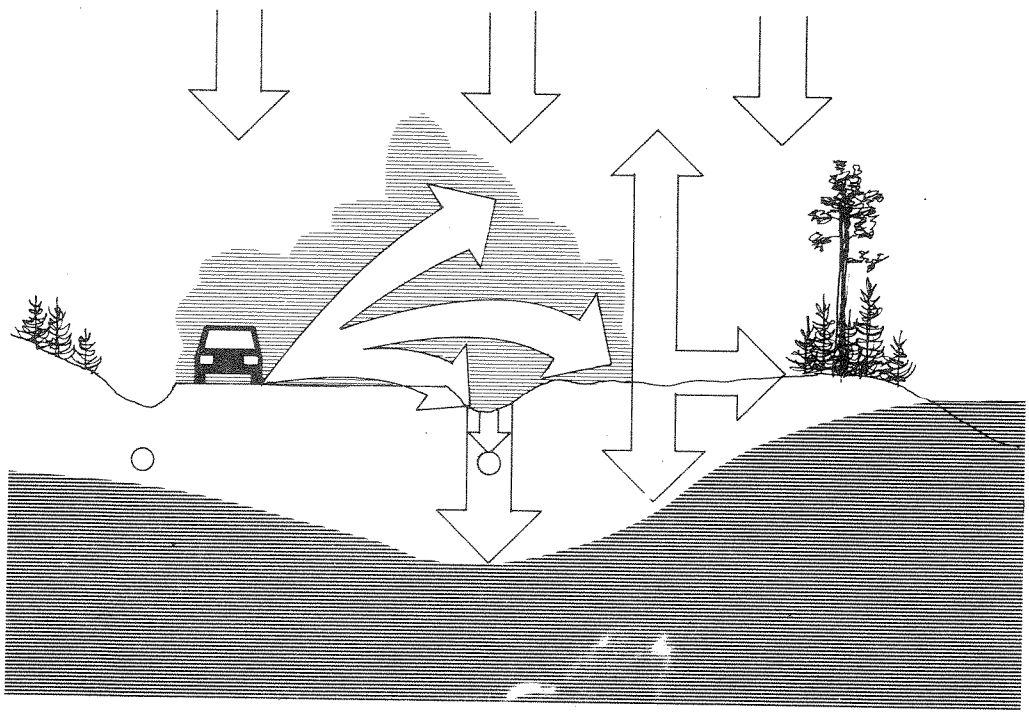


Figure 1. Some of the pollution transport systems studied.

2. METHODS

2.1 The field station and sampling at Jessheim

Nearby Jessheim, 50 km north of Oslo, a section of the highway was prepared for measurements of relevant parameters:

- Traffic density on a continuous basis.
- Meteorological parameters such as precipitation, temperature, wind speed and wind direction on a continuous basis.
- Runoff quantity from the highway surface on a continuous basis.
- Runoff quality from the highway surface. Flow composite samples from two different 50 m sections of the highway respectively with a 10 cm and a 70 cm high roadshoulder barrier.
- Dust deposits on the road surface.
- Dust transport to the near surroundings.
- Horizontal dust transport at different levels above the ground close to the highway.
- Accumulated dust in the snow along the highway.
- Hydraulic performance of the road ditch and the drainage system.
- Changes in water quality in the road ditch.

Traffic density and meteorological parameters were measured by automatic equipment coupled to a datalogger system as shown in figure 2 and 3.

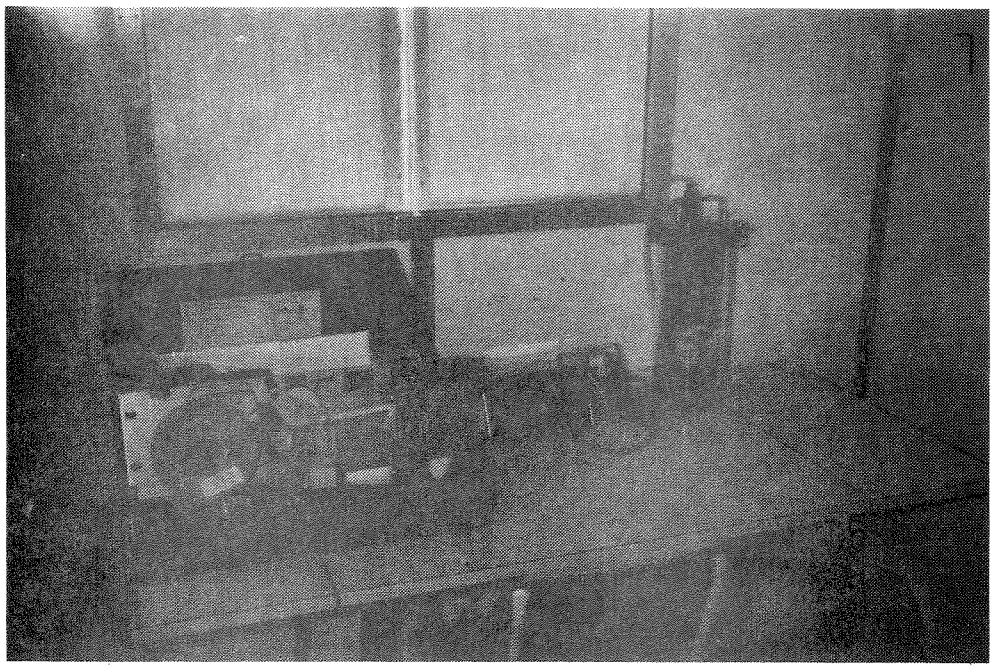


Figure 2. Traffic recorder and datalogger system.

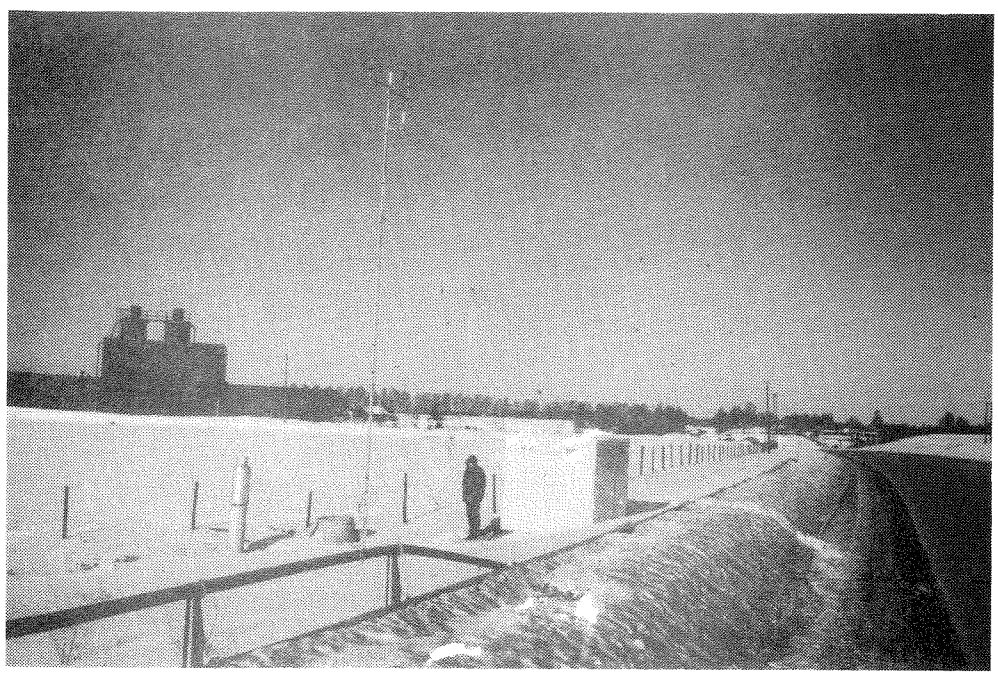


Figure 3. Precipitation gauge, temperature sensor, wind direction sensor and wind speed sensor.

Runoff quantity

The runoff from each of two 50 m sections of the highway was led to a flow splitter system where 12 percent of the water flow was diverted to a 1 m^3 collection tank. A sensor for measuring the water level in the tank was connected to the data logger, and the level was measured every half hour. We were able to collect an equivalent of 20 mm of precipitation before the tank was completely filled up.

Figure 4 shows the flow splitter system (8) and the collection tank.

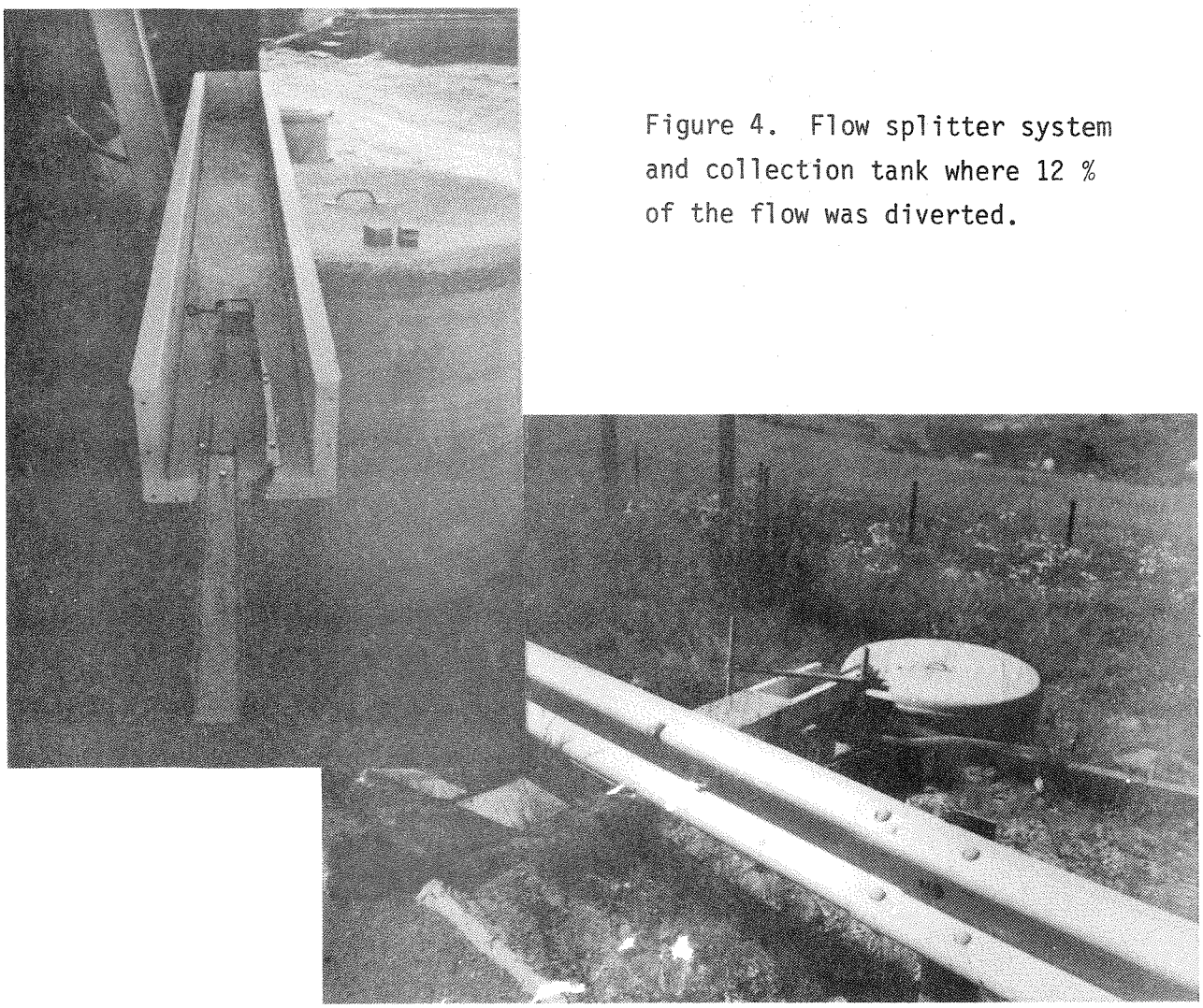


Figure 4. Flow splitter system and collection tank where 12 % of the flow was diverted.

Sampling

Runoff samples were taken from two collection tanks (se figure 4) serving two different 50 m sections of the highway respectively with a 10 cm and a 70 cm high roadshoulder barrier. The samples were taken by pumping all the water in the collection tank up in the flow splitter system again and such taking out a small sample for analysis. Figure 5 shows the 70 cm high barrier.

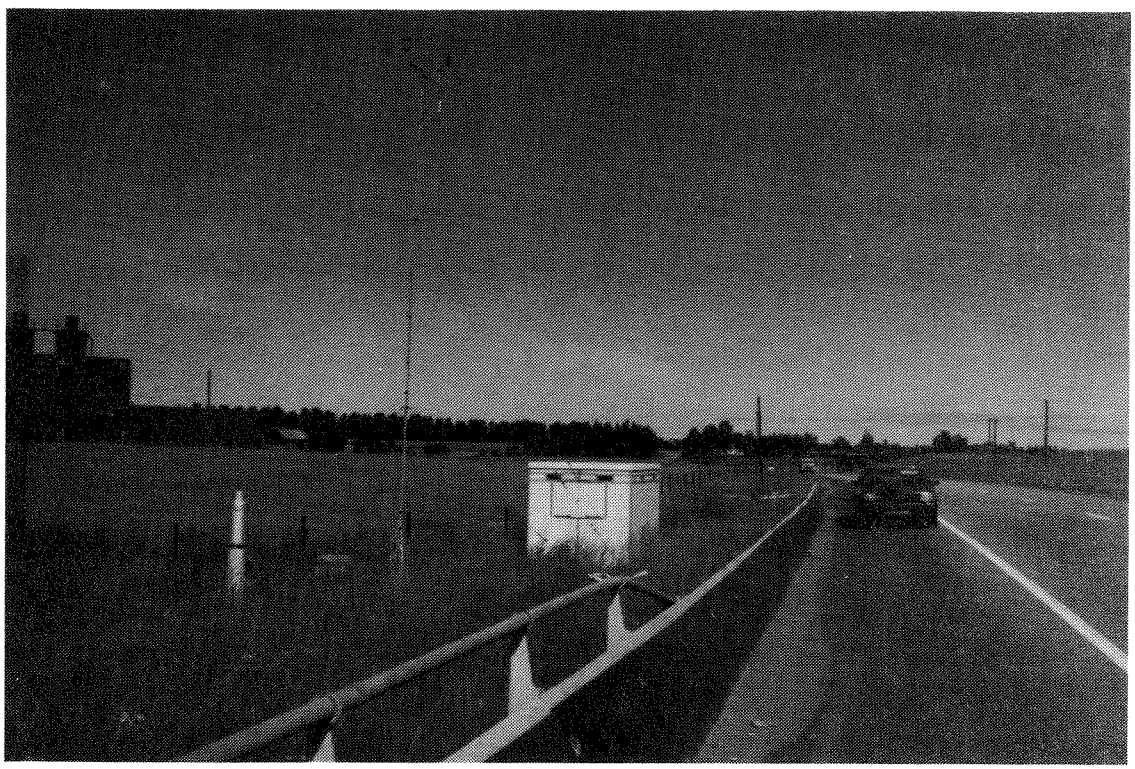


Figure 5. Fifty meter section with 70 cm high roadshoulder barriere.

Dust deposits on the road surface were collected by using an industrial vacuum cleaner.

Dust samples for all analyses except PAH were collected in standard 20 cm sircular plastic buckets on stands as shown in figure 6. The buckets were partly filled with destilled water. A chemical substance was added to prevent biological growth and/or freezing.

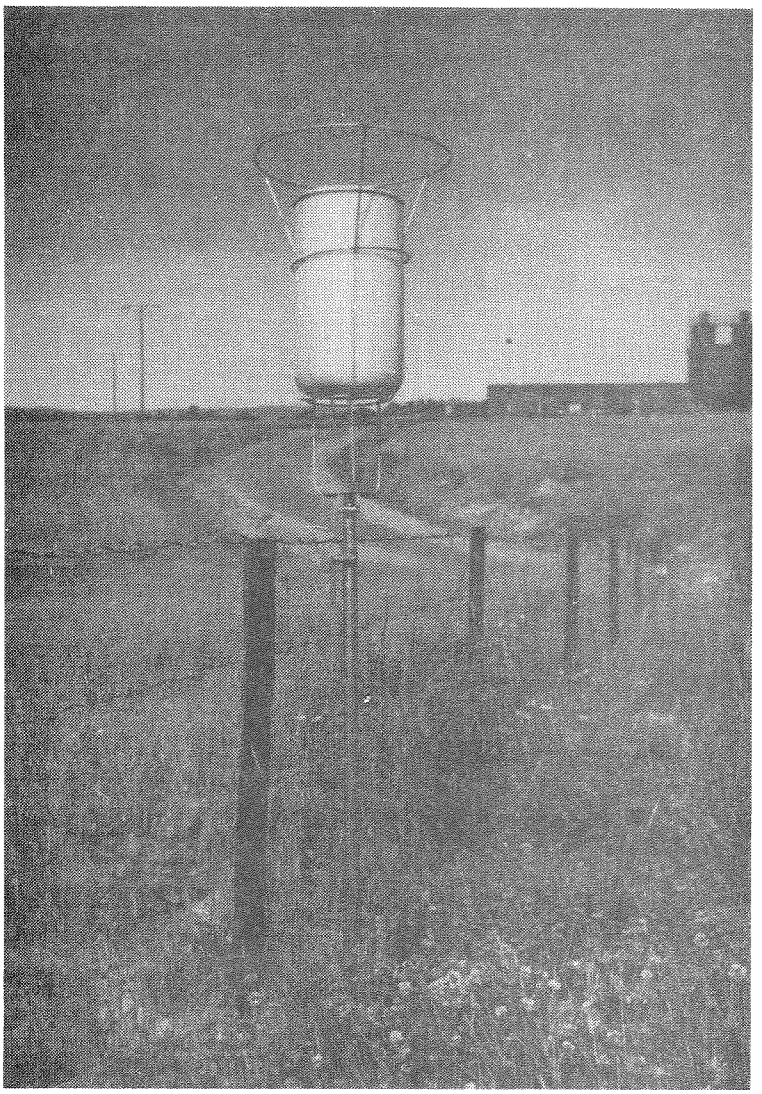


Figure 6. Dust sample collector.

Dust samples for PAH analyses were collected in 10 x 40 x 60 cm aluminium vessels placed directly on the snow surface during snowfall.

Dust transport profiles were measured by specially developed dust collectors for measuring the horizontal dust transport at different levels above the ground as shown in figure 7.

Snow samples were collected using a plexiglass cylinder (diameter 33 mm) coring the snow from the surface to a plate placed just above the earth surface.

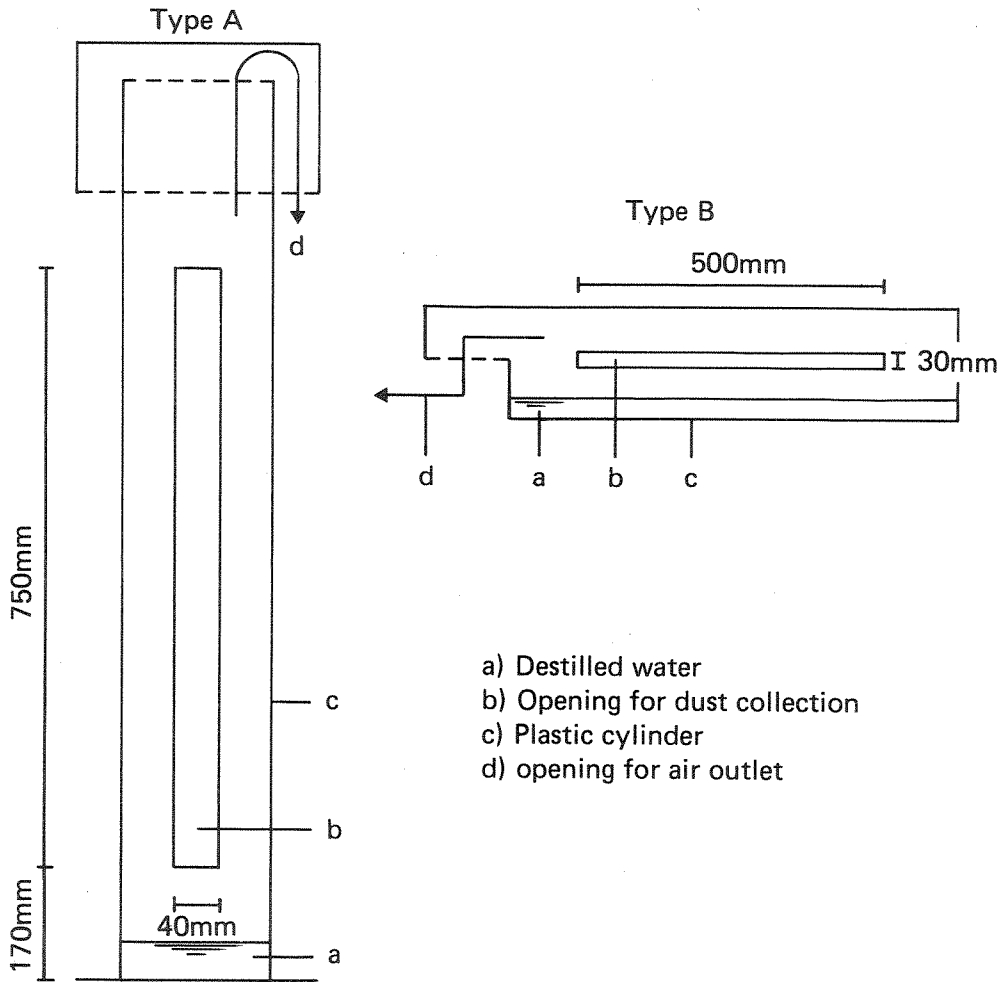


Figure 7. Two types of specially developed dust collectors for measuring the horizontal dust transport at different levels above road surface.

Transport of water and pollution in the ditch and further to the drainage system below the ditch was measured by pumping runoff water into the ditch.

2.2 The field station and sampling at lake Padderudvann

The size of the catchment area for Lake Padderudvann is about 2.4 km^2, and the lake itself represents about 10 percent of the total area. As illustrated in figure 8, the highway runs very close to the lake (15 m at the nearest). There are four distinct inlets to the lake. A, B and C are natural drainage systems whereas D is the drainage system for 22 000 m^2 of the four lane highway.

Through a 1½ year period five water samples have been collected from A, B, D and the outlet E. Snow samples have been collected from the ice-covered lake at various distances from the highway, and 27 samples of the lake sediments have been taken in order to study the distribution of relevant highway pollutants in the lake sediments. In addition, some simple laboratory experiments have been performed in order to estimate the soil-adsorbing effect of important organic highway pollutants (PAH). In tables 1 and 2 is given some key information on the field studies.

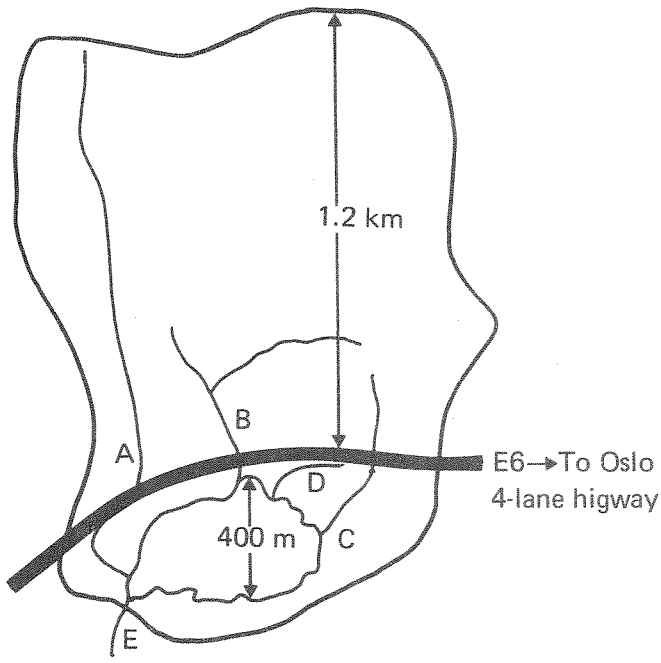


Figure 8. Lake Padderudvann and its catchment area (Lier, 30 km from Oslo).

Table 1. Type and time of sampling and air temperature in the Padderudvann area.

	1981				1982										
	Feb	Mar	Apr	May	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Snow		●					●	●							
Water				●			●	●		●					●
Sediments												●	●		
Temp. +			+	+				+	+	+	+	+	+	+	+
Temp. -	-	-	-		-	-	-	-						-	-

Table 2. Key-data from Lake Padderudvann and its catchment area.

Catchment area (km^2)	2.4	Traffic density total (veh/day)	19 400
Lake (km^2)	0.24	Pavement treatment	sand & salt
Highway pavement (da)	22	Period with studded tyres	Oct.15.Apr.30
Lake volume (m^3)$\cdot 10^6$	3.6	Highway constr. finished (year)	1969

Snow samples were collected using plexiglass cylinder (diameter 8 cm) coring the snow from the surface to the ice on the lake (or to the road side surface). The snow samples were transported in plastic bags to the laboratory and melted (in the bag) prior to analyses. The snow samples for PAH analyses are collected in 50 litre aluminium cans. The extraction (with cyclohexane) is performed directly from the cans.

Water samples were collected on one litre plastic bottles. Regarding the samples for PAH analysis, 50 litre Al-cans were used.

Sediment samples were cored from various parts of the lake, as illustrated on figure 9. A gravity corer (acrylic tubes, diam. 6 cm) was used and for most of the samples the upper 2 cm only were analyzed. Some of the sediment cores were clearly fractionated, as illustrated on figure 33.

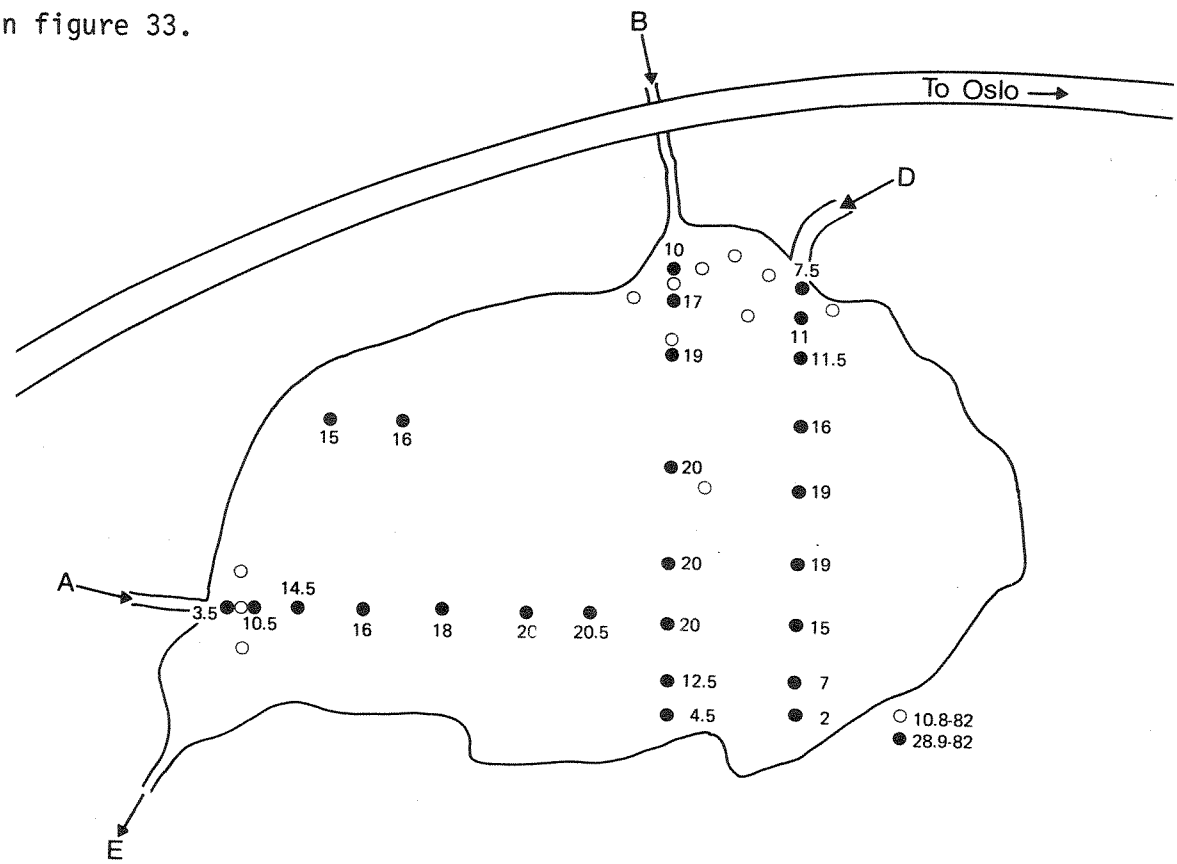


Figure 9. Sediment sampling in Lake Padderudvann (the numbers are referring to the depth in meter).

2.3 Analysis and biological tests

Inorganic compounds such as Ca, Cd, Cu, Zn, Pb, Ni, Cr were all analyzed according to Analytical Methods for Atomic Absorption Spectrophotometry (1). Fe was analyzed colorimetrically on a Technicon Auto Analyzer II (Industrial Methods No. 109-71 W) and Hg according to the procedure for Coleman Hg-Analyzer (MAS-50), which is a flameless atomic absorption method. The metal analyses are with regard to the snow based on digested samples (suprapure HNO_3 in autoclave). SO_4 is determined by precipitation as $BaSO_4$ according to Standard Methods and Cl colourimetrically as an ironthiocyanate complex.

TDR (Total Dried Residue), TFR (Total Fixed Residue), TSM (Total Suspended Matter, and FSR (Fixed Suspended Residue) are all determined according to Standard Methods (2).

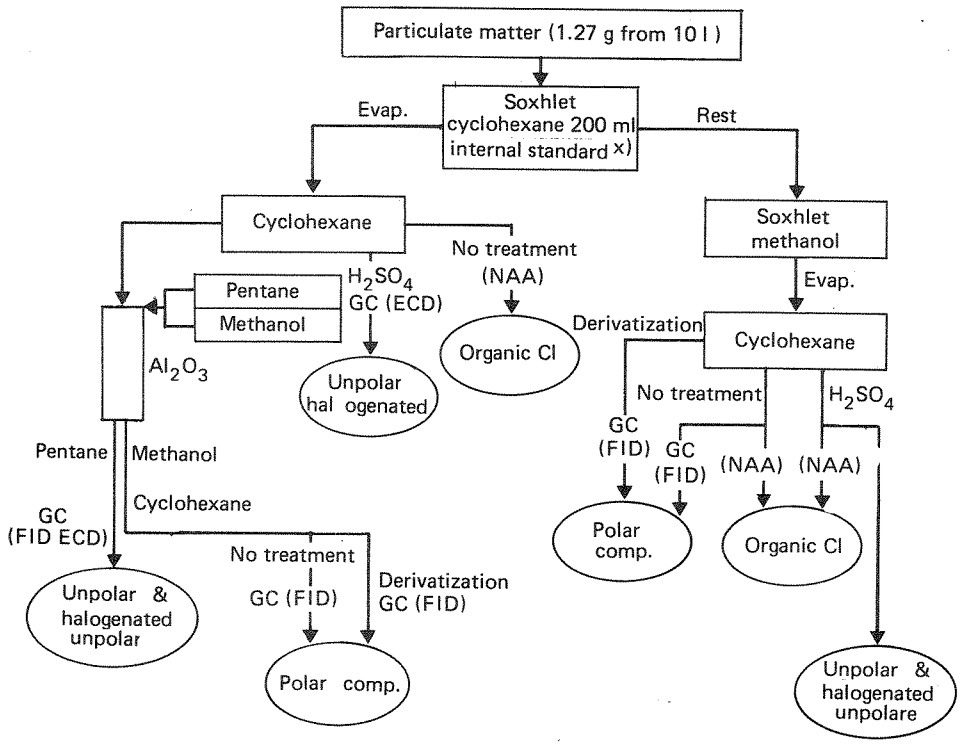
Organic Matter is determined as COD (Chemical Oxygen Demand) and as TOC (Total Organic Carbon) and DOC (Dissolved Organic Carbon) according to Standard Method (2) and M.P. Stainton (3) respectively.

PAH's (Polyaromatic Hydrocarbons) were analyzed by gaschromatography with glass capillary column according to Bjørseth et al. (4).

Sedimentation characteristics of particulate matter in pavement runoff were determined by use of a specially developed sedimentation column.

Analysis of organic micropollutants

The analytical procedure is described in figures 10 and 11. The filtered water and the particles were analyzed separately. It appears from the extraction schemes shown in the two figures that the solvent extractable compounds were divided into an unpolar and a polar fraction. The extracts were analyzed by gashromatographs with different detectors. The cyclohexane extract from the filtered water was further characterized by combined gaschromatography/mass-spectrometry (GC/MS).



Figur 10. Analytical procedure for isolation and separation of organic matter adsorpbed to the particulate matter.

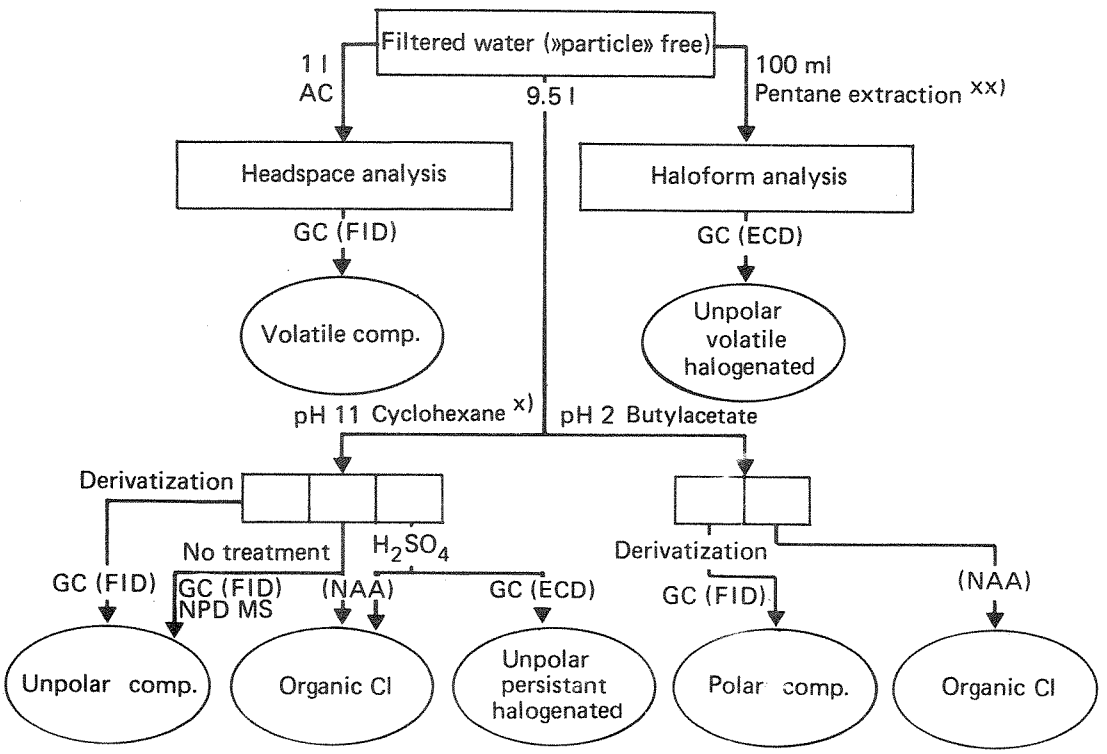


Figure 11. Analytical procedure for isolation and separation of organic matter in filtered water.

Test on heterotrophic organisms (bacteria - fungi - protozoa)

This test was performed by observing the changes in microbiological degradation of a solution of standard organic matter when testsample is added. In the present experiment the concentration of the unfiltered runoff water was varied between 0 and 90 percent, and the microorganisms used was from a local municipal sewage treatment plant. The effect were studied by measuring the changes and differences in oxygen consumption using monometric BOD apparatus.

Test on algae

The experiments included acute toxicity test on two algal species (*Selenastrum capricornutum* and *Synedra acus*) in separate studies: The runoff water sample was filtered (0.45 µm), and 50 percent and 100 percent concentrations of the filtrate were tested on the two species. Prior to the addition of the test algae, some nutritionsalt solution was added (5) (6), and the 50 percent concentration samples were diluted with this solution.

Test on fish and fish eggs

A simple fish experiment was performed on two small salmons (3 - 4 cm long) in a 2 litre beaker. the unfiltered sample-water was used without dilution and was changed daily through the 4 day period the experiment lasted. The water temperature was 6 - 9°C and the system was constantly airated. An identical system with tapwater (City of Oslo) acted as control. The behaviour and condition of fish in both systems were noted daily.

Fish eggs of salmon were put into perforated plexiglass boxes directly into the particulated part of the runoff water. This resulted in a good contact between the eggs and the particulate matter. During the 53 day test period, tap water (City of Oslo) circulated slowly through the system. The eggs hatched after about 5 weeks (see figure 12) and this resulted in an increased contact between the particle pollutants and the fish. Due to the swimming activities some of the particulate matter was lost with the outflowing water.

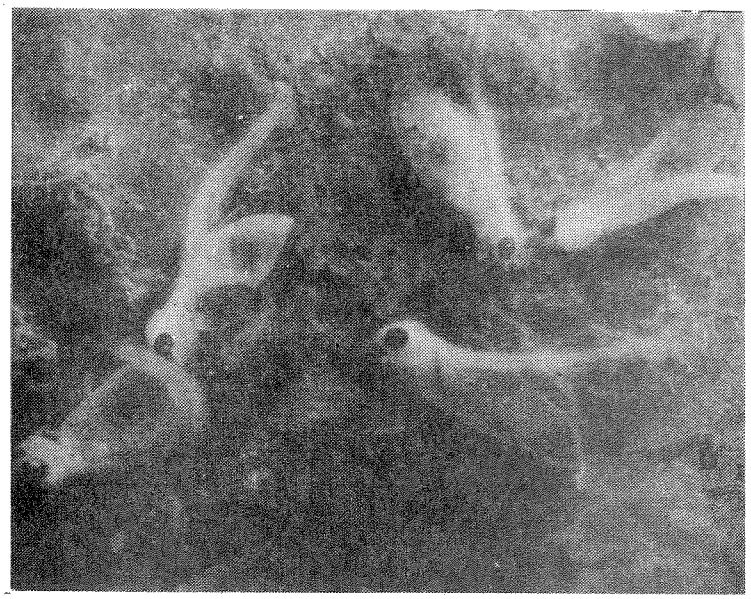


Figure 12. Biological test with hatching of eggs in mud from road surface runoff.

Test on biodegradability of PAH in runoff water

The test was performed by inoculation of a sample of untreated runoff water with earth from the road ditch and a standard addition of organic matter. The duration of the test was 30 days and the content of PAH was analysed before and after the test was performed. The temperature was 20°C during the test.

Ames test on mutagenity

Organic constituents in 10 litre filtrated water were concentrated by liquid-liquid extraction with ether, three times. (150 ml, 100 ml and 100 ml). The total ether-extract was evaporized to almost dryness and transfered to 0.5 ml dimethylsulfoxyd (DMSO). This extract was tested in Ames test with the bacteriatypes TA 98 and TA 100 which are sensitive to different types of mutagenic agencies. Liverenzymes were added in half of the tests to include biologically transformed mutagenes.

Adsorption experiments

The mobility in soil of the pollutants contained in the highway runoff, is an important part of the total project. Even though these

questions are very complex, it was considered pertinent to estimate the fate of some relevant organic micropollutants in various types of soil. The polyaromatic hydrocarbons (PAH) were studied. The equipment used in the laboratory experiments is illustrated on figure 13.

Runoff sample, 50 litre of a "total" sample from pavement runoff (Jessheim Nov. -81) was allowed to stand for 5 days. 48.5 litres were decanted off. The rest was stirred and allowed to resettle for 30 seconds to remove the larger particles. The suspension was filtered and freeze-dried; resulting in 34.5 g. 6.5 g of this matter was used in the soil adsorption experiments (see figure 13).

Artificial precipitation was applied through a period of 20 days with a rate corresponding to about 200 mm/day. The pH of the precipitation was 4.05 and contained the following ions (the numbers in the brackets are µekv/l): Na (40), H (70), Mg (10), NH_4 (40), SO_4 (70), NO_3 (40), Cl (60), Ca (10).

The soils considered in these experiments had different origin with a composition as indicated in table 3.

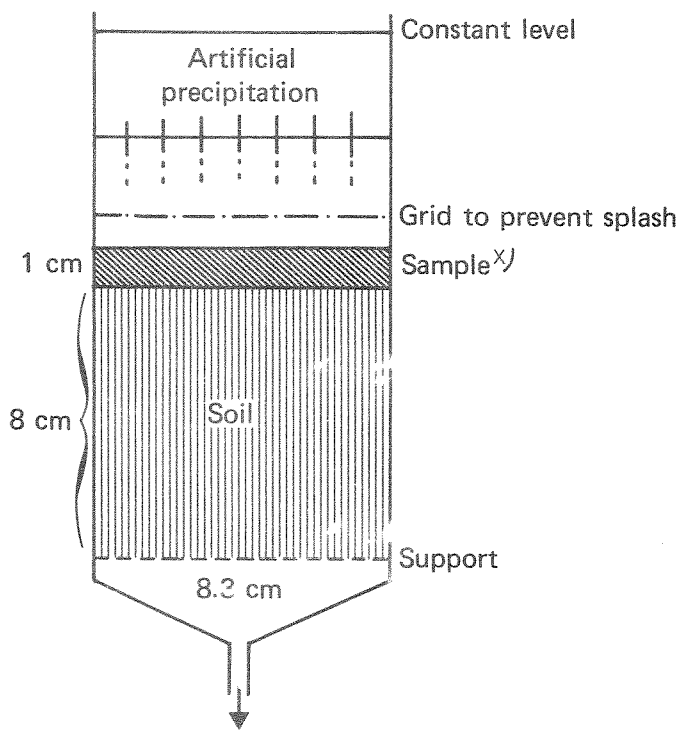


Figure 13. Soil adsorption experiments.

*) 6.5 g of airdried runoff sample mixed with 50 ml of soil.

Table 3. Soil samples used in the adsorption experiments with pollutants in highway runoff.

Soil No.	pH	Organic carbon %	Sand %	Silt %	Clay %	Sample from
1	5.6	0.2	97.5	2.3	0.5	Forest soil
2	7.4	2.2	65.1	25.6	9.2	Cultivated soil
3	4.2	3.7	69.4	20.5	10.1	Forest soil
4	3.6	46.8*	-	-	-	Marsh area

3. RESULTS

3.1 Results from the Jessheim station.

Traffic density

Figure 14 shows the daily traffic density in a typical week at E6 Jessheim.

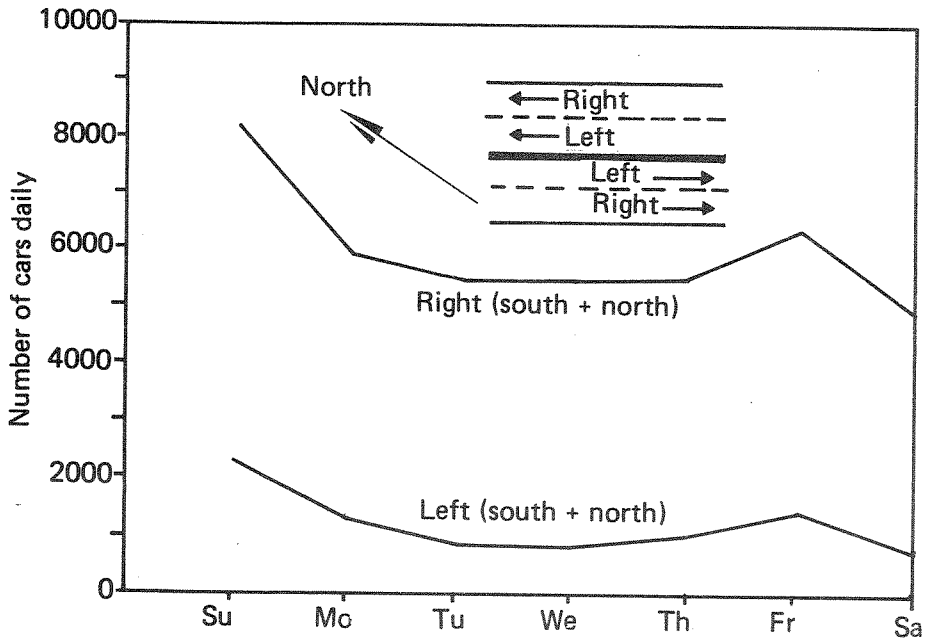


Figure 14. Traffic density in a typical week at E6 Jessheim.

Meteorological data

Figure 15 shows an example of wind data for the Jessheim station. The wind strength and direction are important for the dust transport. Other wind data are shown in appendix A.

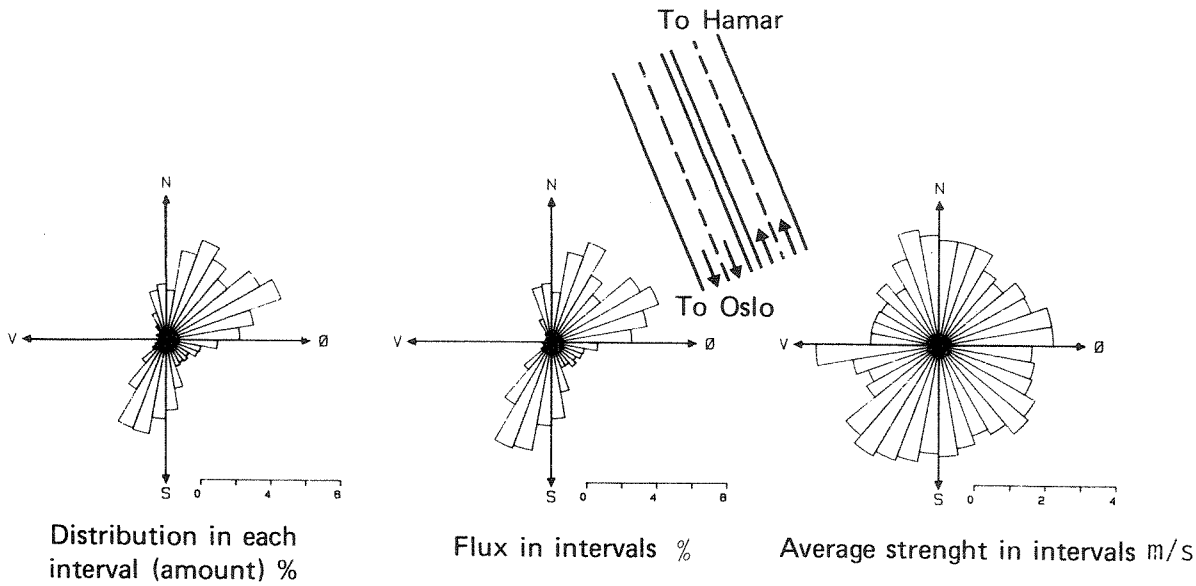


Figure 15. Wind direction and wind strength in 6 m height at the Jessheim station based on 4452 measurements in the period 27.4. - 27.5.1981.

Figure 16 and 17 show the variation in temperature the winter seasons 1980/81 and 1981/82. The figures also show the variation in snow depth at Gardemoen in these periods. (7 km from Jessheim).

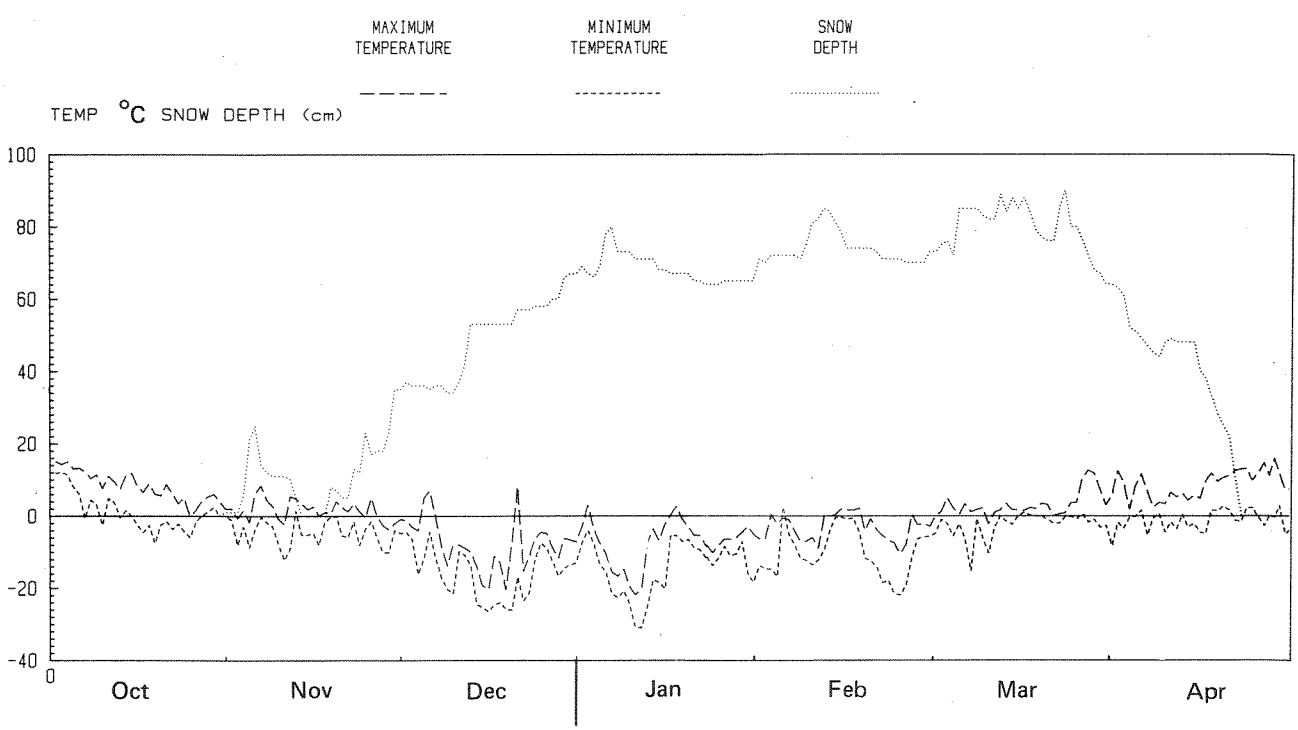


Figure 16. Daily maximum and minimum temperatures and snow depth variations at Gardermoen in the periode Oct. 1980 - Apr. 1981.

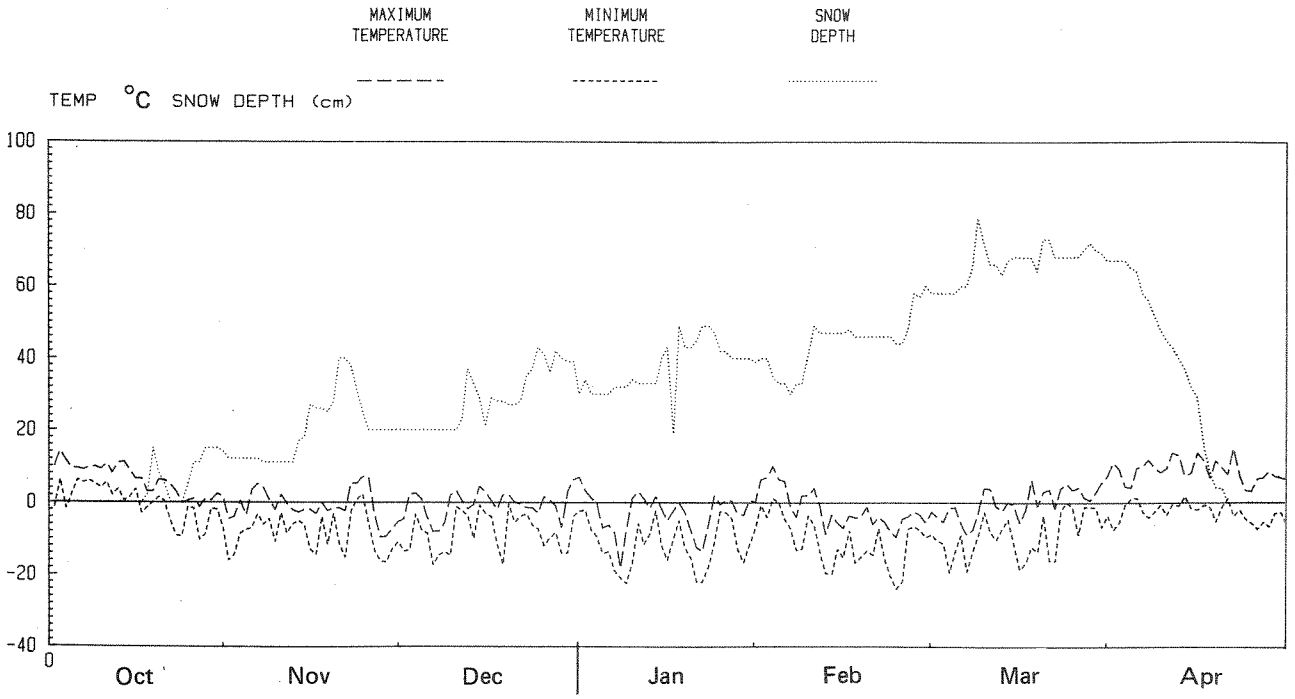


Figure 17. Daily maximum and minimum temperatures and snow depth variations at Gardermoen in the period Oct. 1981 - Apr. 1982.

The precipitation data are given in table 4. The precipitation measured in the winter is too small because some of the snow is blowing out of the sampler before melted by the heating system in the sampler. A comparison between the actual snowfall and what was measured in the gauge during the period 1.1.81 - 22.3.81 showed that the real snowfall was approximately the double of what was collected in the sampler. The numbers in table 4 have been adjusted for this loss by multiplying snowfall precipitation by 2.

Table 4. Precipitation data at the Jessheim station, and mean at Gardermoen, 7 km away from Jessheim.

mm/month	Total	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1980										74	139	46	55
1981		21	22	80	5	30	75	40	15	60	98	126	44
1982		29	35	99	15	47	55	40	78	90			
Mean (Gardermoen)	825	58	41	30	50	53	79	92	95	87	85	87	75

Runoff quality and masstransport of pollutants

Table 5 shows the concentration of different components in runoff from two sections of the highway with a respectively 10 cm and 70 cm high roadshoulder barriere. Each sample represents from 5 to 15 mm of precipitation either as rainfall- or as snowmelt-runoff.

Table 5. Concentration of pollutants in road surface runoff at the Jessheim station.

ROAD-BARR. cm	RUN-OFF mm	SAMPLE NUMBER	SAMPLING PERIOD	pH	COND uS/cm	COD mgO/l	TOC mg/l	DOC mg/l	Ni ug/l	Cr ug/l	Zn ug/l	Pb ug/l	Cd ug/l	Fe mg/l	Hg ug/l	Ca mg/l	Cu ug/l	Cl mg/l	SO4 mg/l	PAH ng/l
	32	1.2	12.09-17.09.80	6.8	54	55	16		104	31	123	91	20	4.5	0.60	12.5	10	186	11.4	1508
	5	2.2	25.09-25.09.80	6.7	101	110	30		141	173	91	245	17	6.2	2.00	15.5	63	3	22.6	1643
	32	3.2	06.10-07.10.80	7.8	41	85	18		50	47	191	174	15	6.4	1.10	5.9	52	3	11.6	2436
	29	4.2	07.10-10.10.80	6.9	42	55	13		105	93	103	99	27	4.9	0.70	5.6	48	5	12.2	2246
	58	5.2	17.10-18.10.80	7.1	40	50	8		55	30		81	12	5.5	1.70	3.1	13	2	11.1	1772
	20	6.2	24.10-28.10.80	6.8	1200	130	15		73	37		84	11	5.9	1.10	6.6	27	480	28.4	4353
	17	7.2	21.11-29.11.80	7.5	2550	170	25		91	46	200	160	10	10.7	13.20	3.9	40	920	45.4	5141
	6	8.2	14.12-02.02.81	8.2	3950	360	38		106	84	600	200	26	43.1	0.94	85.1	210	1700	224.1	11604
	10	9.2	09.03-17.03.81	7.7	5870	240	58		93	150	740	690	6	78.6	0.19	78.6	430	3100	58.6	
70	7	10.2	24.03-02.03.81		1851	270	28		48	60	400	390	4	30.9	5.60	13.1	150	660	20.6	
	20	11.2	03.04-08.04.81		238	320	32		32	37	230	280	2	26.5	5.00	5.7	60	49	4.9	
	5	12.2	09.05-09.05.81	7.4	390		320	260	37	39	370	360	5	30.1		18.7	180	46	55.2	
	28	13.2	25.05-28.05.81	7.2	98		320	240	6	13	170	132	2	8.3		6.5	160	7	12.2	3907
	18	14.2	16.06-28.06.81	6.9	68	150	28		5	15	140	174	1	10.4		10.2	180	43		3516
	44	15.2	29.09-06.09.81		82	50	12		10	9	150	62	1	3.1		3.6	70	13	8.4	2701
	28	16.2	16.11-24.11.82	7.7	236	340	35		25	28	375	275	2	30.1		20.6	125	690	55.1	8831
	25	17.2	12.03-12.03.82	7.5	294	160	29		18	16	250	213	2	14.1		25.9	150	900	520.1	13687
	17	18.2	12.03-15.03.82	7.9	99	850	54		51	75	675	650	4	57.3		30.9	213	240	150.1	
	17	19.2	01.05-11.05.82	7.6	27	150	34		26	14	250	156	1	11.9		13.1	88	44	50.1	
	32	1.1	12.09-17.09.80	7.2	58	65	17		436	26	120	161	15	4.3	5.10	13.8	10	1100	12.8	1403
	5	2.1	25.09-25.09.80	6.7	89	80	26		166	190	177	203	20	10.9	1.70	13.5	99	3	24.1	2611
	32	3.1	06.10-06.10.80	9.1	67	60	17		112	114	186	155	10	4.8	1.70	6.1	80	2	13.8	1947
10	29	4.1	07.10-10.10.80	6.9	44	80	12		76	38	119	128	28	4.2	2.00	5.3	57	5	14.4	1890
	5	12.1	30.04-30.04.81	7.5	200	310	26	14.4	22	32	340	220	2	27.4		9.9	130	24	25	
	28	13.1	25.05-28.05.81	7.1	90	125	18	7.8	10	15	160	174	1	9.3		5.7	170	6	10	
	18	14.1	16.06-28.06.81	6.9	110	240	54	37.1	12	120	200	920	1	12.7		16.6	200	57	16	3508

Table 6 shows the total monthly mass transport of different pollutants in road surface runoff from the road section with a 70 cm high roadshoulder barriere.

Table 6. Mass transport of different pollutants in road surface runoff from the section with a 70 cm high road shoulder barrier .

MONTH/YR	COD kg/km	TOC kg/km	Ni g/km	Cr g/km	Zn g/km	Pb g/km	Cd g/km	Fe kg/km	Hg g/km	Ca kg/km	Cu g/km	Cl kg/km	SO4 kg/km	PAH mg/km
SEP 80	105.38	29.39	413.93	80.06	200.55	226.69	28.71	8.08	4.42	21.71	31.90	906.00	22.17	2517.28
OCT 80	182.40	35.20	174.18	132.71	386.69	294.18	37.65	13.42	3.98	13.13	130.64	120.49	35.52	6383.34
NOV 80	142.12	20.90	76.08	38.46	167.20	133.76	8.36	8.95	11.04	3.26	33.44	769.12	37.95	4297.88
DEC 80	243.88	31.98	108.00	62.50	332.80	193.44	15.60	20.66	11.91	25.57	89.96	1255.28	98.40	7561.68
JAN 81	63.36	6.69	18.66	14.78	105.60	35.20	4.58	7.59	0.17	14.98	36.96	299.20	39.44	2042.30
FEB 81	31.68	3.34	9.33	7.39	52.80	17.60	2.29	3.79	0.08	7.49	18.48	149.60	19.72	1021.15
MAR 81	374.88	90.60	145.27	234.30	1155.88	1077.78	9.37	122.77	0.30	122.77	671.66	4842.20	91.53	23430.00
APR 81	471.80	47.60	56.00	66.64	425.60	477.40	3.92	42.66	7.95	11.89	130.20	332.08	14.14	15400.00
MAY 81	157.00	114.36	7.06	11.42	130.52	116.08	1.16	7.71	1.41	4.79	114.54	6.44	9.58	2786.90
JUN 81	321.75	67.65	14.03	111.38	280.50	902.55	1.65	19.06	3.30	22.11	313.50	82.50	24.75	5794.80
JUL 81	171.60	36.08	7.48	59.40	149.60	481.36	0.88	10.16	1.76	11.79	167.20	44.00	13.20	3090.56
AUG 81	64.35	13.53	2.81	22.28	56.10	180.51	0.33	3.81	0.66	4.42	62.70	16.50	4.95	1158.96
SEP 81	85.44	23.83	335.62	64.91	162.61	183.80	23.28	6.55	3.58	17.60	25.86	734.60	17.98	2041.04
OCT 81	106.70	25.61	21.34	19.21	320.10	132.31	2.13	6.62	3.20	7.68	149.38	27.74	17.93	5763.93
NOV 81	336.60	49.50	180.18	91.08	396.00	316.80	19.80	21.19	26.14	7.72	79.20	1821.60	89.89	10179.18
DEC 81	60.67	6.87	10.99	7.66	67.96	50.94	1.10	5.01	1.23	3.14	20.44	170.92	11.32	1636.14
JAN 82	179.52	18.48	13.20	14.78	198.00	145.20	1.06	15.89	0.53	10.88	66.00	364.32	29.09	4662.77
FEB 82	254.32	26.18	18.70	20.94	280.50	205.70	1.50	22.51	0.75	15.41	93.50	516.12	41.21	6605.59
MAR 82	1053.41	93.81	75.19	95.63	1012.01	934.93	6.74	75.74	4.80	66.96	420.85	1517.59	888.07	34095.85
APR 82	525.72	53.04	62.40	74.26	474.24	531.96	4.37	47.53	8.86	13.24	145.08	370.03	15.76	17160.00
MAY 82	155.10	35.16	26.88	14.48	258.50	161.30	1.03	12.30	2.07	13.55	90.99	45.50	51.80	4136.00
JUN 82	235.95	49.61	10.29	81.68	205.70	661.87	1.21	13.98	2.42	16.21	229.90	60.50	18.15	4249.52
JUL 82	171.60	36.08	7.48	59.40	149.60	481.36	0.88	10.16	1.76	11.79	167.20	44.00	13.20	3090.56
AUG 82	334.62	70.36	14.59	115.83	291.72	938.65	1.72	19.82	3.43	22.99	326.04	85.80	25.74	6026.59
MEAN MONTHLY	242.91	41.08	75.40	62.55	302.53	370.06	7.47	21.92	4.41	19.63	150.65	607.59	67.98	7297.17
MEAN YEARLY	2914.93	492.92	904.83	750.58	3630.39	4440.69	89.65	262.98	52.87	235.55	1807.81	7291.06	815.75	87566.01

Table 7 shows the sedimentation characteristics of different particle fractions in runoff samples. Also shown is the content of total suspended and dry solids.

Table 7. Total suspended solids, total dry solids and sedimentation characteristics of different road surface runoff samples.

Number	Collection date	Rainfall = r Snowmelt = s	Total suspended solids		Total dry solids		Concentration (mg/l) of particles with different sedimentation velocities (cm/min)									
							>60		8.5-60		2-8.5		1-2		<1	
		r/s	total mg/l	volatile %	total mg/l	volatile %	total mg/l	volatile %	total mg/l	volatile %	total mg/l	volatile %	total mg/l	volatile %	total mg/l	volatile %
1.2	17.09.80	r	175	26	289	29	-	-	-	-	-	-	-	-	-	-
2.2	30.09.80	r	388	11	502	17	33	21	43	26	26	20	33	23	250	-
3.2	7.10.80	r	251	-	392	-	37	-	44	-	26	-	29	-	115	-
4.2	10.10.80	r	174	-	337	-	50	-	17	-	15	-	22	-	70	-
5.2	21.10.80	r+s	270	-	370	-	165	-	35	-	12	-	10	-	48	-
6.2	28.10.80	s	230	-	1100	-	67	-	25	-	25	-	28	-	85	-
7.2	24.11.80	s	600	-	2100	-	104	-	69	-	81	-	102	-	244	-
8.2	4.02.81	s	1428	-	4069	-	181	-	104	-	79	-	99	-	965	-
9.2	20.03.81	s	1669	13	5430	5	6	-	123	-	79	-	85	-	1376	-
10.2	2.04.81	s	948	17	2032	10	86	11	114	16	96	15	97	14	555	-
11.2	24.04.81	r	1300	11	2100	-	123	11	723	12	291	13	144	14	319	-
12.2	20.05.81	r	1800	12	700	-	113	13	112	15	70	22	42	21	195	-
13.2	29.05.81	r	542	-	770	-	457	6	121	10	75	9	140	10	-	
14.2	30.06.81	r	485													
16.2	11.02.82	s	670													
17.2	2.03.82	s	285													
18.2	28.03.82	s	2110													
19.2	13.05.82	r+s	594													
1.1	17.09.80	r	179	13	383	15	-	-	-	-	-	-	-	-	-	-
2.1	30.09.80	r	355	12	475	16	99	7	47	21	30	21	35	18	144	-
3.1	7.10.80	r	162	-	228		23	-	11	-	17	-	14	-	97	-
4.1	10.10.80	r	178	-	350		43	-	17	-	16	-	17	-	85	-
11.1	24.04.81	r	2420	7	3334	-	1500	5	477	8	123	12	125	13	300	15
12.1	20.05.81	r	584	11	718	-	220	7	90	16	44	20	50	16	130	-
13.1	29.05.81	r	650	-	820	-	73	27	50	16	46	16	104	13	377	-

Figure 18 shows the relationship between particle size and sedimentation velocity in a pavement runoff sample. (Microscope analysis of different sedimentation fractions).

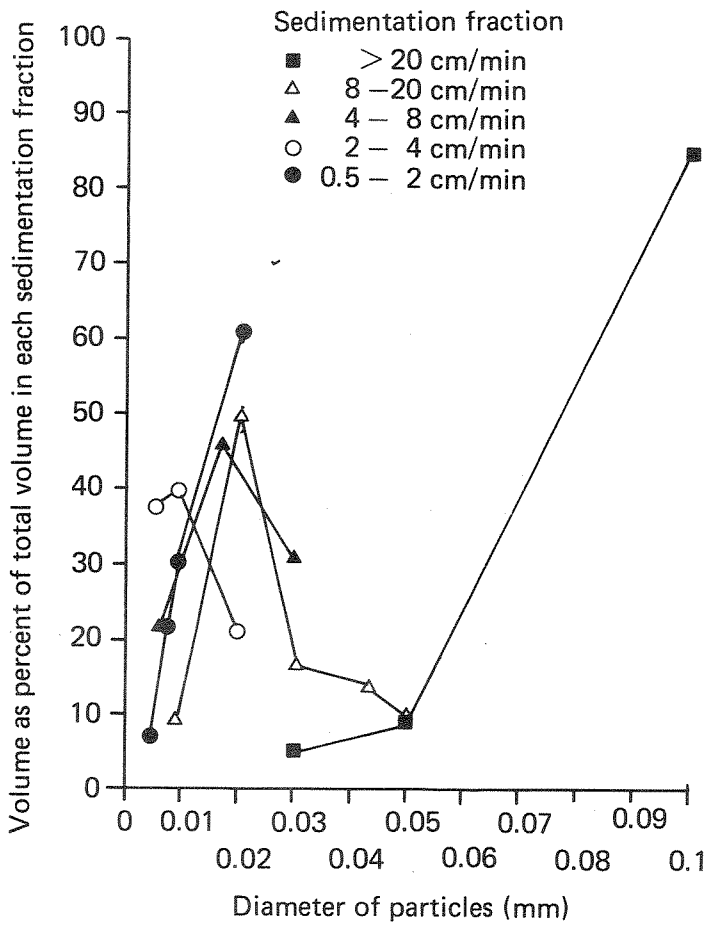


Figure 18. Relationship between sedimentation velocity and particle size in a pavement runoff sample. Each point represents the medium size of a group of particles. The sum of the points with a specific symbol is always 100 %.

Table 8 shows long term sedimentation data for a snowmelt and a rainfall runoff sample.

Table 8. Sedimentation tests with snowmelt and rainfall runoff samples. Rest concentration of total suspended matter at different sedimentation time.

	Sedimentation time									
	Unsedimentated sample mg/l	1 h mg/l	2 h mg/l	7 h mg/l	1 day mg/l	2 days mg/l	5 days mg/l	6 days mg/l	8 days mg/l	15 days mg/l
Snowmelt runoff (8.2 2.04.81)	930	360	270		150	110	70			2.0
Rainfall runoff (19.2 13.05.82)	594	45.6		15.8	11.5	6.0	5.0	3.0	2.3	

Table 9, 10 and 11 show the concentration of different PAH-components in runoff from the two road sections with a 10 cm and a 70 cm high roadshoulder barriere.

Table 9. Concentration of PAH in road surface runoff from the section of the road with a 70 cm high roadshoulder barrier 1980/81.

	ng/l							
Date	17.09.80	30.09.80	07.10.80	10.10.80	21.10.80	28.10.80	24.11.80	04.02.81
Sample number	1.2	2.2	3.2	4.2	5.2	6.2	7.2	8.2
Naftalene	25		61					
2-Metylnaftalene	19						55	
1-Metylnaftalene		11						
Bifenylene	15						47	
Acenaftylene	14							
Acenaftene	24			16		87	67	
4-Metylbifenylene	40							
Dibenzofurane	11	9		10			87	322
Fluorene	23	24	23	17		88	205	564
2-Metylfluorene	69	12	49				123	270
1-Metylfluorene	68	48	57				222	854
Dibenzothiophene	73	35	72	34		163		1059
Fenantrene	144	106	244	156	68	396	966	2668
Antracene	21	21	59	44		42	79	136
Acridine	48							
Carbazolene	8			12				
2-Metylantracene	31	34	44	57	28	93	170	218
1-Metylfenantrene	64	87	138	199	57	291	390	1073
Fluorantene	102	245	447	357	321	499	396	1573
Pyrene	173	286	386	403	363	570	734	1444
Benzo(a)fluorene	48	83	75	59	95	107		170
Benzo(b)fluorene	21					97		
1-Metylpyrene	58	126	80	47	52	192		
Benzo(c)fenantrene	28							
Benzo(a)antracene	36	60	109	86	46	139		
Trifenylen/Chrysene	121	211	332	291	194	416	187	433
Benzo(b)fluorantene	28	108	109	102	129	157	302	395
Benzo(j,k)fluorantene	25	95	70	97	89	277	254	300
Benzo(e)pyrene	25		42		108	202	203	
Benzo(a)pyrene	14	29	39	26	61	84	124	120
O-Phenylenepyrene	23	18		65	61	154	230	
Benzo(ghi)perylene	102			152	100	299	300	
Sum	1508	1643	2436	2246	1772	4353	5141	11604

Table 10. Concentration of PAH in road surface runoff from the section of the road with a 70 cm high roadshoulder barrier. 1981/82.

	ng/l				
Date	29.05.81	30.06.81	06.10.81	11.02.82	02.03.82
Sample number	13.2	14.2	15.2	16.2	17.2
Naftalene			87		
Bifenylene		54			
Acenaftylene	45				
Acenaftene	16		84		
Dibenzofurane	38			309	
Fluorene	122	39	53	291	94
9-Methylfluorene				50	121
2-Metylfluorene	29			130	145
1-Metylfluorene				124	335
Dibenzothiophene	42	66		112	231
Fenantrene	839	397	174	2173	1164
Antracene	214			312	
2-Metylantracene	38	62			604
1-Metylfenantrene	30	209	76	227	1085
9-Metylantracene	16				
Fluorantene	339	638	455	709	2706
Pyrene	554	630	411	1460	3357
Benzo(a)fluorene	18	45	37	25	367
Benzo(b)fluorene	33			89	311
1-Metylpyrene			62		
Benzo(a)antracene	31	97	54	171	
Trifenylen/Chrysene	305	472	375	763	989
Benzo(b)fluorantene	401	531	158	942	902
Benzo(j,k)fluorantene			50		
Benzo(e)pyrene	238	119	178	628	578
Benzo(a)pyrene	87	82	94	314	214
Perylene	48				
O-Phenylenepyrene	100	75	148		157
Dibenz(a,h)antracene	88				
Benzo(ghi)perylene	236		205		347
Sum	3907	3516	2701	8831	13687

Table 11. Concentration of PAH in road surface runoff from the section of the road with a 10 cm high roadshoulder barrier. 1980/81.

	ng/l				
Date	17.09.80	30.09.80	07.10.80	10.10.80	30.06.81
Sample number	1.1	2.1	3.1	4.1	14.1
Naftalene	43		138	19	
2-Metylnaftalene	55		22		
1-Metylnaftalene	14				
Bifenyle	13				55
Acenaftylene	14				
Acenaftene	20	29	21	24	
Dibenzofurane	10	40	7		
Fluorene	23	67	25	27	24
9-Methylfluorene	10	9			
2-Metylfluorene			57		21
1-Metylfluorene	85				89
Dibenzothiophene	37	93	54	22	
Fenantrene	143	314	216	112	233
Antracen	24	204	41	23	28
Acridine	40				
2-Metylantracene	25	40	43	25	103
1-Metylfenantrene	64	76	99	89	216
9-Metylantracen	7				
Fluorantene	125	348	251	348	837
Pyrene	170	360	276	350	793
Benzo(a)fluorene	58	69	157	92	85
1-Metylpyrene	34	88		155	
Benzo(a)antracen	65	32	92	82	81
Trifenylen/Chrysen	160	356	252	255	521
Benzo(b)fluoranten	55	251	108	87	168
Benzo(j,k)fluoranten		157	80	107	120
Benzo(e)pyrene	Mask			24	Mask
Benzo(a)pyrene	11	29	8	16	
O-Phenylenepyrene	12	23		33	79
Benzo(ghi)perylene	86	26			55
Sum	1403	2611	1947	1890	3508

Experiments with the snowmelt runoff sample; 7.2, 24.11.80

One of the snowmelt runoff samples (7.2, 24.11.80) was used in the experiments described below:

- Analysis of PAH, TOC, heavy metals and other components in untreated, sedimentated (2h) and filtrated sample.

- Analysis of organic micropollutants (look at figures 10 and 11).

- Toxicity test with heterotrophic organisms (bacteria, fungi and protozoa).

- Toxicity test with algae.

- Toxicity test with fish and fish eggs.

- Ames test on mutagenity.

- Demonstration of biodegradability-rate of PAH components in a sample inoculated with earth from the road ditch.

PAH, TOC, heavy metals and other components

Figure 19 shows the content of PAH in the sample. As can be seen, a lot of the PAH's are assosiated with very fine particulate matter that does not settle within two hours.

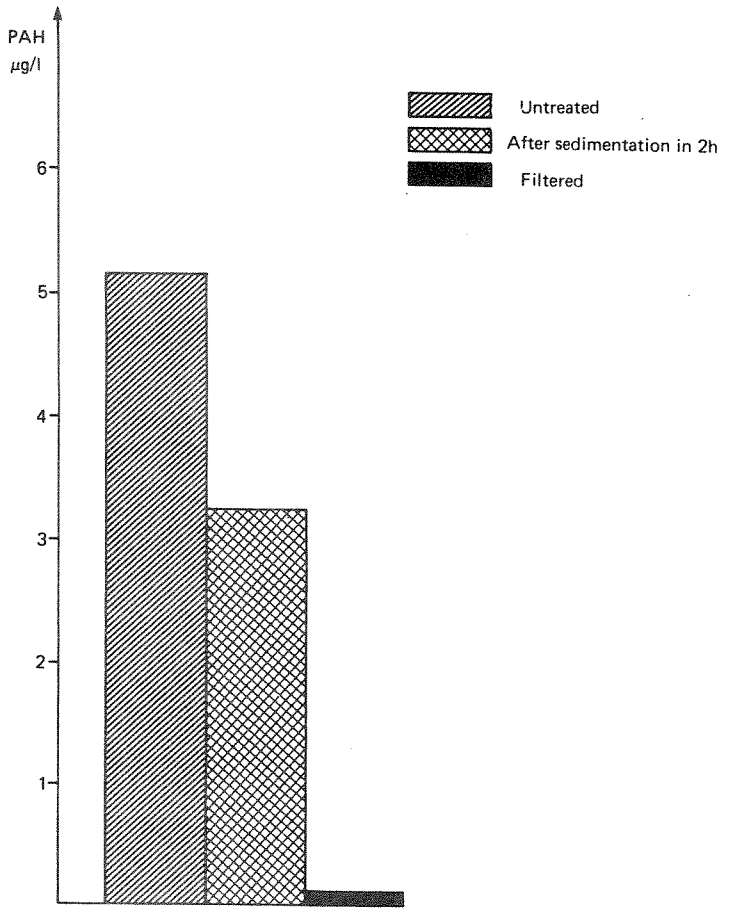


Figure 19. PAH content in unsedimentated, sedimentated and filtrated sample (7.2, 24.11.83).

Figure 20 shows similarly the content of organic carbon TOC in the sample. As can be seen most of the organic carbon are associated with the particles that settle within two hours.

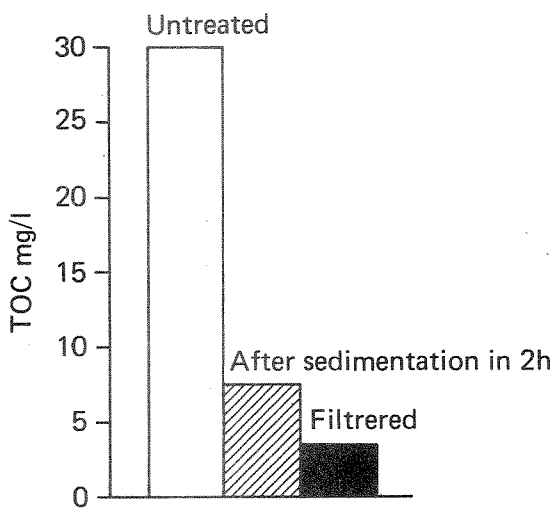


Figure 20. TOC content in unsedimentated, sedimentated and filtrated sample (7.2, 24.11.80).

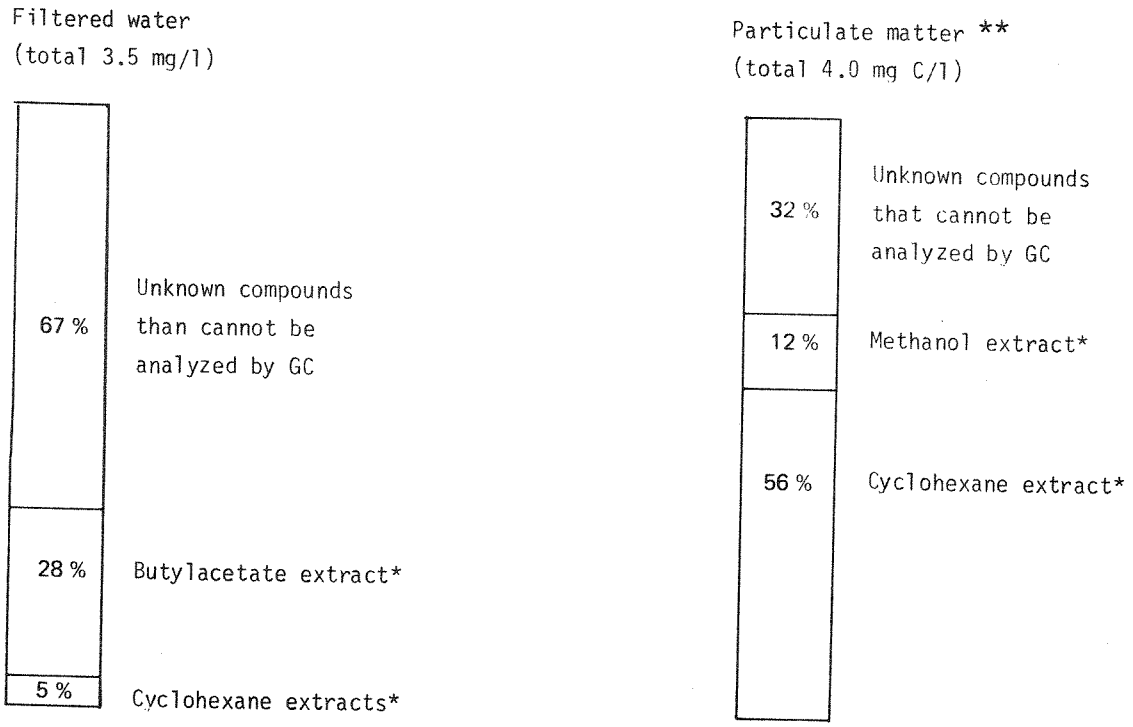
Table 12 shows the content of heavy metals and some other components in untreated, sedimentated and filtrated sample. The sample had been stored for some days before it was sedimentated and filtrated.

Table 12. Content of heavy metals and other components in untreated, sedimentated and filtrated sample (7.2, 24.11.80).

	cond. µs/cm	SO_4 mg/l	Cl mg/l	COD mg/l	Ni µg/l	Cr µg/l	Pb µg/l	Cu µg/l	Zn µg/l	Cd µg/l	Fe mg/l	Ca mg/l	Hg µg/l
Untreated	2550	45.4	920	170	91	46	160	40	200	10	10.7	5.93	13.2
Sedimentated (2h)	810	18.6	280	31	107	5	137	45	28	18	1.94	5.35	0.10
Filtrated	805	8.6	280	22	66	4	127	35	16	<10	0.28	5.02	2.03

Organic micropollutants

Organic micropollutants were analyzed according to figure 10 and 11. Some results are summarized in figures 21 and table 13. These results suggest that about 1/3 of the organic matter in the filtered runoff water is extractable with organic solvents (cyclohexane, butylacetate). Similarly, about 2/3 of the organic matter associated with the particles may be extracted into an organic solvent (cyclohexane, methanol). Due to the complex nature of the gaschromatograms from these extracts (including a high background), only a small fraction of these organics can be identified.



* Due to the complex nature of the gaschromatograms, only a small fraction of these organics can be identified.

** Look at ** in table 13.

Figure 21. Estimated distribution of organic matter as percent carbon (from GC and total C-analysis) (7.2, 24.11.80).

Table 13. Organic micropollutants in runoff water from highway (µg/l). (7.2, 24.11.80).

	Filtered water	Particulate** matter
Haloforms	0.5	-
Other compounds*	50	similar to filtered sample
HCB,PCB (and other persistent halogenated compounds)	0.05	0,27
Extractable unpolar org. Cl, tot/persistent	1.0/0.5	100/63

Cont. table 13.

	Filtered water	Particulate matter
Polar compounds	low	low
Extractable polar org. Cl, tot/persistent	9.0/-	3.0/3.0
* Alkanes, phenols, PAH, toluene, benzene, phthalates. - not analyzed.		
** The sample was sedimentated for 2 h before decantated and filtrated. Thus the particulate matter represents only a fraction of the total particulate matter in the untreated sample, see figures 19 and 20.		

The sample was found to contain low concentrations of alkanes, phenols, phthalates and PAH, i.e. compounds that might come from automobile traffic. The concentration of haloforms and other volatile compounds like benzene and toluene in the sample, was very low and comparable to the concentrations found in Norwegian tap water.

The sample was found to contain about 110 µg/l of organically bound chlorine, and most of this is associated with the particles. About half of the organochlorine is associated with persistent compounds. The concentration of persistent organochlorine in this sample (63 µg/l) is higher than normally found in background samples.

Effect on heterotrophic organisms

The microbiological activity of heterotrophes, as percent of normal, is plotted versus time (days) of incubation in Figure 22. The results clearly show that the runoff water has no negative effect on the activity of the microorganisms, on the contrary, a stimulating effect is observed by increased concentration of the sample.

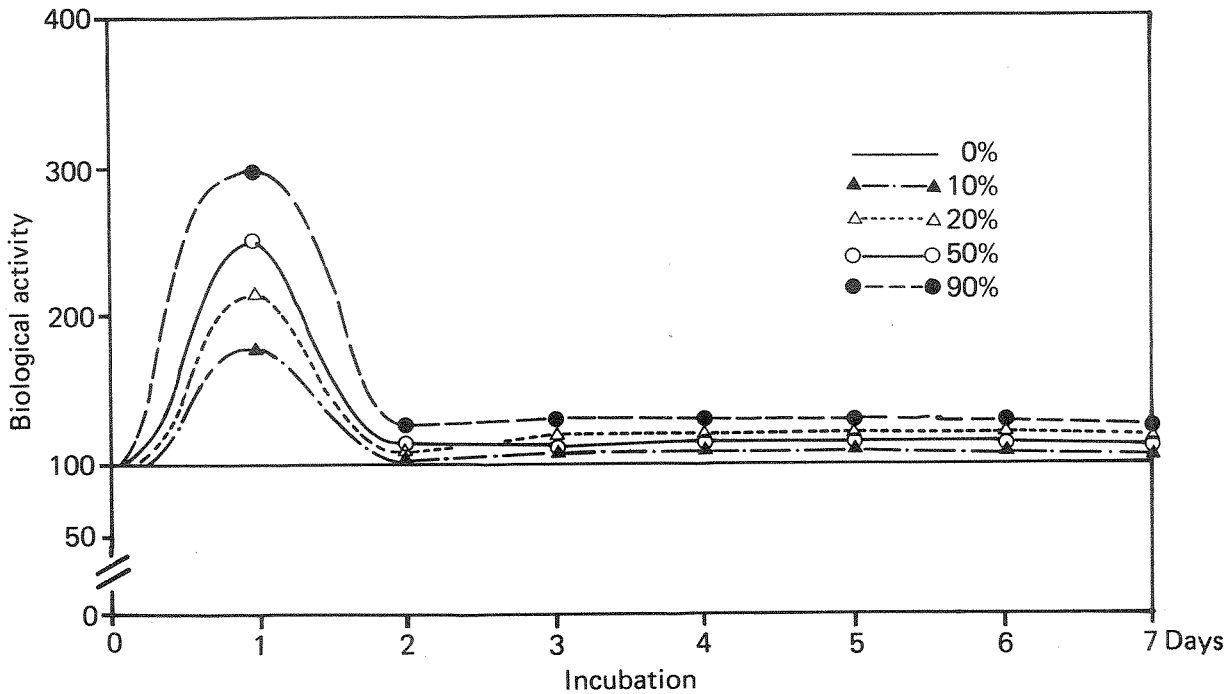


Figure 22. Biological test with heterotrophes.

Effect on algae

Figure 23 illustrates the increase in number of algae with time during a 4 day period. Two different concentrations of filtered runoff water (50 percent and 100 percent) were compared with the control (0 percent). It can be seen from these results that the effect of the sample on the growth is small. The mean growth rate during the first 3 days may be calculated as follows:

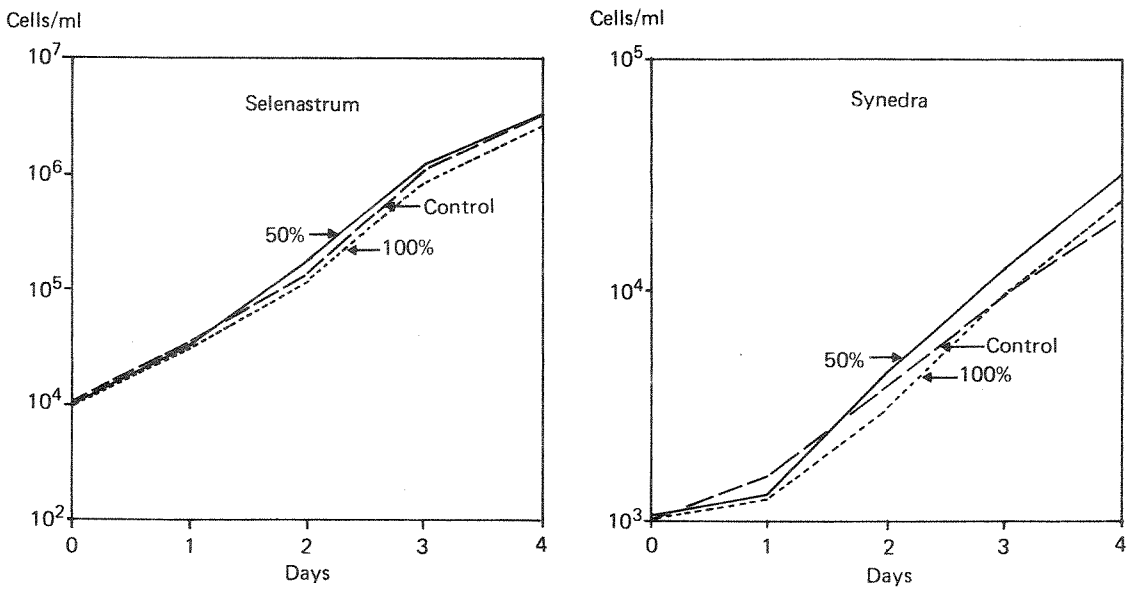


Figure 23. Growth-curves for algae with undiluted and 50 percent diluted runoff water.

$$\text{Growth rate } \mu_{0-3} = \frac{\log n_3 - \log n_o}{\log 2 \cdot 3} \cdot \text{days}^{-1}$$

Where n_o and n_3 are the number of cells at start and after 3 days, respectively. The growth rate (μ_{0-3} = as percent of control) is plotted versus concentration of sample on figure 24. It appears from these curves that 50 percent concentration of filtered runoff sample has a small stimulating effect on both Selenastrum capricornutum and Synedra acus, and that the acute toxic effect in undiluted sample (100 percent) is neglectable.

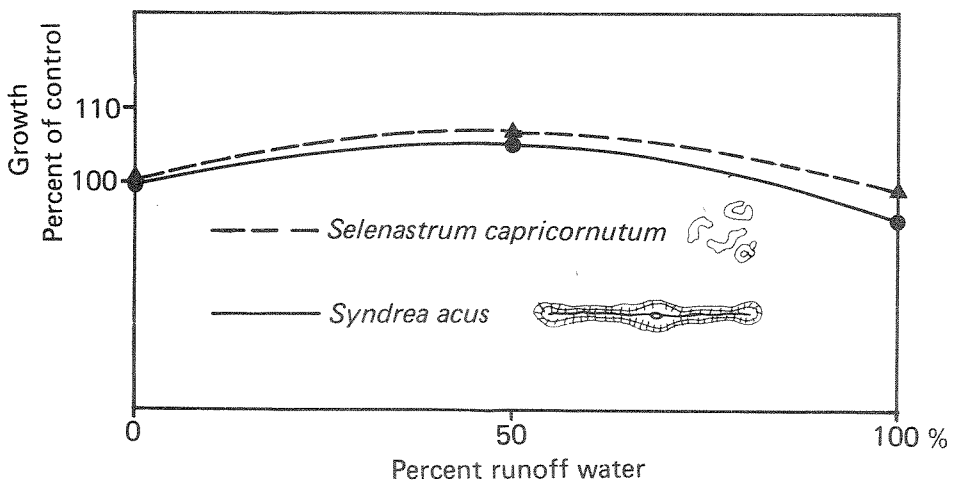


Figure 24. Dose/response-curves for the effect of runoff water on the growth-rate of algae.

Test on fish and fish eggs

A simple fish experiment was performed on two small salmons (3-4 cm long) in a 2 litre beaker. The unfiltered sample-water was used without dilution and was changed daily through the 4 day period the experiment lasted. The water temperature was 6 - 9°C and the system was constantly aerated. An identical system with tapwater (City of Oslo) acted as control. The behaviour and condition of the fish in both systems were noted daily.

Fish eggs of salmon (50) were put into perforated plexiglass boxes directly onto the particulated part of the runoff water. This resulted in a good contact between the eggs and the particulate matter (see Figure 12). During the 53 day test period tap water (City of Oslo) circulated slowly through the system. The eggs hatched after about 5 weeks, and this resulted in an increased contact between the particle pollutants and the fish. Due to the swimming activities some of the particulate matter was lost with the outflowing water.

Figure 25. Biological test was performed with small salmons (7.2, 24.11.80).

Ames test on mutagenity

For a description of the test, see chapter 3.3.

Extracts from a 1 litre filtrated snowmelt runoff sample (7.2, 24.11.80) were tested in an ordinary Ame's test. Liverenzymepreparate was added to half of the beakers to look at a potensially indirekt mutagenic effect. After 48 hours the bacteriocolonies were counted. The results are shown in figure 26. Spontaneous mutations mean the "natural" mutations that occur without adding toxic extracts. What is described as "netto", therefore, means the increase in mutations when adding the extracts from the runoff samle.

The results suggest that the filtrated snowmelt runoff sample have a low mutagenic effect, the values beeing in the same order of magnitude as one finds when using Ame's test on chlorinated drinking water. It should however be emphasized that there are som controversies among scientist's on the validity of the results from Ames test. This means that no final conclusion should be made from this single test.

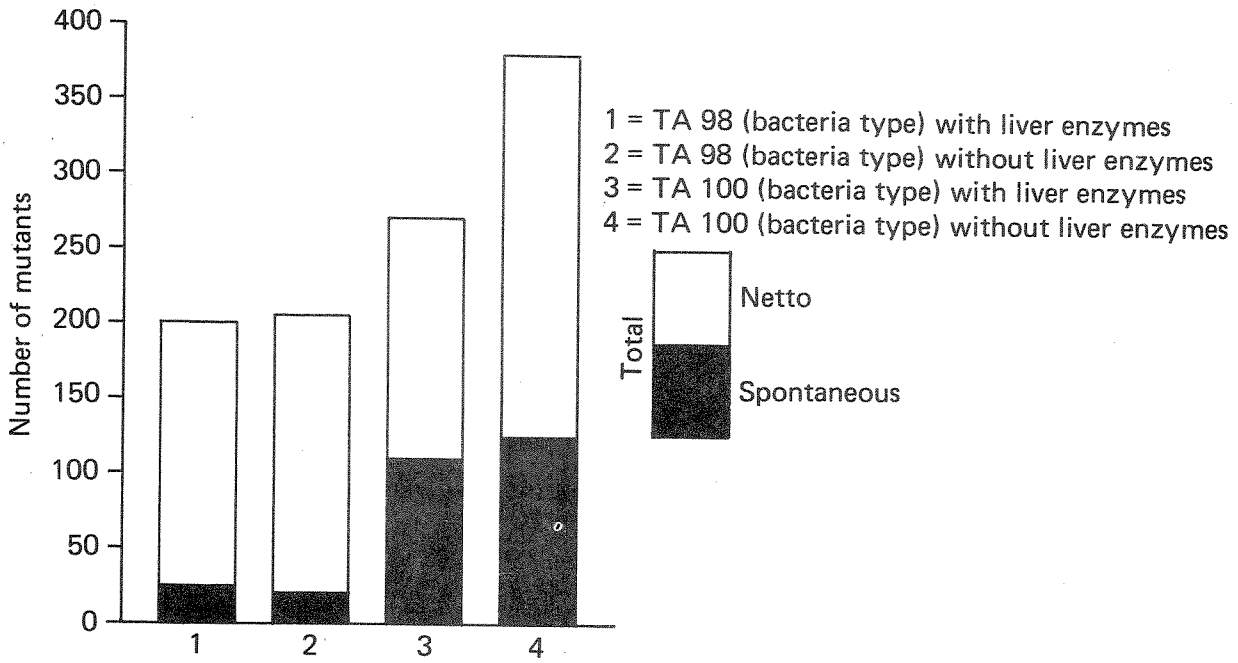


Figure 26. Test of Mutagenity.(Ames test) Mutagenic agents in 1 l filtrated snowmelt runoff (7.2, 24.11.80).

Biodegradability of PAH components in a sample inoculated with earth from the road ditch

A sample of untreated runoff water was inoculated with earth from the road ditch and a standard addition of organic matter. The PAH content was measured before the test started and after a 30 days period. The temperature was 20°C during the test. As can be seen from table 14 the total concentration decreased from 5141 ng/l to 724 ng/l.

Table 14. Biodegradation of PAH in sample (7.2, 24.11.80) inoculta-ted with earth from the road ditch.

	ng/l			
	Untrea-ted	After sedimen-tation in 2h	Filt-ered	After biodegra-dation in 4 weeks
2-Metylnaftalene	55	66		
1-Metylnaftalene				
Bifenyle	47	52		
Acenaftylene				
Acenaftene	67			
Dibenzofurane	84	86		
Fluorene	205	154		
2-Metylfluorene	123	64		
1-Metylfluorene	222	122		
Dibenzothiophene				
Fenantrene	966	832	15	97
Antracen	79			
2-Metylantracene	170			
1-Metylfenantrene	390	266		
Fluorantene	396	391	16	78
Pyrene	734	538	19	425
Trifenylen/Chrysen	187	75	10	
Benzo(b)fluoranten	302	137	30	
Benzo(j,k)fluoranten	254	157		
Benzo(e)pyrene	203	86		54
Benzo(a)pyrene	124			70
O-Phenylenepyrene	230			
Benzo(ghi)perylene	300	172	11	
Sum	5141	320	101	724

Dust transport to the near surroundings

Table 15 shows the dustfall of PAH at different distances from the highway. The dustfall of PAH was collected in stainless steel buckets (height · length · width = 10 cm · 40 cm · 60 cm) placed directly on the snow while it was snowing. The values thus represent a winter situation when studded tyres are used on the cars.

Table 15. Dustfall of PAH along E6 Jessheim.

Side	Date	Distance to road (m)	Dustfall ng PAH/day x m^2
southern	13.11-10.12.80		4400
southern	10.12-18.12.80		12660
northern	10.12-18.12.80	20	12310
northern	13.1 - 4.2.81		31240
southern	12.11-10.12.80		1980
southern	10.12-18.12.80		7630
northern	10.12-18.12.80	50	5400
northern	12.1 - 4.2.81		4860
northern	4.2 - 20.2.81		12280

Tables 16 - 26 show the dustfall of the components dry matter, lead, copper, zinc, calsium, iron, sulfate, chlorine, cadmium, nickel and chromium along E6 Jessheim in a period of two years. The dust was collected in circular plastic buckets on stands as shown in figure 6.

Table 16. Dustfall of dry matter along E6, Jessheim.

DATO-YEAR	DAYS	DISTANCE TO ROAD	WATER SOLUBLE		WATER INSOLUBLE		TOTAL	
		(m)	g/m2	g/30d*m2	g/m2	g/30d*m2	g/m2	g/30d*m2
24/10-24/11-80	31.00	6.00	27.56	26.67	129.33	125.16	156.89	151.83
13/1-23/2-81	41.00	6.00	30.22	22.11	161.78	118.38	192.00	140.49
22/2-20/5-81	87.00	6.00	38.60	13.31	378.00	130.34	416.60	143.66
25/5-15/7-81	51.00	6.00	5.00	2.94	43.00	25.29	48.00	28.24
11/8-8/9-81	28.00	6.00	1.21	1.30	15.70	16.82	16.91	18.12
8/9-16/10-81	38.00	6.00	1.78	1.41	20.40	16.11	22.18	17.51
16/10-22/12-81	37.00	6.00	141.00	114.32	789.00	639.73	930.00	754.05
11/2-23/3-82	40.00	6.00	14.60	10.95	89.30	66.98	103.90	77.93
12/6-22/7-82	40.00	6.00	2.30	1.73	57.20	42.90	59.50	44.63
24/10-24/11-82	31.00	20.00	0.76	0.74	3.51	3.40	4.27	4.13
13/1-23/2-81	41.00	20.00	0.71	0.52	3.24	2.37	3.95	2.89
22/2-20/5-81	87.00	20.00	1.40	0.48	11.00	3.79	12.40	4.28
25/5-15/7-81	51.00	20.00	1.40	0.82	1.90	1.12	3.30	1.94
11/8-8/9-81	28.00	20.00	0.22	0.24	1.05	1.13	1.27	1.36
8/9-16/10-81	38.00	20.00	0.89	0.70	0.90	0.71	1.79	1.41
16/10-22/12-81	37.00	20.00	3.50	2.84	8.73	7.08	12.23	9.92
11/2-28/3-82	40.00	20.00	1.60	1.20	5.40	4.05	7.00	5.25
12/6-22/7-82	40.00	20.00	0.99	0.74	0.70	0.53	1.69	1.27
24/10-24/11-80	31.00	100.00	0.49	0.47	1.07	1.04	1.56	1.51
13/1-23/2-81	41.00	100.00	0.44	0.32	1.02	0.75	1.46	1.07
22/2-20/5-81	87.00	100.00	0.70	0.24	3.80	1.31	4.50	1.55
11/8-8/9-81	28.00	100.00	0.44	0.47	0.35	0.38	0.79	0.85
8/9-16/10-81	38.00	100.00	0.48	0.38	0.50	0.39	0.96	0.77
16/10-22/12-81	37.00	100.00	1.60	1.30	2.42	1.96	4.02	3.26

Table 17. Dustfall of lead along E6, Jessheim.

DATO-YEAR	DAYS	DISTANCE TO ROAD	WATER SOLUBLE		WATER INSOLUBLE		TOTAL	
		(m)	mg/m2	mg/30d*m2	mg/m2	mg/30d*m2	mg/m2	mg/30d*m2
24/10-24/11-80	31.00	6.00	0.11	0.11	15.51	15.01	15.62	15.12
13/1-23/2-81	41.00	6.00	0.67	0.49	22.04	16.13	22.71	16.62
22/2-20/5-81	87.00	6.00		0.00	72.60	25.03	72.60	25.03
25/5-15/7-81	51.00	6.00		0.00	5.50	3.24	5.50	3.24
11/8-8/9-81	28.00	6.00	0.72	0.77	3.18	3.41	3.90	4.18
8/9-16/10-81	38.00	6.00	3.82	3.02	1.78	1.41	5.60	4.42
16/10-22/12-81	37.00	6.00	0.60	0.49	58.90	47.76	59.50	48.24
11/2-28/3-82	48.00	6.00	0.86	0.54	16.60	10.38	17.46	10.91
12/6-22/7-82	40.00	6.00	0.46	0.35	20.00	15.00	20.46	15.35
12/6-22/7-82	40.00	12.00	0.88	0.66	2.60	1.95	3.48	2.61
24/10-24/11-82	31.00	20.00	0.71	0.69	1.78	1.72	2.49	2.41
13/1-23/2-81	41.00	20.00	0.20	0.15	1.42	1.04	1.62	1.19
22/2-20/5-81	87.00	20.00		0.00	5.00	1.72	5.00	1.72
25/5-15/7-81	51.00	20.00		0.00	0.25	0.15	0.25	0.15
11/8-8/9-81	28.00	20.00	0.41	0.44	0.45	0.48	0.86	0.92
8/9-16/10-81	38.00	20.00	1.77	1.40	0.15	0.12	1.92	1.52
16/10-22/12-81	37.00	20.00	4.54	3.68	0.82	0.66	5.36	4.35
11/2-28/3-82	48.00	20.00	2.40	1.50	0.73	0.46	3.13	1.96
12/6-22/7-82	40.00	25.00	1.20	0.90	1.00	0.75	2.20	1.65
24/10-24/11-80	31.00	100.00	0.98	0.95	0.58	0.56	1.56	1.51
13/1-23/2-81	41.00	100.00	0.42	0.31	0.67	0.49	1.09	0.80
22/2-20/5-81	87.00	100.00		0.00	2.30	0.79	2.30	0.79
11/8-8/9-81	28.00	100.00	0.27	0.29	0.21	0.23	0.48	0.51
8/9-16/10-81	38.00	100.00	1.23	0.97	0.14	0.11	1.37	1.08
16/10-22/12-81	37.00	100.00	2.34	1.90	0.25	0.20	2.59	2.10

Table 18. Dustfall of copper along E6, Jessheim.

DATO-YEAR	DAYS	DISTANCE TO ROAD	WATER SOLUBLE		WATER INSOLUBLE		TOTAL	
		(m)	mg/m2	mg/30d*m2	mg/m2	mg/30d*m2	mg/m2	mg/30d*m2
24/10-24/11-80	31.00	6.00	0.03	0.03	2.31	2.24	2.34	2.26
13/1-23/2-81	41.00	6.00	0.12	0.09	1.91	1.40	2.03	1.49
22/2-20/5-81	87.00	6.00		0.00	8.40	2.90	8.40	2.90
25/5-15/7-81	51.00	6.00		0.00	0.80	0.47	0.80	0.47
11/8-8/9-81	28.00	6.00	0.72	0.77	0.56	0.60	1.28	1.37
8/9-16/10-81	38.00	6.00	0.70	0.55	0.16	0.13	0.86	0.68
16/10-22/12-81	37.00	6.00	0.60	0.49	7.20	5.84	7.80	6.32
11/2-28/3-82	48.00	6.00	0.17	0.11	1.80	1.13	1.97	1.23
12/6-22/7-82	40.00	6.00	0.25	0.19	7.50	5.63	7.75	5.81
12/6-22/7-82	40.00	12.00	0.11	0.08	0.22	0.17	0.33	0.25
24/10-24/11-82	31.00	20.00	0.10	0.10	0.18	0.17	0.28	0.27
13/1-23/2-81	41.00	20.00	0.02	0.01	0.10	0.07	0.12	0.09
22/2-20/5-81	87.00	20.00		0.00	0.30	0.10	0.30	0.10
25/5-15/7-81	51.00	20.00		0.00	0.10	0.06	0.10	0.06
11/8-8/9-81	28.00	20.00	0.12	0.13	0.10	0.11	0.22	0.24
8/9-16/10-81	38.00	20.00	0.70	0.55	0.10	0.08	0.80	0.63
16/10-22/12-81	37.00	20.00	0.40	0.32	0.13	0.11	0.53	0.43
11/2-28/3-82	48.00	20.00	0.35	0.22	0.12	0.08	0.47	0.29
12/6-22/7-82	40.00	25.00	0.11	0.08	0.08	0.06	0.19	0.14
24/10-24/11-80	31.00	100.00	0.04	0.04	0.12	0.12	0.16	0.15
13/1-23/2-81	41.00	100.00	0.09	0.07	0.07	0.05	0.16	0.12
22/2-20/5-81	87.00	100.00		0.00	0.25	0.09	0.25	0.09
11/8-8/9-81	28.00	100.00	0.28	0.30	0.10	0.11	0.38	0.41
8/9-16/10-81	38.00	100.00	3.10	2.45	0.10	0.08	3.20	2.53
16/10-22/12-81	37.00	100.00	0.40	0.32	0.10	0.08	0.50	0.41

Table 19. Dustfall of zinc along E6, Jessheim.

DATO-YEAR	DAYS	DISTANCE TO ROAD (m)	WATER SOLUBLE mg/m2	WATER SOLUBLE mg/30d*m2	WATER INSOLUBLE mg/m2	WATER INSOLUBLE mg/30d*m2	TOTAL mg/m2	TOTAL mg/30d*m2	
24/10-24/11-80	31.00	6.00	0.28	0.27	9.69	9.38	9.97	9.65	
13/1-23/2-81	41.00	6.00	1.11	0.81	11.42	8.36	12.53	9.17	
22/2-20/5-81	87.00	6.00		0.00	38.30	13.21	38.30	13.21	
25/5-15/7-81	51.00	6.00		0.00	2.00	1.18	2.00	1.18	
11/8-8/9-81	28.00	6.00	3.87	4.15	1.21	1.30	5.08	5.44	
8/9-16/10-81	38.00	6.00	8.92	7.04	0.94	0.74	9.86	7.78	
16/10-22/12-81	37.00	6.00	1.50	1.22	41.60	33.73	43.10	34.95	
11/2-28/3-82	48.00	6.00	1.90	1.19	10.90	6.81	12.80	8.00	
12/6-22/7-82	40.00	6.00	3.30	2.48	7.20	5.40	10.50	7.88	
12/6-22/7-82	40.00	12.00	3.40	2.55	1.20	0.90	4.60	3.45	0.00
24/10-24/11-82	31.00	20.00	5.07	4.91	0.58	0.56	5.65	5.47	
13/1-23/2-81	41.00	20.00	3.38	2.47	0.89	0.65	4.27	3.12	
22/2-20/5-81	87.00	20.00		0.00	2.80	0.97	2.80	0.97	
25/5-15/7-81	51.00	20.00		0.00	0.18	0.11	0.18	0.11	
11/8-8/9-81	28.00	20.00	1.35	1.45	0.34	0.36	1.69	1.81	
8/9-16/10-81	38.00	20.00	5.30	4.18	0.64	0.51	5.94	4.69	
16/10-22/12-81	37.00	20.00	1.80	1.46	0.24	0.19	2.04	1.65	
11/2-28/3-82	48.00	20.00	4.80	3.00	0.32	0.20	5.12	3.20	
12/6-22/7-82	40.00	25.00	2.30	1.73	0.57	0.43	2.87	2.15	
24/10-24/11-80	31.00	100.00	1.38	1.34	0.25	0.24	1.63	1.58	
13/1-23/2-81	41.00	100.00	1.56	1.14	0.31	0.23	1.87	1.37	
22/2-20/5-81	87.00	100.00		0.00	0.30	0.10	0.30	0.10	
11/8-8/9-81	28.00	100.00	1.67	1.79	0.35	0.38	2.02	2.16	
8/9-16/10-81	38.00	100.00	3.69	2.91	0.27	0.21	3.96	3.13	
16/10-22/12-81	37.00	100.00	1.30	1.05	0.22	0.18	1.52	1.23	

Table 20. Dustfall of calsium along E6, Jessheim.

DATO-YEAR	DAYS	DISTANCE TO ROAD (m)	WATER SOLUBLE mg/m2	WATER SOLUBLE mg/30d*m2	WATER INSOLUBLE mg/m2	WATER INSOLUBLE mg/30d*m2	TOTAL mg/m2	TOTAL mg/30d*m2
24/10-24/11-80	31.00	6.00	778.00	752.90	3060.00	2961.29	3838.00	3714.19
13/1-23/2-81	41.00	6.00	1458.00	1066.83	2040.00	1492.68	3498.00	2559.51
22/2-20/5-81	87.00	6.00	2040.00	703.45	5130.00	1768.97	7170.00	2472.41
25/5-15/7-81	51.00	6.00		0.00	82.80	48.71	82.80	48.71
11/8-8/9-81	28.00	6.00	484.00	518.57	14.00	15.00	498.00	533.57
8/9-16/10-81	38.00	6.00	280.00	1.00	16.60	13.11	296.60	14.11
16/10-22/12-81	37.00	6.00	6711.00	5441.35	10420.00	8448.65	17131.00	13890.00
11/2-28/3-82	48.00	6.00	1366.00	853.75	447.00	279.38	1813.00	1133.13
12/6-22/7-82	40.00	6.00	244.00	183.00	184.00	138.00	428.00	321.00
12/6-22/7-82	40.00	12.00	72.20	54.15	18.20	13.65	90.40	67.80
24/10-24/11-82	31.00	20.00	87.10	84.29	6.49	6.28	93.59	90.57
13/1-23/2-81	41.00	20.00	59.10	43.24	8.90	6.51	68.00	49.76
22/2-20/5-81	87.00	20.00	215.00	74.14	24.50	8.45	239.50	82.59
25/5-15/7-81	51.00	20.00		0.00	0.60	0.35	0.60	0.35
11/8-8/9-81	28.00	20.00	79.70	85.39	2.90	3.11	82.60	88.50
8/9-16/10-81	38.00	20.00	35.40	27.95	0.15	0.12	35.55	28.07
16/10-22/12-81	37.00	20.00	272.00	220.54	9.87	8.00	281.87	228.54
11/2-28/3-82	48.00	20.00	160.00	100.00	12.70	7.94	172.70	107.94
12/6-22/7-82	40.00	25.00	52.50	39.38	10.20	7.65	62.70	47.03
24/10-24/11-80	31.00	100.00	36.40	35.23	2.00	1.94	38.40	37.16
13/1-23/2-81	41.00	100.00	25.60	18.73	2.40	1.76	28.00	20.49
22/2-20/5-81	87.00	100.00	84.00	28.97	4.90	1.69	88.90	30.66
11/8-8/9-81	28.00	100.00	25.60	27.43	2.70	2.89	28.30	30.32
8/9-16/10-81	38.00	100.00	36.80	29.05	0.80	0.63	37.60	29.68
16/10-22/12-81	37.00	100.00	83.60	67.78	1.90	1.54	85.50	69.32

SHEIM

Table 21. Dustfall of iron along E6, Jessheim.

DATO-YEAR	DAYS	DISTANCE TO ROAD	WATER SOLUBLE		WATER INSOLUBLE		TOTAL	
		(m)	mg/m2	mg/30d*m2	mg/m2	mg/30d*m2	mg/m2	mg/30d*
24/10-24/11-80	31.00	6.00	6.27	1.60	782.00	756.77	788.27	758.37
13/1-23/2-81	41.00	6.00	10.22	1.87	421.00	308.05	431.22	309.92
22/2-20/5-81	87.00	6.00	0.00	7.60	3380.00	1165.52	3380.00	1173.12
25/5-15/7-81	51.00	6.00	0.00	0.35	250.00	147.06	250.00	147.41
11/8-8/9-81	28.00	6.00	0.38	0.11	111.50	119.46	111.88	119.57
8/9-16/10-81	38.00	6.00	0.76	0.10	74.50	58.82	75.26	58.92
16/10-22/12-81	37.00	6.00	3.01	4.00	1918.00	1555.14	1921.01	1559.14
11/2-28/3-82	48.00	6.00	30.60	2.00	739.00	461.88	769.60	463.88
12/6-22/7-82	40.00	6.00	3.70	1.00	242.00	181.50	245.70	182.50
12/6-22/7-82	40.00	12.00	2.70	0.16	36.60	27.45	39.30	27.61
24/10-24/11-82	31.00	20.00	2.89	0.04	20.70	20.03	23.59	20.07
13/1-23/2-81	41.00	20.00	1.87	0.03	20.40	14.93	22.27	14.96
22/2-20/5-81	87.00	20.00	0.00	0.15	120.00	41.38	120.00	41.53
25/5-15/7-81	51.00	20.00	0.00	0.10	8.40	4.94	8.40	5.04
11/8-8/9-81	28.00	20.00	0.10	0.10	14.90	15.96	15.00	16.06
8/9-16/10-81	38.00	20.00	0.70	0.10	13.40	10.58	14.10	10.68
16/10-22/12-81	37.00	20.00	0.90	0.10	61.80	50.11	62.70	50.21
11/2-28/3-82	48.00	20.00	6.40	0.25	40.80	25.50	47.20	25.75
12/6-22/7-82	40.00	25.00	6.40	0.08	15.50	11.63	21.90	11.71
24/10-24/11-80	31.00	100.00	4.13	0.02	7.11	6.88	11.24	6.90
13/1-23/2-81	41.00	100.00	1.47	0.01	6.98	5.11	8.45	5.12
22/2-20/5-81	87.00	100.00	0.00	0.10	43.00	14.83	43.00	14.93
11/8-8/9-81	28.00	100.00	0.13	0.10	7.90	8.46	8.03	8.56
8/9-16/10-81	38.00	100.00	0.70	0.10	2.00	1.58	2.70	1.68
16/10-22/12-81	37.00	100.00	1.34	0.10	22.90	18.57	24.24	18.67

Table 22. Dustfall of sulfate along E6, Jessheim.

DATO-YEAR	DAYS	DISTANCE TO ROAD	WATER SOLUBLE		WATER INSOLUBLE		TOTAL	
		(m)	g/m2	g/30d*m2	g/m2	g/30d*m2	g/m2	g/30d*
24/10-24/11-80	31	6	174	168	0	0	174	168
13/1-23/2-81	41	6	560	410	0	0	560	410
22/2-20/5-81	87	6	425	147	0	0	425	147
25/5-15/7-81	51	6	0	0	0	0	0	0
11/8-8/9-81	28	6	35	38	0	0	35	38
8/9-16/10-81	38	6	248	196	0	0	248	196
16/10-22/12-81	37	6	903	732	0	0	903	732
11/2-28/3-82	48	6	439	274	0	0	439	274
12/6-22/7-82	40	6	112	84	0	0	112	84
12/6-22/7-82	40	12	80	60	0	0	80	60
24/10-24/11-82	31	20	80	77	0	0	80	77
13/1-23/2-81	41	20	53	39	0	0	53	39
22/2-20/5-81	87	20	180	62	0	0	180	62
25/5-15/7-81	51	20	0	0	0	0	0	0
11/8-8/9-81	28	20	21	22	0	0	21	22
8/9-16/10-81	38	20	198	156	0	0	198	156
16/10-22/12-81	37	20	227	184	0	0	227	184
11/2-28/3-82	48	20	193	121	0	0	193	121
12/6-22/7-82	40	25	72	54	0	0	72	54
24/10-24/11-80	31	100	54	52	0	0	54	52
13/1-23/2-81	41	100	28	20	0	0	28	20
22/2-20/5-81	87	100	135	47	0	0	135	47
11/8-8/9-81	28	100	17	18	0	0	17	18
8/9-16/10-81	38	100	172	136	0	0	172	136
16/10-22/12-81	37	100	164	133	0	0	164	133

Table 23. Dustfall of chloride along E6, Jessheim.

DATO-YEAR	DAYS	DISTANCE TO ROAD	WATER SOLUBLE		WATER INSOLUBLE		TOTAL	
		(m)	g/m2	g/30d*m2	g/m2	g/30d*m2	g/m2	g/30d*
24/10-24/11-80	31	6	13955	13505	0	0	13955	13505
13/1-23/2-81	41	6	13866	10146	0	0	13866	10146
22/2-20/5-81	87	6	17600	6069	0	0	17600	6069
25/5-15/7-81	51	6	0	0	0	0	0	0
11/8-8/9-81	28	6	48	52	0	0	48	52
8/9-16/10-81	38	6	191	151	0	0	191	151
16/10-22/12-81	37	6	64104	51976	0	0	64104	51976
11/2-28/3-82	48	6	4490	2806	0	0	4490	2806
12/6-22/7-82	40	6	70	53	0	0	70	53
12/6-22/7-82	40	12	15	11	0	0	15	11
24/10-24/11-82	31	20	120	116	0	0	120	116
13/1-23/2-81	41	20	99	72	0	0	99	72
22/2-20/5-81	87	20	215	74	0	0	215	74
25/5-15/7-81	51	20	0	0	0	0	0	0
11/8-8/9-81	28	20	16	17	0	0	16	17
8/9-16/10-81	38	20	118	93	0	0	118	93
16/10-22/12-81	37	20	508	412	0	0	508	412
11/2-28/3-82	48	20	330	206	0	0	330	206
12/6-22/7-82	40	25	6	4	0	0	6	4
24/10-24/11-80	31	100	50	48	0	0	50	48
13/1-23/2-81	41	100	50	37	0	0	50	37
22/2-20/5-81	87	100	36	12	0	0	36	12
11/8-8/9-81	28	100	18	19	0	0	18	19
8/9-16/10-81	38	100	123	97	0	0	123	97
16/10-22/12-81	37	100	201	163	0	0	201	163

Table 24. Dustfall of cadmium along E6, Jessheim.

DATO-YEAR	DAYS	DISTANCE TO ROAD	WATER SOLUBLE		WATER INSOLUBLE		TOTAL	
		(m)	ug/m2	ug/30d*m2	ug/m2	ug/30d*m2	ug/m2	ug/30d*
24/10-24/11-80	31.00	6.00	9.00	8.71	110.00	106.45	119.00	115.16
13/1-23/2-81	41.00	6.00	4.00	2.93	90.00	65.85	94.00	68.78
22/2-20/5-81	87.00	6.00	0.00	0.00	750.00	258.62	750.00	258.62
25/5-15/7-81	51.00	6.00	0.00	0.00	< 30.00	< 17.65	< 30.00	< 17.65
11/8-8/9-81	28.00	6.00	3.00	3.21	< 20.00	< 21.43	< 23.00	< 24.64
8/9-16/10-81	38.00	6.00	4.00	3.16	< 20.00	< 15.79	< 24.00	< 18.95
16/10-22/12-81	37.00	6.00	2.00	1.62	390.00	316.22	392.00	317.84
11/2-28/3-82	48.00	6.00	4.00	2.50	60.00	37.50	64.00	40.00
12/6-22/7-82	40.00	6.00	2.00	1.50	60.00	45.00	62.00	46.50
12/6-22/7-82	40.00	12.00	1.00	0.75	4.00	3.00	5.00	3.75
24/10-24/11-82	31.00	20.00	17.00	16.45	1.30	1.26	18.30	17.71
13/1-23/2-81	41.00	20.00	3.00	2.20	1.30	0.95	4.30	3.15
22/2-20/5-81	87.00	20.00	0.00	0.00	1.00	0.34	1.00	0.34
25/5-15/7-81	51.00	20.00	0.00	0.00	< 20.00	< 11.76	< 20.00	< 11.76
11/8-8/9-81	28.00	20.00	< 3.00	< 3.21	< 20.00	< 21.43	< 23.00	< 24.64
8/9-16/10-81	38.00	20.00	3.00	2.37	< 20.00	< 15.79	< 23.00	< 18.16
16/10-22/12-81	37.00	20.00	6.00	4.86	< 20.00	< 16.22	< 26.00	< 21.08
11/2-28/3-82	48.00	20.00	3.00	1.88	1.00	0.63	4.00	2.50
12/6-22/7-82	40.00	25.00	2.00	1.50	2.00	1.50	4.00	3.00
24/10-24/11-80	31.00	100.00	11.00	10.65	0.89	0.86	11.89	11.51
13/1-23/2-81	41.00	100.00	2.00	1.46	0.44	0.32	2.44	1.79
22/2-20/5-81	87.00	100.00	0.00	0.00	0.50	0.17	0.50	0.17
11/8-8/9-81	28.00	100.00	< 3.00	< 3.21	< 20.00	< 21.43	< 23.00	< 24.64
8/9-16/10-81	38.00	100.00	4.00	3.16	< 20.00	< 15.79	< 24.00	< 18.95
16/10-22/12-81	37.00	100.00	4.00	3.24	< 20.00	< 16.22	< 24.00	< 19.46

Table 25. Dustfall of nickel along E6, Jessheim.

DATO-YEAR	DAYS	DISTANCE TO ROAD	WATER SOLUBLE		WATER INSOLUBLE		TOTAL	
		(m)	mg/m2	mg/30d*m2	mg/m2	mg/30d*m2	mg/m2	mg/30d*m2
24/10-24/11-80	31.00	6.00	< 0.27	< 0.26	1.60	1.55	1.87	1.81
13/1-23/2-81	41.00	6.00	0.71	0.52	1.87	1.37	2.58	1.89
22/2-20/5-81	87.00	6.00	0.00	0.00	7.60	2.62	7.60	2.62
25/5-15/7-81	51.00	6.00	0.00	0.00	0.35	0.21	< 0.35	< 0.21
11/8-8/9-81	28.00	6.00	0.17	0.18	0.11	0.12	< 0.28	< 0.30
8/9-16/10-81	38.00	6.00	0.76	0.60	< 0.10	0.08	< 0.86	< 0.68
16/10-22/12-81	37.00	6.00	2.11	1.71	4.00	3.24	6.11	4.95
11/2-28/3-82	48.00	6.00	< 0.20	< 0.13	2.00	1.25	2.20	1.38
12/6-22/7-82	40.00	6.00	0.17	0.13	1.00	0.75	1.17	0.88
12/6-22/7-82	40.00	12.00	0.08	0.06	0.16	0.12	0.24	0.18
24/10-24/11-82	31.00	20.00	< 0.27	< 0.26	0.04	0.04	< 0.31	< 0.30
13/1-23/2-81	41.00	20.00	< 0.07	< 0.05	0.03	0.02	< 0.10	< 0.07
22/2-20/5-81	87.00	20.00	0.00	0.00	0.15	0.05	0.15	0.05
25/5-15/7-81	51.00	20.00	0.00	0.00	< 0.10	< 0.06	< 0.10	< 0.06
11/8-8/9-81	28.00	20.00	0.10	0.11	< 0.10	< 0.11	< 0.20	< 0.21
8/9-16/10-81	38.00	20.00	0.24	0.19	< 0.10	< 0.08	0.34	0.27
16/10-22/12-81	37.00	20.00	0.73	0.59	< 0.10	< 0.08	0.83	0.67
11/2-28/3-82	48.00	20.00	< 0.20	< 0.13	0.25	0.16	< 0.45	< 0.28
12/6-22/7-82	40.00	25.00	0.10	0.08	0.08	0.06	0.18	0.14
24/10-24/11-80	31.00	100.00	< 0.27	< 0.26	0.02	0.02	< 0.29	< 0.28
13/1-23/2-81	41.00	100.00	< 0.07	< 0.05	0.01	0.01	< 0.08	< 0.06
22/2-20/5-81	87.00	100.00	0.00	0.00	< 0.10	< 0.03	< 0.10	< 0.03
11/8-8/9-81	28.00	100.00	0.10	0.11	< 0.10	< 0.11	< 0.20	< 0.21
8/9-16/10-81	38.00	100.00	0.20	0.16	< 0.10	< 0.08	< 0.30	< 0.24
16/10-22/12-81	37.00	100.00	0.33	0.27	< 0.10	< 0.08	< 0.43	< 0.35

Table 26. Dustfall of chromium along E6 Jessheim.

DATO-YEAR	DAYS	DISTANCE TO ROAD	WATER SOLUBLE		WATER INSOLUBLE		TOTAL	
		(m)	mg/m2	mg/30d*m2	mg/m2	mg/30d*m2	mg/m2	mg/30d*
24/10-24/11-80	31.00	6.00	0.03	0.03	1.60	1.55	1.63	1.58
13/1-23/2-81	41.00	6.00	< 0.04	< 0.03	1.51	1.10	1.55	1.13
22/2-20/5-81	87.00	6.00	0.00	0.00	6.40	2.21	6.40	2.21
25/5-15/7-81	51.00	6.00	0.00	0.00	0.50	0.29	0.50	0.29
11/8-8/9-81	28.00	6.00	0.02	0.02	0.13	0.14	0.15	0.16
8/9-16/10-81	38.00	6.00	0.02	0.02	0.11	0.09	0.13	0.10
16/10-22/12-81	37.00	6.00	0.02	0.02	5.81	4.71	5.83	4.73
11/2-28/3-82	48.00	6.00	< 0.05	< 0.03	1.40	0.88	1.45	0.91
12/6-22/7-82	40.00	6.00	< 0.02	< 0.02	0.39	0.29	0.41	0.31
12/6-22/7-82	40.00	12.00	< 0.02	< 0.02	0.06	0.05	0.08	0.06
24/10-24/11-82	31.00	20.00	< 0.02	< 0.02	0.06	0.06	0.08	0.08
13/1-23/2-81	41.00	20.00	< 0.01	< 0.01	0.05	0.04	0.06	0.04
22/2-20/5-81	87.00	20.00	0.00	0.00	0.20	0.07	0.20	0.07
25/5-15/7-81	51.00	20.00	0.00	0.00	< 0.10	< 0.06	< 0.10	< 0.06
11/8-8/9-81	28.00	20.00	0.02	0.02	< 0.10	< 0.11	< 0.12	< 0.13
8/9-16/10-81	38.00	20.00	0.02	0.02	< 0.10	< 0.08	< 0.12	< 0.09
16/10-22/12-81	37.00	20.00	0.02	0.02	< 0.10	< 0.08	< 0.12	< 0.10
11/2-28/3-82	48.00	20.00	0.08	0.05	0.07	0.04	0.15	0.09
12/6-22/7-82	40.00	25.00	< 0.02	< 0.02	0.03	0.02	< 0.05	< 0.04
24/10-24/11-80	31.00	100.00	< 0.02	< 0.02	0.04	0.04	< 0.06	< 0.06
13/1-23/2-81	41.00	100.00	< 0.01	< 0.01	0.03	0.02	< 0.04	< 0.03
22/2-20/5-81	87.00	100.00	0.00	0.00	< 0.10	< 0.03	< 0.10	< 0.03
11/8-8/9-81	28.00	100.00	0.02	0.02	< 0.10	< 0.11	< 0.12	< 0.13
8/9-16/10-81	38.00	100.00	0.02	0.02	< 0.10	< 0.08	< 0.12	< 0.09
16/10-22/12-81	37.00	100.00	0.02	0.02	< 0.10	< 0.08	< 0.12	< 0.10

There is a marked stratification in the dust transport versus height close to the highway. This is indicated in table 27 where is shown the difference in the amount of dust collected in dust samplers placed in the same level as the road surface and in approximately 1 m height above the road sureface. The dust was collected in circular plastic buckets on stands as shown in figure 6. Figures 27, 28 and 29 show the stratification in horisontal dust transport of different particle fractions as measured by the dust collectors shown in figure 7.

Table 27. Comparison of dustfall in dustcollectors at two different heights, 6 m from the road.

Height m	Period	Dry matter g/m^2	Pb mg/m^2	Cu mg/m^2	Zn mg/m^2	Ca mg/m^2	Cl mg/m^2	Fe mg/m^2
0	24.10-24.11.83	157	15.5	2.34	9.95	2140	13950	788
1	" "	73.0	7.90	0.88	4.60	1330	4450	365
0	13.01-23.02.81	192	22.7	2.03	12.5	3500	13850	431
1	" "	50.0	6.30	0.61	4.00	680	1590	125
0	22.02-20.05.81	416	33.9	8.7	38.3	7170	17600	3390
1	" "	223	17.2	2.6	13.2	3600	8120	450
0	25.05-15.07.81	48.0	5.50	0.80	2.00	-	-	250
1	" "	8.40	0.80	0.10	0.33	-	-	38

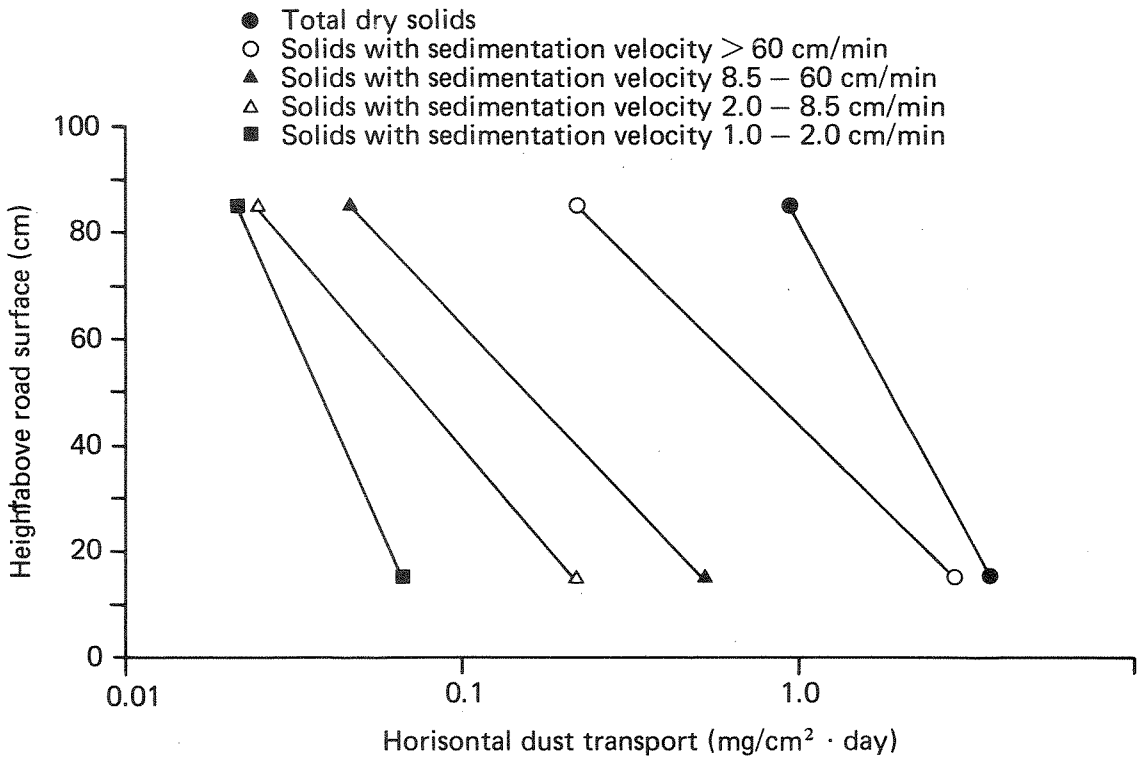


Figure 27. Horisontal dust transport of different particle fractions in different heights at the edge of asphalt as measured by collector type B (see figure 7), (2 m from the active driving area). Collection period: 02.10. - 21.10.1980.

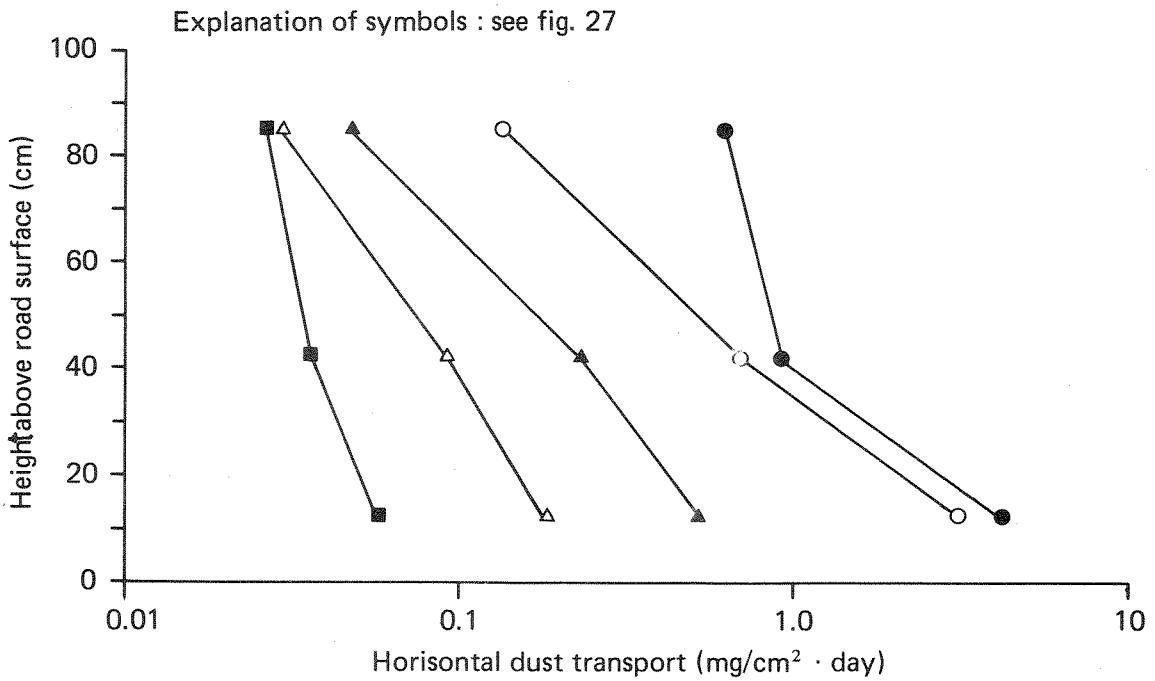


Figure 28. Horisontal dust transport of different particle fractions in different heights at the edge of the asphalt as measured by collector type b (see figure 7), (2 m from the active driving area). Collection period: 30.4.-20.04.81.

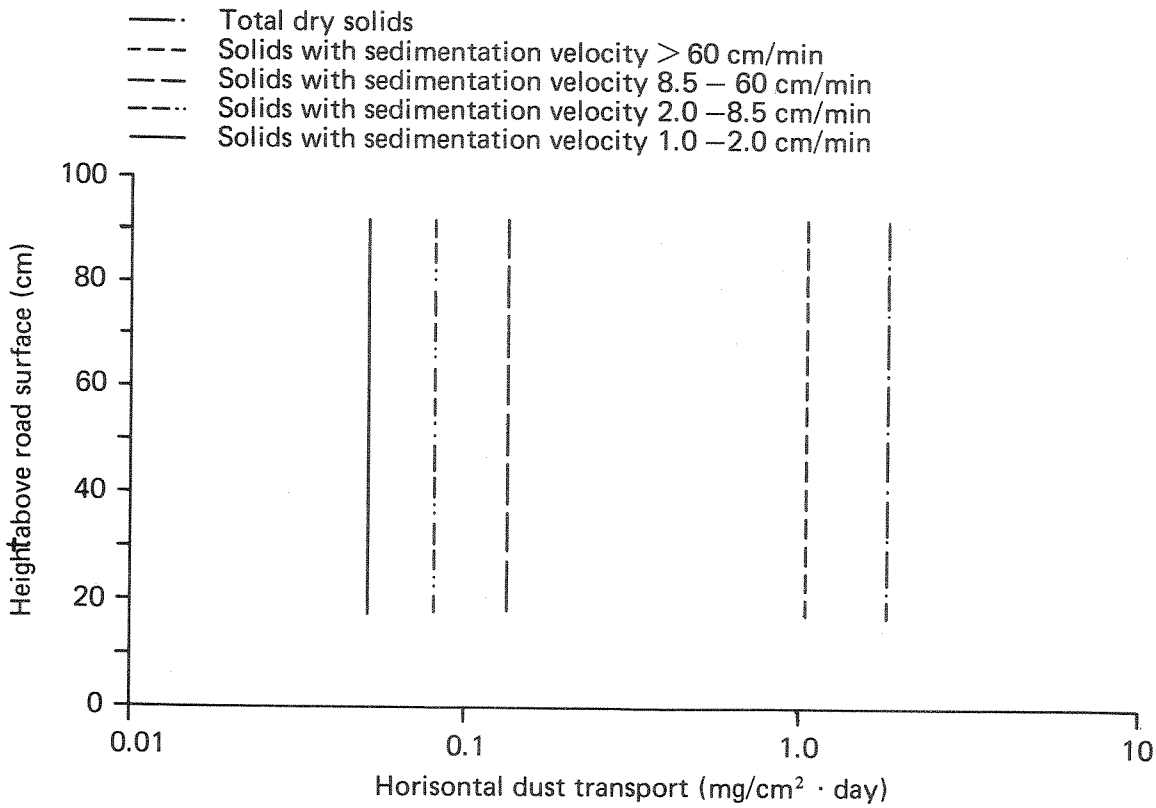


Figure 29. Horisontal dust transport of different particle fractions as measured by collector type A (see figure 7), (2 m from the active driving area). Collection period: 2.10.-21.10.1980.

Accumulated pollution in snow along the highway

Table 28 shows the concentration of different pollutants in the bank of snow close to the highway at 4 different sites along E6 from Jessheim to Oslo. The average traffic density is 8000, 18000, 30000 and 50000 vehicles per day (ADT) respectively.

Table 29 shows total suspended solids, total dry solids and sedimentation characteristics of the same 4 samples as in table 7.

Table 28. Concentration of pollutants in the bank of snow at 4 different sites along E6 from Jessheim to Oslo. The samples were taken 27.03.81 just before the main melting period and represents approximately 4 months of accumulated pollution.

Site	Average traffic density (ADT) vehicles/day	Conductivity µsiem/l	SO_4 mg/l	Cl mg/l	TOC mg/l	COD mg/l	Ni µg/l	Cr µg/l	Pb mg/l	Cu µg/l	Zn µg/l	Cd µg/l	Fe mg/l	Ca mg/l	Hg µg/l
Jessheim	8000	280	5.2	71	37	200	99	0.13	0.41	0.31	0.94	3.75	82	69	0.32
Klofta	18000	1190	12.0	490	62	330	89	0.11	0.33	0.38	1.11	4.56	58	160	0.30
Karihaugen	30000	1430	25.6	540	78	610	140	0.16	2.03	0.68	1.60	31.0	123	289	0.92
Helsfyr *)	50000	1110	19.4	380	186	2800	690	0.94	6.88	1.53	6.43	45.0	479	540	1.68

*) significant melting had occurred.

Table 29. Total suspended solids, total dry solids and sedimentation characteristics of a sample from the bank of the snow at 4 different sites along E6 from Jessheim to Oslo. The samples were taken 27.03.81 just before the main melting period and represent approximately 4 months of accumulated pollution.

Site	Average traffic density vehicles	Total suspended solids		Total dry solids		Concentration (mg/l) of particles with different sedimentation velocities (cm/min)					
		total mg/l	volatile %	total mg/l	volatile %	>60 total mg/l	20-60 total mg/l	8.5-20 total mg/l	2-8.5 total mg/l	1-2 total mg/l	<1 total mg/l
Jessheim	8000	3500	6.6	3750	7.4	1411	1540	137	306	195	100
Kløfta	18000	4900	7.1	5200	9.0	834	413	327	218	453	2650
Karihaugen	30000	7650	7.3	9200	7.1	1307	1104	539	927	353	3420
Helsfyr *)	50000	19750	8.0	25000	7.9	3517	2213	1509	1500	1518	9500

*) significant melting had occurred.

Table 30 shows the content of PAH in the bank of snow at two sites on Mosseveien, south of Oslo. The sites were located 3 km from each other on the same road and with the same traffic density. One of the sites represented an asphalt pavement while the other represented concrete pavement. The concrete section had a total length of 5.0 km and the sample was collected 2.5 km from the beginning of the section. The depth of snow in the bank of snow and the topography around the higways were quite similar at both sites.

Table 30. Concentration of PAH in the bank of snow of an asphalt and a concrete pavement section of the same highway and the same traffic load. Samples were collected 17.02.82.

Component	Asphalt pavement ng/l	Concrete pavement ng/l
Naftalene	195	123
2-Metylnaftalene	883	
1-Metylnaftalene	668	
Bifenylene	382	
Dibenzofuranene	810	199
Fluorene	1237	485
9-Methylfluorene	767	220
2-Metylfluorene	763	274
1-Metylfluorene	1707	639
Dibenzothiophene	2222	803
Fenantrene	6787	4055
Antracene	246	165
2-Metylantracene	725	
1-Metylfenatrene	2117	1366
Fluorantene	3143	1820
Pyrene	3066	1886
Benzo(a)fluorene	396	179
Benzo(b)fluorene	192	
Tracene		228
Trifenylene/Chrysene	1070	665
Benzo(b)fuorantene	1501	799
Benzo(j,k)fluorantene	207	
Benzo(e)pyrene	630	360
Benzo(a)pyren		250
O-Phenylenepyrene	240	270
Dibenz(a,h)perylene		
Benzo(ghi)perylene	319	391
Total	30323	15177

Table 31 shows the concentration and total content per m^2 of different pollutants in snow at different distances from the highway.

Table 31. Concentration and total content per m^2 of different pollutants in snow at different distances from the highway. The samples were taken 02.03.82. The snow had then been lying for approximately 2 months without significant melting.

Distance from highway (m)	Pb		Zn		Cu		Fe		Cd		Ni		Ca		TOC		Cl	
	µg/l	mg/m²	µg/l	mg/m²	µg/l	mg/m²	mg/l	mg/m²	µg/l	µg/m²	µg/l	mg/m²	mg/l	mg/m²	mg/l	mg/m²	mg/l	mg/m²
3	263	66	175	44	79	20	27	6790	1.4	350	44	11	17	4270	16	4024	31	7800
5	156	63	100	41	54	22	13	5320	1.1	450	18	7.4	4.4	1800	13	5310	4.7	1920
7	131	14	138	15	54	6.0	18	2000	1.0	111	19	2.1	6.7	745	15	1670	38	4220
10	66	7.7	88	10	38	4.5	5.2	608	1.0	116	46	5.4	3.7	433	11	1290	20	2340
19	34	3.8	38	4.2	18	2.0	1.8	200	0.43	48	15	1.7	0.51	57	4.3	478	12	1334
37	31	2.2	63	4.4	54	3.8	1.2	84	1.2	84	34	2.4	0.68	48	6.0	421	3.1	218
57	8.4	0.93	25	2.8	27	3.0	0.84	93	0.30	33	5	0.56	0.29	32	3.5	388	2.1	233
104	9.1	1.1	38	4.7	30	3.7	0.31	38	0.51	62	11	1.4	0.78	96	3.1	381	6.0	737

Dust deposits on the road surface

No regular measurements of the dust deposits were done. The dust deposits when measured as dry solids, varied a lot during the year and almost 100 % were found in a concentrated area at the side of the road (see figure 5).

The deposits were ordinarily small but just after the melting of the snowbank they were big. Usually road sweepers are used to clean up the highways just after the snow melting period in the early spring. In the spring 1981 we told the drivers of the road sweepers not to sweep our two sections.

We then measured the amount of dust at the two sections in the area close to the roadside barriere at three different occasions from the 05.05.81 to the 30.06.81. The results are shown in figure 30. The figure also shows the mean concentration of pollutants in the runoff from the two sections. The runoff from the sections had an almost equal concentration, while the amount of dust was much bigger on the section with the high roadshoulder barrier .

The results indicate that there is no simple relationship between the amount of dust on the roadshoulder and the concentration in the runoff. The results together with what was measured next spring further indicate a dramatic peak in concentration just after the snowbank has melted.

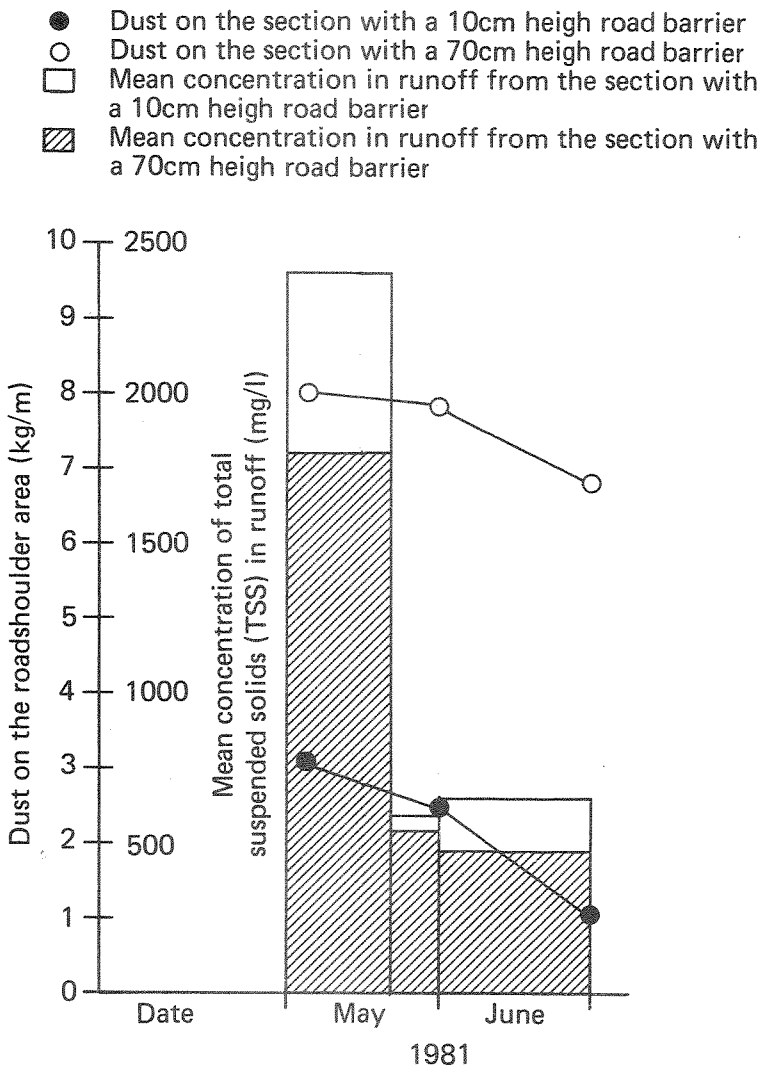


Figure 30. Amounts of dust on the roadshoulder area in the period after the melting of the snow bank and the mean concentration of total suspended solids in the runoff water in this period.

Hydraulic performance of the road ditch and the drainage system

The hydraulic performance of the road ditch and the drainage system is very much dependent on the material used in the ditch. As an example of the big span in hydraulic performance two rainfall events were simulated by pumping water into the road ditches at the side of the highway (ditch 2) and in the middle of the highway (ditch 1) close to the Jessheim station. The ditches seemed after visual inspection to be quite

similar except that there were growing much more grass in the road ditch in the middle of the road compared to the one at the side of the highway.

The hydraulic performance of the two ditches was on the other hand extremely different. Figure 31 shows this. While in the middle of the highway the water from a very heavy rainfall infiltrated altogether, almost none of the water from a very light rainfall infiltrated in the other ditch. All of the water in the impermeable ditch finally reached the drainage system via the gutters in the ditch, while only a small portion of the water in the permeable ditch reached the drainage pipe line.

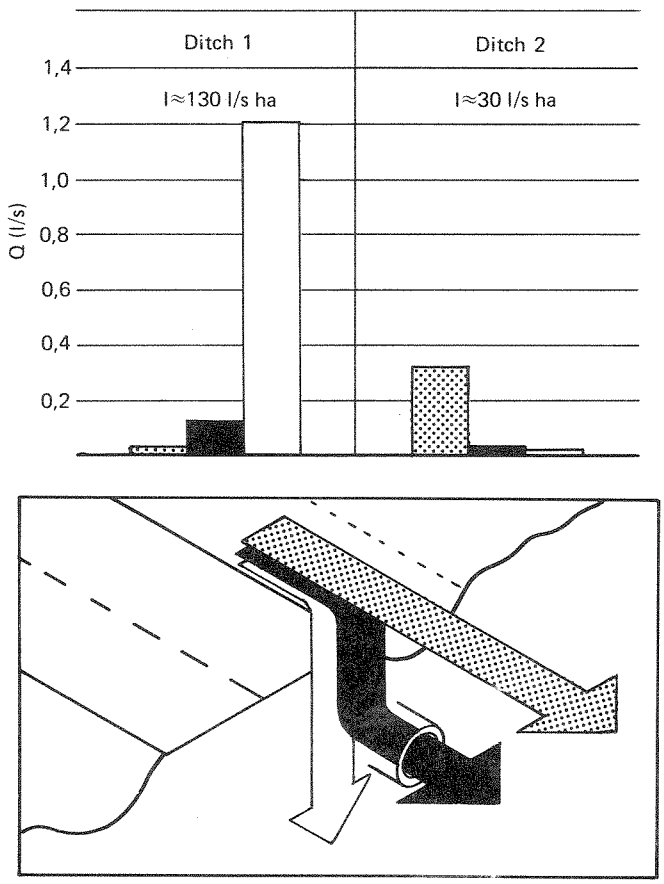


Figure 31. Hydraulic performance of the road ditches at the four lane highway at the Jessheim station. Impermeable ditch (ditch 2) at the side of the road, and permeable ditch (ditch 1) in the middle of the highway.

Changes in water quality in the road ditch

When the water is flowing in the road ditch a dramatic change in the water quality can occur. To demonstrate this, runoff water from the two 1 m^3 collection tanks was pumped into the relatively impermeable ditch at the Jessheim site (see previous page). The flowrate was 0.5 l/s corresponding to a rainfall of 10 - 60 l/s·ha (depending on the catchment area, infiltration etc.). Samples were collected at different distances from the outlet of the pumping tube and tests were performed to find changes in sedimentation characteristics. The results are shown in figure 32.

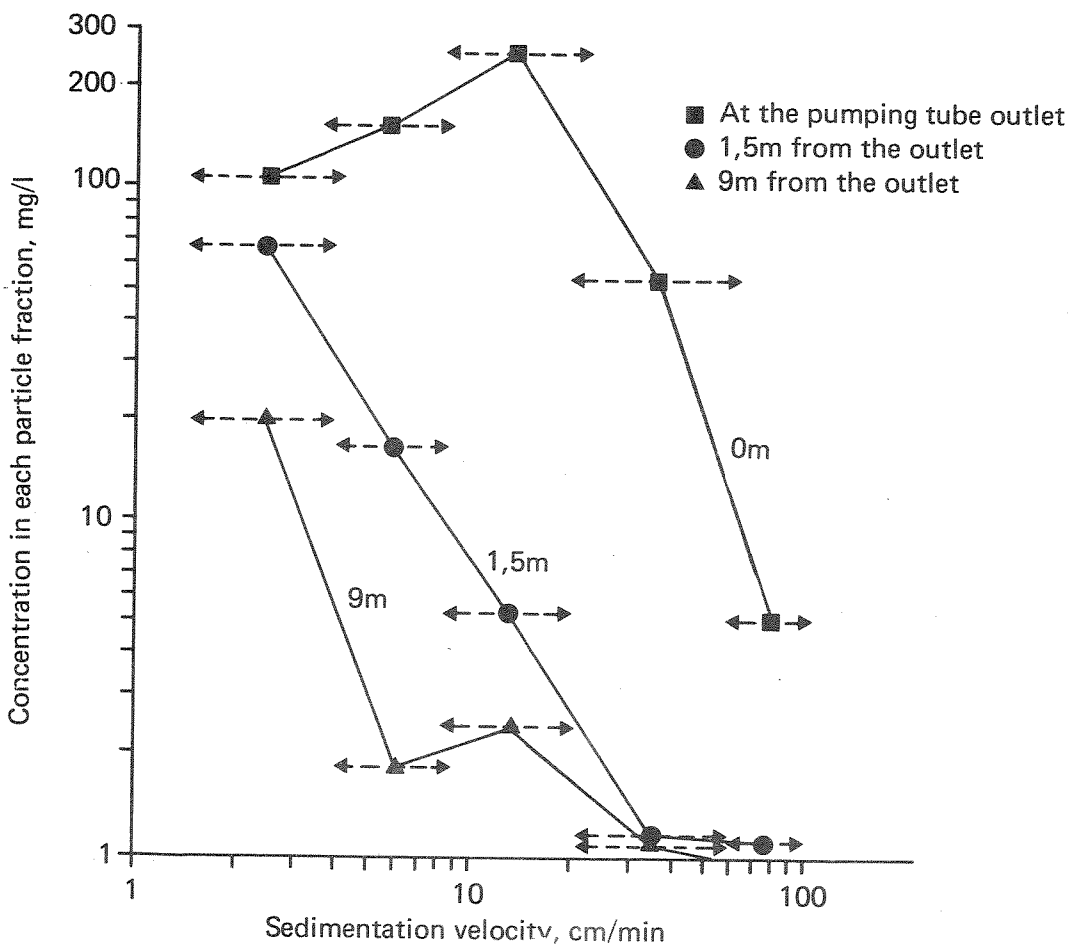


Figure 32. Changes in sedimentation characteristics in runoff water in a road ditch.

3.2 Results from the Lake Padderudvann Station

Snow

In table 32 are given all relevant snow data. The table includes results from 1981 and 1982. Considering the latter data set, it appears that pollutants are concentrated in the banks of snow on the road shoulders (snow depth 450 cm), and that these concentrations are reducecd to about one fifth at the 13 m distance from the highway. Between 13 and 53 m there are generally small changes. Considering also the snow analyses from 1981, which include the snowpack at 300 m distance, the results suggest generally a small concentration decrease compared to half-distance (150 m). However, at a distance of 150 m from the highway the concentrations in the snow on the ice-covered lake definitely are not dramatically high compared to the control.

Table 32. Composition of snow at variaous distances from highway (March 1981 & March 1982).

Year	pH	Conductivity	COD, mg O/l	TOC, mg C/l	Total dried residue	Total fixed residue	Total suspended matter	Total suspended residue	SO_4, mg SO_4/l	Cl, mg Cl/l *	Distance, m
82	-	-	-	33.0	-	-	-	-	-	166	5
82	-	-	-	6.0	-	-	-	-	-	8.9	13
82	-	-	-	17.6	-	-	-	-	-	3.4	19
81	7.2	28	38	4.8	304	246	142	127	1.5	2.8	50
82	-	-	-	5.3	-	-	-	-	-	14.2	53
81	6.6	17	17	4.1	253	190	57	47	1.4	1.9	150
81	6.1	28	11	3.2	182	124	13	9	3.9	3.6	300
81	7.1	30	18	2.6	214	161	40	35	1.7	2.3	
81	5.3	10	25	3.4	178	141	13	6	1.1	0.9	

Distance, m	Pb, µg Pb/l **	Zn, µg Zn/l **	Cd, µg Cd/l **	Fe, mg Fe/l **	Ca, mg Ca/l **	Ni, µg Ni/l **	Cr, µg Cr/l **	Cu, µg Cu/l **	Hg, µg Hg/l	PAH, µg/l	Snow-depth, cm
5	500	338	2.4	41.8	58.5	49	-	117	-	-	450
13	109	63	0.7	3.3	2.8	14	-	37	-	-	45
19	53	75	0.5	1.66	2.0	19	-	43	-	-	70
50	154	90	0.7	2.1	6.8	14	24	0.1	5.0	12.8	
53	44	50	0.7	0.5	1.6	19	-	20	-	-	70
150	80	50	0.3	0.9	2.6	13	19	0.1	0.05	1.25	
300	19	50	0.3	0.3	1.5	64	11	0.1	1.1	0.74	
31	30	0.3	1.2	5.8	148	14	0.0	0.6	-		
22	30	0.2	0.1	0.1	11	17	0.1	0.0	1.19		

* Filtered, ** Digested.

Considering TOC and the metal ions concentrations which are present in both data sets (1981 and 1982), it appears that the pollutants are present in very high concentrations within a 5 m distance from the highway, however, that this is also reduced to about one fifth at 13 m distance.

It is essential to emphasize that the procedure for the snow sample treatment prior to analysis, which involves melting the snow in the plastic bag, results in an undefined loss of material, as one observes an adsorption of some black matter to the plastic surface. Experien-

ces from simliar studies on the composition of "clean" snow, show that this loss due to surface adsorption (during melting) may represent more than 5 mg C/l. In the case of highway exposed snow, this loss may be even higher.

The snow-samples for PAH-analysis are, as mentioned above, taken directly into the extraction-vessel, and thereby their loss-potentials probably are neglectable. The detailed results of PAH in snow at 50, 150 and 300 m distance from the highway, given in table 33 (and table 32), show a massive PAH pollution even 50 m away. This is reduced with a factor of 1/10 between 50 m and 150 m and a further reduction to about one half, additional 150 m away. It is interesting to notice that these air transported pollutants apparently are fractionated during air transport and that several important compounds are only found in the snow at 50 m distance from the highway.

Table 33. PAH in snow, water and sediments from Lake Padderudvann.

	ng/l													ng/g	
	Snow *)				Water									Sedim. **)	
					A			B			E			***)	
	50m	150m	300m	Control	5/4	9/6	4/11	10/3	5/4	4/11	5/4	9/6	4/11	Nº33	Nº13
Napthalene		67	36							4					
2-Methylnapthalene		25								4			3		
1-Methylnapthalene		22							45	2			2		
Dibenzofuran													1		
Fluorene	96												2		
Dibenzothiophene	136														
Phenanthrene	1385	155	45	140	18	6	5	3	136	4	24	4	10	180	70
Anthracene	379	9		20			1			1			1	160	
2-Methylanthracene	34	10											2		
1-Methylanthracene	133	31											2		
Fluoranthene	2665	175	86	166	62	9	6	29	616	5	25	4	16	248	66
Pyrene	2002	113	55	123	51	6	7	21	402	5	14	11	13	122	110
Benzo(b)fluorene									38						
Benzo(a)anthracene	677	23	20	15											
Triphenylene/Crysene	1147	170	119	147	13	7	1	8	149	10		14	2	110	20
Benzo(b)fluoranthene / Benzo(j,k)fluoranthene	1171	196	205	327	13	5	2	8	60	3	14	32	1	96	30
Benzo(e)pyrene	609					3	4	6	40	2	27	12	3		80
Benzo(a)pyrene	602			54			1	6	10	1	23	3	1		
O-Phenylenepyrene	432			101									1		
Dibenzanthracene	214														
Benzo(ghi)perylene	551			98											
Sum	12,230	1000	570	1190	160	40	30	80	1500	40	130	80	60	920	380

*) See table 32.

**) Some difficulties due to oil components in the sediment.

***) See figure 34.

Water

Considering the pollutants in the three inflowing water systems, A, B (natural) and D (drainage water from highway) and comparing these results with the quality of the outflowing water, E, the following statements may be relevant (see table 34):

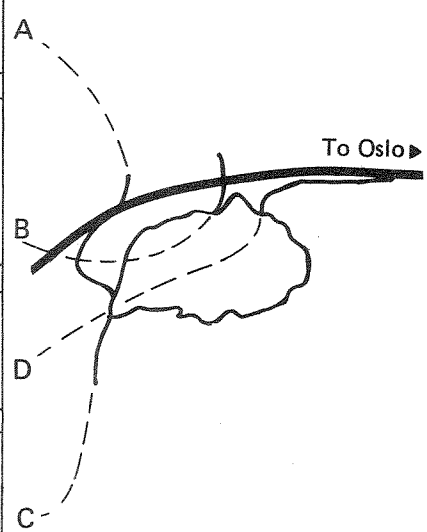
- In general, no dramatic differences in quality of the outflowing water (E) from the lake is recognized compared to the natural, inflowing brooks (A and B). Except for, may be chloride, the mean concentration of the components analyzed is generally the same in the outflowing water as in the two natural inflowing brooks, A and B.

- The runoff from the highway (D) is highly polluted; however, the lake apparently acts as an effective sink for those pollutants considered.

- Based on the samples taken form the outflowing water during winter, spring, summer, and autum (1982), the quality does, with one exception, satisfy most standards for drinking water. The exception is connected to the PAH content during the spring (see table 33). The maximum PAH levels do, however, not dramatically ecxeed the WHO accepted limits of 100 ng/l.

Table 34. Chemical composition of inflowing and outflowing water.

Date	mS/m Cond.	mg/l SO_4	Cl	COD	TOC	Ca	µg/l Fe	Cd	Cu	Zn	Pb	Ni	xx)– CrT	mg/l x) TSM	x) TDR	ng/l PAH
82 3/4	32.3	21.0	9.0	<10	5.4	54	125	<0.1	16	25	1.0	<0.5	1.3	6.4	-	-
" 3/10	34.2	21.0	13.0	<10	4.7	54	113	<0.1	23	25	1.4	14	1.8	3.7	-	-
" 4/5	-	-	-	-	8.1	51	190	0.1	90	50	1.1	-	2.4	-	-	157
" 6/9	28.9		4.2	-	3.5	49	-	0.1	7	13	<0.5	<5	-	0.7	-	36
" 11/4	-	21.0	9.0	<10	5.6	53	30	0.1	8	10	1.1	<5	2.0	-	-	27
1/n Σx	32	21	9	-	6	52	115	-	29	25	1	-	1.9	3.6	-	73
81 5/6	23.8	-	22	-	-	-	-	-	42	10	7	-	-	-	-	-
82 3/4	20.3	17.0	5.0	22	12.8	33	228	0.2	23	63	2.1	<5	0.9	9.6	-	-
" 3/10	22.4	26.0	8.0	23	13.6	32	463	1.3	28	25	3.9	7	1.0	19.9	-	81
" 4/5	-	-	6.3	-	9.5	37	350	0.1	25	37	1.6	<5	0.8	-	-	1506
" 4/5	-	-	6.6	-	11.1	42	475	0.2	150	37	2.7	19	1.8	-	-	-
" 6/9	31.1	-	6.1	-	7.0	51	-	<0.1	5	63	0.5	<5	-	0.8	-	-
" 11/4	-	-	-	23	8.4	55	40	<0.1	8	<10	0.6	<5	0.7	-	-	42
1/n Σx	25	22	6	23	10	42	310	-	40	39	2	-	1	10	-	540
81 5/6	450	-	84	-	-	-	-	-	60	90	220	-	-	-	-	-
82 3/4	1001	160	3800	520	40.0	81	40*	4.1	150	610	763	45	48	1302	5500	-
" 3/4	995	150	4000	580	48.0	78	37*	3.7	188	550	613	39	43	1621	577	-
" 3/10	435	130	1380	440	41.0	59	3*	3.1	163	550	462	50	49	1190	240	-
" 4/5	-	-	35	-	4.0	47	2*	0.2	110	90	64	-	5.6	-	-	-
1/n Σx	810	147	2300	-	3.3		21*	3	153	450	425	45	37	1370	-	high
82 3/4	32.8	22.0	15.0	<10	4.7	50	163	<0.1	23	25	0.7	11	0.9	2.4	-	
" 3/10	33.0	25.0	16.0	>10	5.6	49	125	0.3	22	63	1.1	14	1.9	4.0	-	
" 4/5	-	-	16.0	-	6.2	49	260	0.2	140	50	0.6	-	0.6	-	-	127
" 6/9	28.7	-	14.4	-	5.6	43	15	<0.1	1	13	0.9	<5	-	0.8	-	80
" 11/4	-	-	-	14	6.1	49	30	<0.1	11	<10	1.0	<5	0.8		-	60
1/n Σx	32	23	15	-	6	48	120	-	39	32	1	-	1	2.4		90



x) TSM: Total Suspended Matter, TDR: Total Dried Residue.
xx) Digested sample.
* x 10^3.

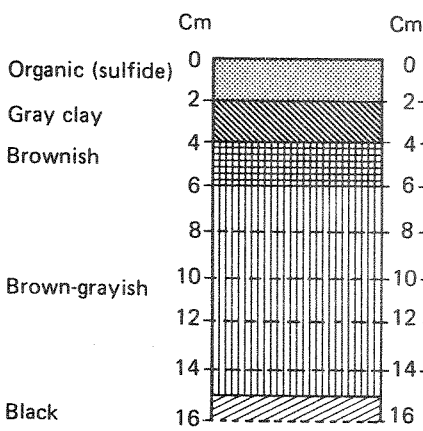
Sediments

The repeated sampling at the same location suggests, as shown in table 35 some methodical difficulties. Lead in the upper 2 cm of this location has a mean concentration of 108 µg Pb/g, zink: 267 µg Zn/g, cadmium: 1.1 µgCd/g.

Table 35. Four different cores from Station No. 33. (see figure 34).

Sample	1	2	3	4
Pb µg/g	144	90	116	80
Zn µg/g	334	223	252	257
Cd µg/g	1.1	0.9	1.3	1.1

In the comments given below, these limitations of the results are taken into account. with regard to the vertical distribution of the heavy metals in the 15 cm core, the data given i figure 4 suggest that the upper 2 cm generally have significantly higher concentrations than the fractions below (the maximum concentration at the 12-16 cm depth will not be commented here).



	Nº 33*)			Nº 36*)			Nº 40*)		
Cm	Pb	Zn	Cd	Pb	Zn	Cd	Pb	Zn	Cd
	µg/g								
0–2	144	334	1.1	229	424	2.1	142	354	1.5
2–4	91	248	0.5				74	190	0.3
4–6				60	217	0.6			
6–8	30	162	0.8				78	300	1.8
8–10				35	107	0.3			
10–12	44	136	0.2						
12–14				133	439	3.0			
14–16	149	615	2.5						

*) see Figure 5.

Figur 33. Sediment core. Composition at various levels.

The horizontal distribution of the heavy metals in the lake sediments is illustrated in figure 34. The lead concentration in the upper 2 cm of the bottom surface of Lake Padderudvann differs between less than 60 µg/g and about 254 µg/g (dry weight). Maximum lead concentrations are mostly found in the middle of the lake. The result does, however, not clearly suggest that D is likely to be the dominating source for the sedimented lead. Compared to what may be considered as a normal lead concentration in unpolluted lake sediments, the Padderudvann sediment (top layer) appears to be in the range of three times higher. The horizontal zink distributions in the sediments are generally similar to those of lead. The concentration in the top layer differs between 100 µg Zn/g and 460 µg Zn/g. As for the lead, the sediment samples taken near to the shore, have, with one exception, the lowest concentration of these two metals. The results do not indicate that sedimenting properties of the particulate matter in the highway runoff water (D) are so uniform that one concentration maximum of these two metals is found in the upper 2 cm sediment. With regard to cadmium in the sediments, these concentrations are comparatively low, with a maximum of 2 µg Cd/g and a lower limit of 0.5 µg Cd/g.

Considering sample No. 13 (figure 34) as a representative for the less exposed part of the lake, and comparing the Pb, Zn and Cd concentrations with those of, for instance, sample No. 18, one may indicate an increase with a factor of about three.

Comparing PAH's in the upper 2 cm sediment layer at sampling station No. 13 which appear to be in the less exposed area of the lake, with the corresponding sample at No. 33 (see table 33 and figure 34), the concentration differences are about 3-fold. It should be emphasized that the PAH-data given are only from two samples. Besides, the sample size, on which the analyses are based, is rather limited, and consequently the results are only indicative. However, the concentration-levels found do not appear to be unnormally high compared to lake sediments from other urbane areas (7).

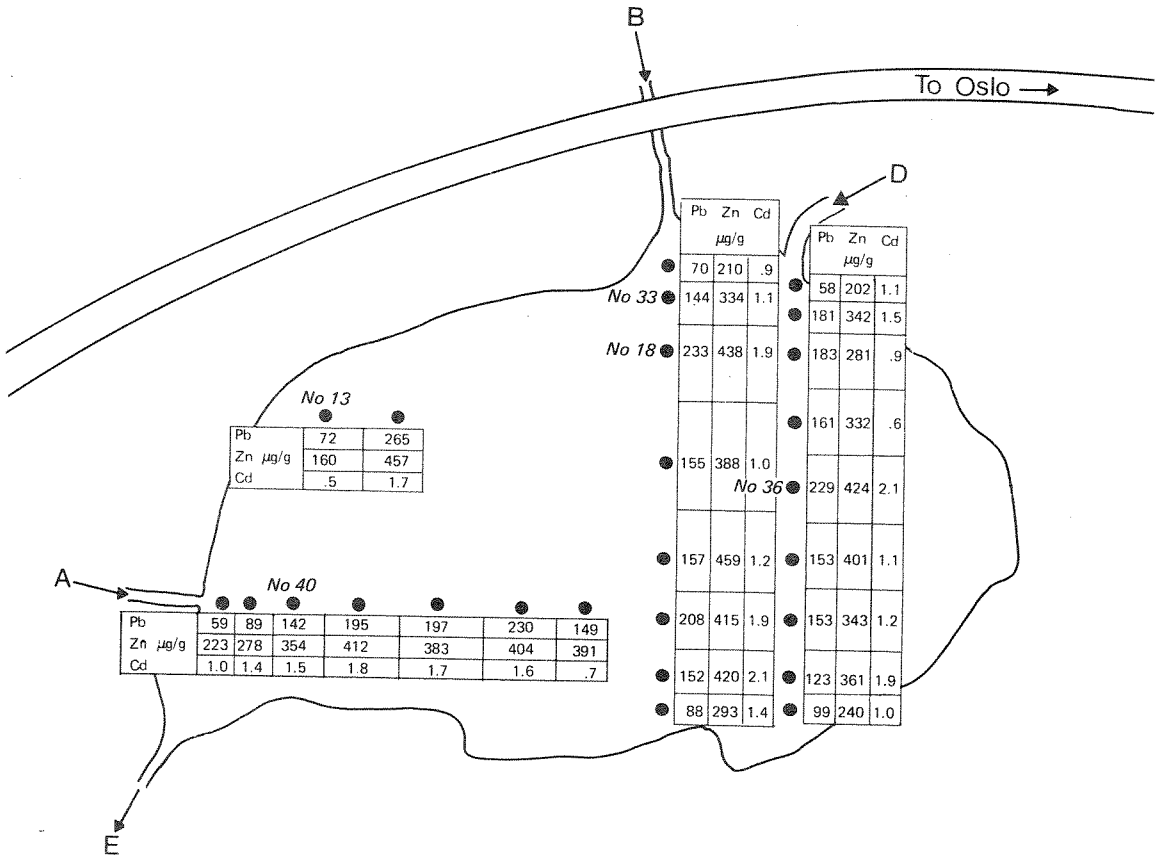


Figure 34. Pb, Zn and Cd in the upper 2 cm of sediment (µg/g dry weight).

Adsorption experiments

The composition and volume of the eluated precipitation are given in table 36. Table 37 gives some details with regard to the PAH's. It appears from the results that most of the PAH's are retained in the soil. Based in soil volume, the most sandy soil (lowest content of organic carbon) is letting 8 percent of the PAH's through. The most effective soil in this respect is the forest soil with considerably more organic matter. The 8 cm profile of this soil retains 99 percent of this group of organic micropollutants. Based on soil weight, the most inorganic soil is still the less effective PAH retainer, whereas the organic soil (96 percent ignition loss) apparently is more than 20 times as effective.

Table 36. Adsorption of highway pollutants to soil. Apparent capacity to retain PAH's. (Soil volume 480 cm^3. Total PAH applied 90,4 µg).

In eluate						PAH retained by soil µg per gram 1)				
Soil No.	Volume eluate l	Σ PAH ng/l	TOC mg C/l	PAH %	Soil dens. g/cm^3	Soil	Org.C	Sand	Silt	Clay
1	10 +9	540) 200) 380	5.4) 4.1) 4.8	6) 2) 8	1.60	0.1	55	0.1	4.6	21
2	19	80	9.4	2	1.25	0.2	7	0.2	0.6	1.6
3	19	45	23.7	1	1.05	0.2	4.7	0.3	0.9	1.8
4	18	110	5.6	2	0.07	2.5	5.5	-	-	-

1) See Table 3.

Table 37. PAH in soileluates. Airdried runoff sample (A) placed on top of soil column. (See figure 13 and table 3).

	ng/l					
	A	Soil 1		Soil 2	Soil 3	Soil 4
		10 l	9 l	19 l	19 l	18 l
2-Methylnapthalene		80	84			15
1-Methylnapthalene			54			7
Dibenzofuran	63					
2-Methylfluorene	42					
1-Methylfluorene	56					
Dibenzothiophene	72					
Phenanthrene	1072	56	16	20		45
Anthracene	147	83				
2-Methylanthracene	494	182		7		
1-Methylanthracene	672	140		10		
Fluoranthene	3314		30	8	16	17
Pyrene	3529		15	8	8	27
Benzo(a)anthracene	405					
Triphenylene/Chrysene	1643			10	8	
Benzo(b)fluoranthene	923					
Benzo(j,k)fluoranthene	130			8	8	
Benzo(e)pyrene	974			4	5	
Benzo(a)pyrene	366			6		
	13,902	541	199	81	45	111

4. SUMMARY AND CONCLUSIONS

In a 3 year programme the pollution transport from a highway 50 km north of Oslo and the impact on a lake close to the highway 20 km south of Oslo has been studied.

Nearby Jessheim 50 km north of Oslo two 50 m sections of the highway with different roadshoulder barrier heigths were prepared for measurements of such parameteres as:

- Traffic density, precipitation, temperature, wind speed and wind direction.
- Runoff quantity and quality from the road surface.
- Dust-transport to the surroundings.

At lake Padderudvann 20 km south of Oslo the following studies were included.

- The composition of the inflowing and outflowing water to the lake, including the drainage system from the highway.
- The composition of the snow on the lake.
- The composition of the lake sediments.

The chemical analysis used to characterize the pollution included the most relevant drinking water parameters with special emphazises on Polyaromatic hydrocarbons (PAH) and heavy metals.

A lot of effort was also put in characterizing the particulate matter in the water e.g.

A screening analysis to characterize the organic micropollutants was also performed.

Biological analysis included toxicity tests on bacteria, fungi, protozoa, algae, fish and fish eggs. Besides Ame's test on mutagenity and biodegradability of PAH components have been performed.

An adsorption experiment was performed to look at the mobility of pollutants in different soil types.

The results from the Jessheim stations suggests that:

- The pollutants are partly transported to the surroundings as dustfall, partly transported as runoff from the road surface.

- While most of the other pollutants are assosiated with coarse dust that deposits within a few meteres from the roadside, PAH apparently are assosiated with very fine dust particles and could therefore be transported in considerable amounts up to 50 - 100 m from the roadside.

- Probably 3 - 6 times more PAH is deposited in a distance 6 - 100 m from the road compared to what is transported as direct pavement runoff.

- Probably less than 1/10, 1/5, 1/5 and 1/5 of the components Pb, Cu, Fe and Zn are deposited in a distance 6 - 100 m from the road compared to what are transported as direct pavement runoff.

- During the winter the pollution accumulates in the bank of snow or the snow cover along the highway.

- The pollutants that have accumulated in the snow are released during melting periods, especially in March and April.

- Half of the yearly mass transport of PAH in runoff from the road surface and the bank of snow are released during some intensive melting weeks in March and April.

- When the PAH components are deposited on the soil surface they seem to be strongly adsorbed and imobilized especially in soils with a high content of organic matter. This is indicated by adsorption experiments.

- The PAH components that are adsorbed in the soil surface seems to undergo a rapid bacterial degradation. This is indicated by a test where a runoff sample was inoculated by earth from the road ditch.

- When the pollutants are accumulated in the snow along the road, this prevents the adsorption of pollutants in the soil surface and in this way mobilizes the pollution.

- The snowmelt runoff from the bank of snow usually contains a lot of fine suspended matter that does not sedimentate even after several days. Some of the most severe pollutants like PAH are to a great extent adsorbed to this fine suspended matter in the runoff.

- In a snowmelt sample, approximately 1/3 of the dissolved organic matter and 2/3 of the organic matter that was connected to the particulates were found to be extractable with organic solvents. Only a fraction of this is, however, identified. The sample contained organic chlorine in the range of 10 µg Cl/l. The identified chlor-organic matter can, however, explain only a few percent of the organic chlorine in the sample.

- Acute toxicity tests on heterotrophic organisms (bacteria, fungi, protozoa), on algae, fish and fish eggs did not show any negative effects on growth (or behaviour). The heterotrophic organisms were clearly stimulated by the runoff water, the algae were stimulated in their growth rate with rather high concentration (at least 50 percent), and neither the fish eggs nor the 1 year old salmon appeared to be affected by undiluted runoff water. This, and other studies of runoff water from highways, suggest that the pollutants are associated with particulate matter, and that the total amount of "available" organics (and inorganics) are moderate. None of the tests on acute toxicity suggest any negative effect. It is, however, essential to emphasize that chronic effects and the bioaccumulation potential have not been evaluated, and that future research and development of biological tests should investigate these aspects.

- Ames test on mutagenity indicate that filtered runoff water have a low mutagenic effect.

The results from the Padderudvann station are summarized below. The water analysis, including most relevant drinking water parameters, suggest that:

- The contributary brooks are to a relatively moderate extent affected by inorganic highway traffic pollutants (such as lead, zink, chromium, iron, chloride), whereas organic pollutants and suspended matter are noticeably high (such as PAHs).

- The washout water from the pavement is rich in inorganic and organic pollutants, and suspended matter.

- The lake acts as a sink most of the year for important pollutants. This appears from the composition of the outflowing water from the lake.

- The quality of the outflowing water does with one exception satisfy the WHO standard for drinking water (see Appendix B). The exception is connected to the PAH content during the spring-melting periode. The lake when the limit of 100 ng/l was exceeded with a factor of 1.3. It should however be emphasized that this represents the surface water of the lake and that a drinking water intake ordinary is below stratified depth.

The snow analysis show:

- That during the winter a considerable amount of the pollutants are deposited within 5 m from the road side.

- That the pollutants are also transported some distance through the air, most of them being depositet within 100 m.

- That the concentrations of the inorganic micropollutants in the snow on the lake are more than ten times higher than in the lake water itself.

The sediment analysis show a significant effect on the heavy metal concentration in the upper 2 cm of the sediments, and further:

- That these are distributed all over the lake, with a possible maximum in the deeper parts.

- That the enrichment of Pb, Zn and Cd relative to "normal" is 2 - 4 fold.

5. REFERENCES

(1) Perkin Elmer,: "Analytical Methods for Atomic Absorption Spectrophotometry".

(2) Standard Methods for the Examination of Water and Wastewater 13th ed. N.Y., 1971, pp. 330-336.

(3) M.P. Stainton, J. Fisheries Research Board of Canada 30, 1973, pp. 1441-1445.

(4) A. Bjørseth, B. Olufsen and M. Skogland, "Analytical method for PAH". (In Norwegian). Report 740312-5 Central Institute for Industrial Research, Blindern, Oslo, Norway 1977.

(5) R. Staub, Z. Schweiz, Hydrol 23, 1961, pp. 82-198.

(6) T. Källqvist, In algal assays in water pollution research, Proc. Nord. Symp. Oslo, Oct. 1972, NORDFORSK Publ. 2, 1973, pp. 5-17.

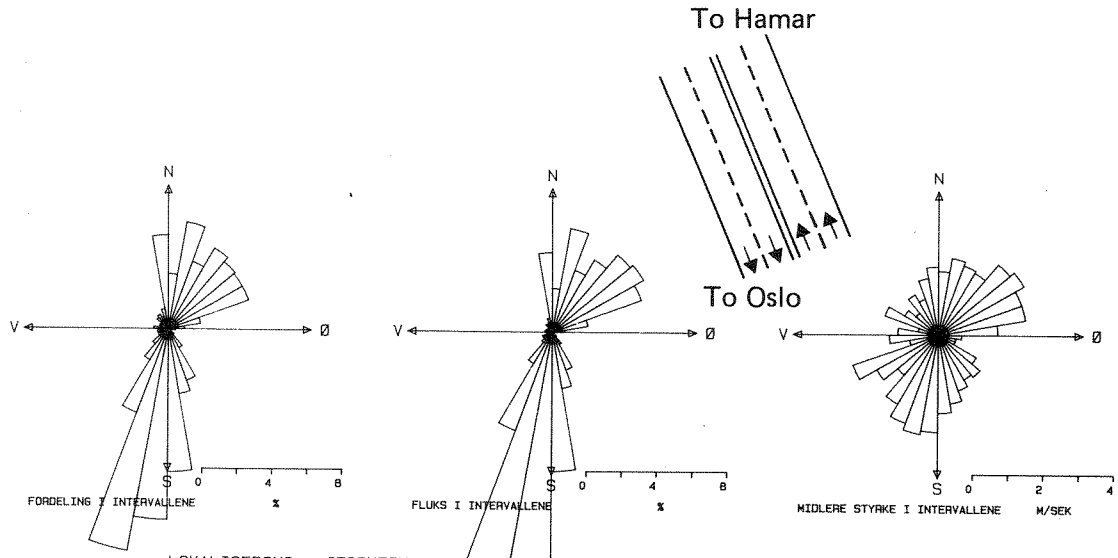
(7) S.G. Wakeham, C. Schaffner and W. Giger, Geochim, Cosmochim. Acta 44, 1980, pp. 415-429.

(8) J. Ferguson: Personal communication.

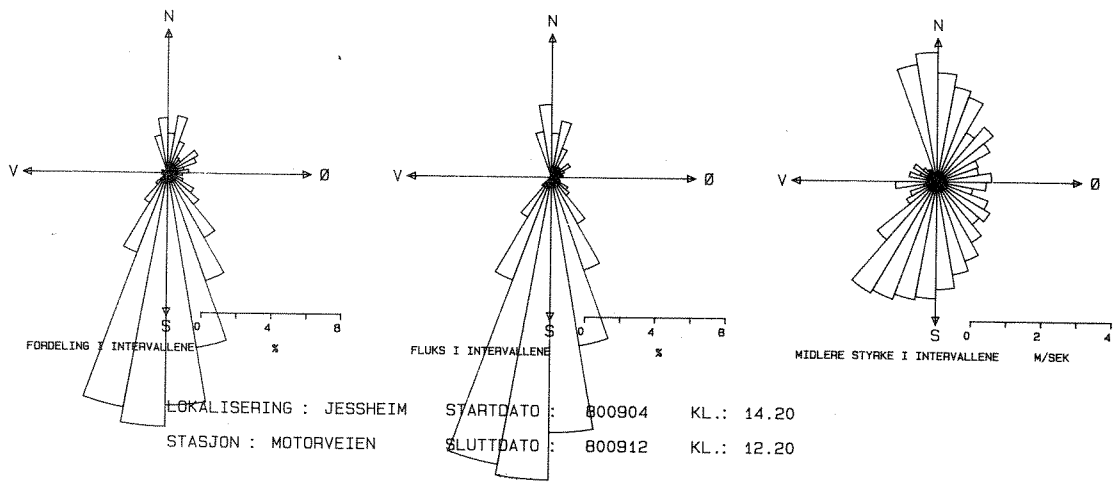
LYG/GUM
13.03.84

A P P E N D I X A

Wind Data at the Jessheim station



LOKALISERING : JESSHEIM STARTDATO : 800828 KL.: 21.00
STASJON : MOTORVEIEN SLUTTDATO : 800904 KL.: 10.50



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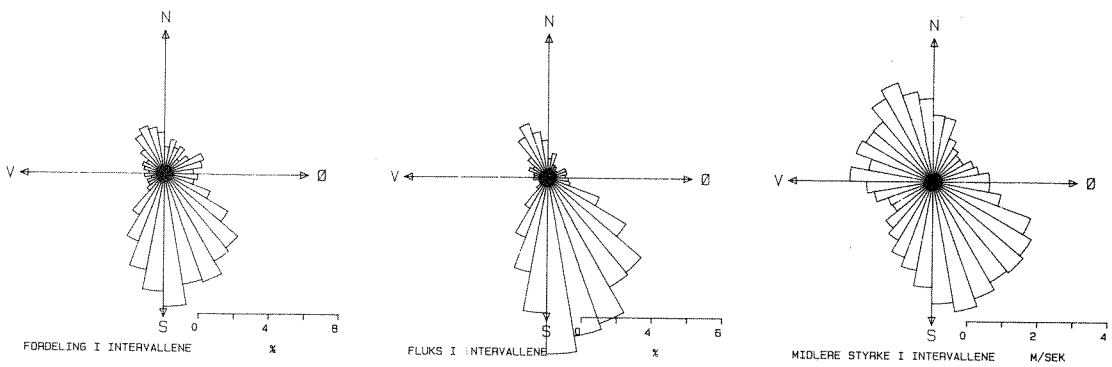
STASJON : MOTORVEIEN SLUTTDATO : 800912 KL.: 12.20

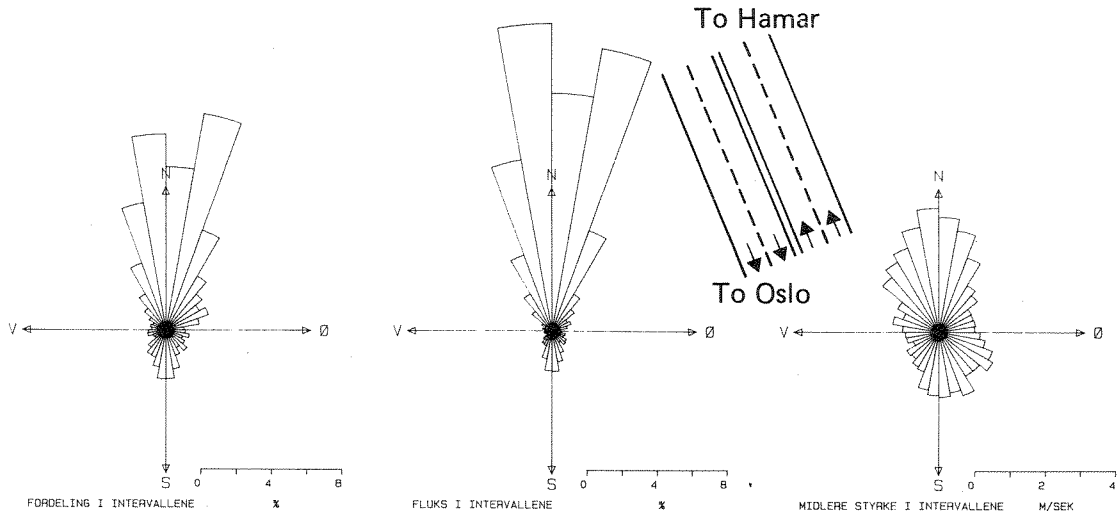


LOKALISERING : JESSHEIM STARTDATO : 800912 KL.: 12.30
STASJON : MOTORVEIEN SLUTTDATO : 801010 KL.: 13.10

Distribution in each interval (amount

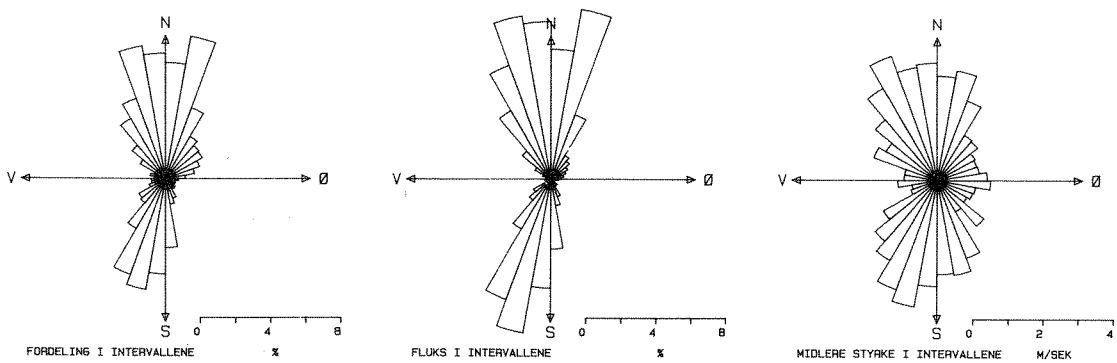
Flux in interval

Average strenght in interval



LOKALISERING : JESSHEIM STARTDATO : 801010 KL.: 12.40

STASJON : MOTORVEIEN SLUTTDATO : 801113 KL.: 17.00



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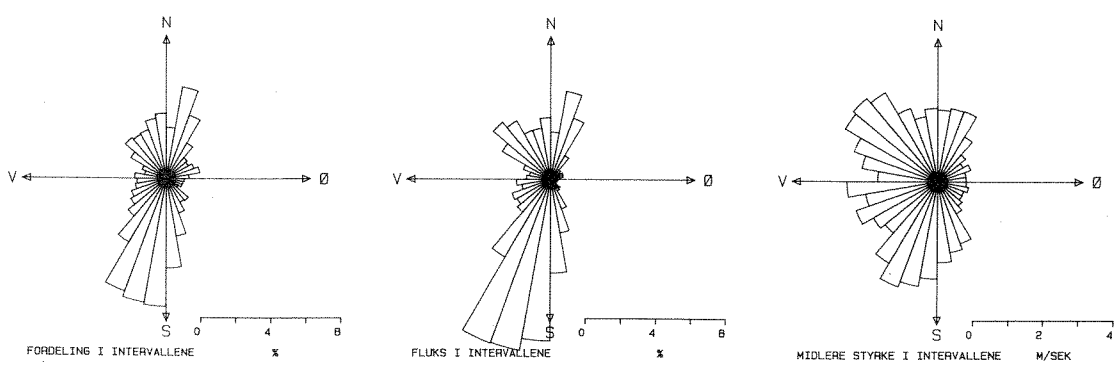
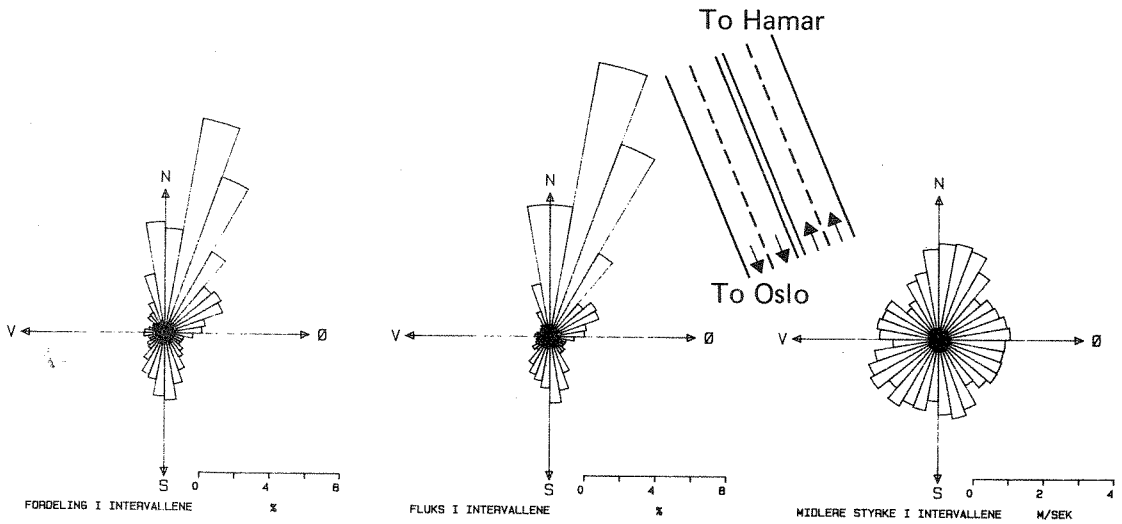
STASJON : MOTORVEIEN SLUTTDATO : 801210 KL.: 21.30



LOKALISERING : JESSHEIM STARTDATO : 810113 KL.: 14.35

STASJON : MOTORVEIEN SLUTTDATO : 810218 KL.: 22.35

Distribution in each interval (amount) | Flux in interval | Average strenght in intervals



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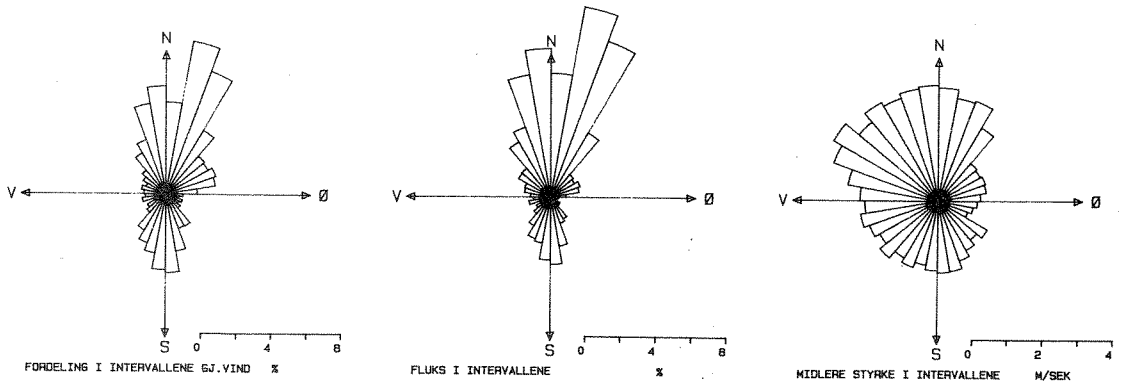

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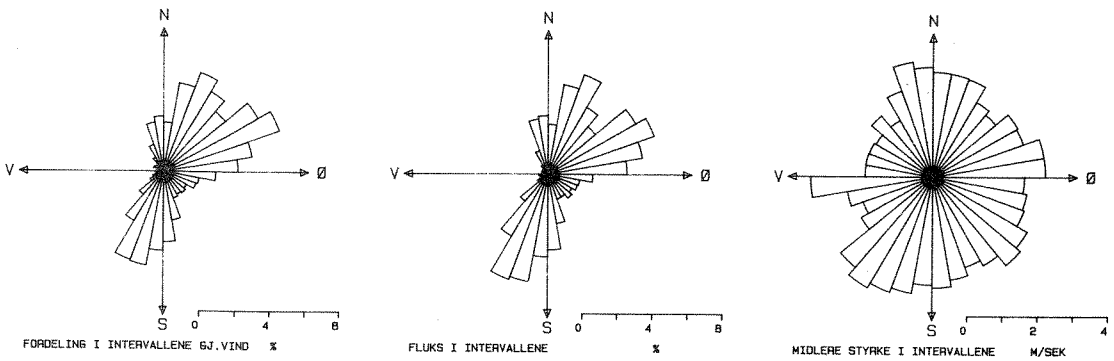
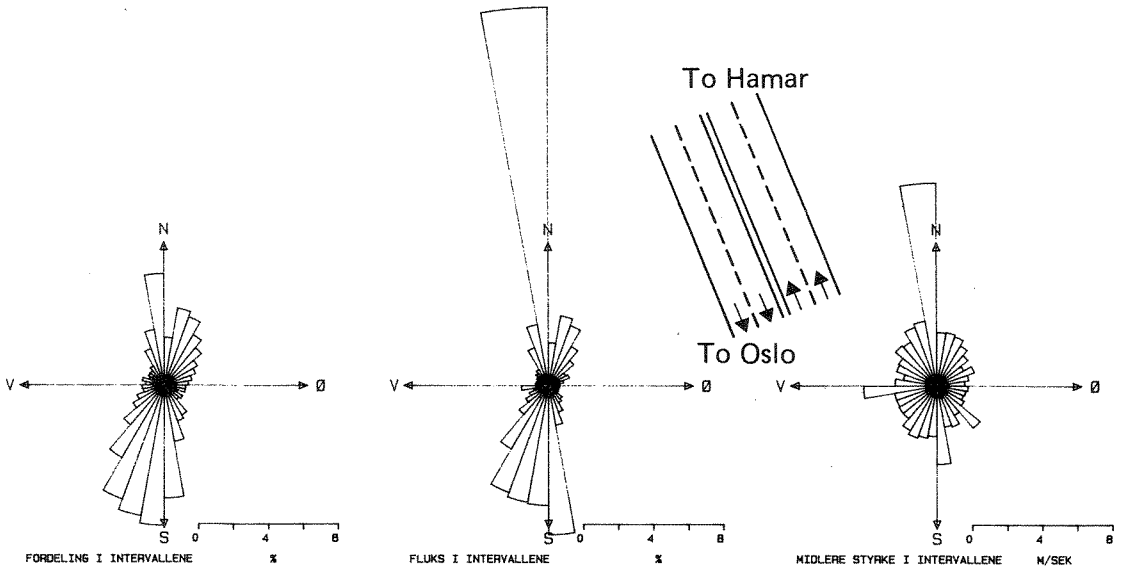
STASJON : MOTORVEIEN SLUTTDATO : 19810427 KL.: 0.00



LOKALISERING : JESSHEIM STARTDATO : 19810427 KL.: 15.30
STASJON : MOTORVEIEN SLUTTDATO : 19810527 KL.: 0.00

Distribution in each interval (amount) | Flux in interval | Average strenght in intervals



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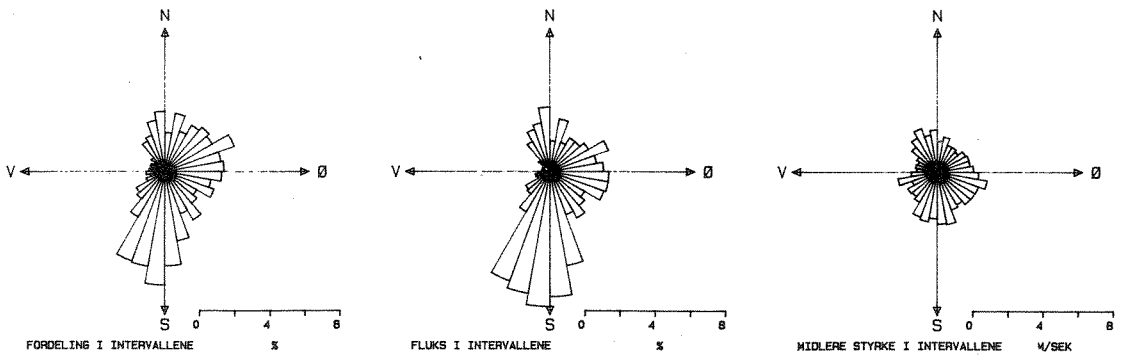

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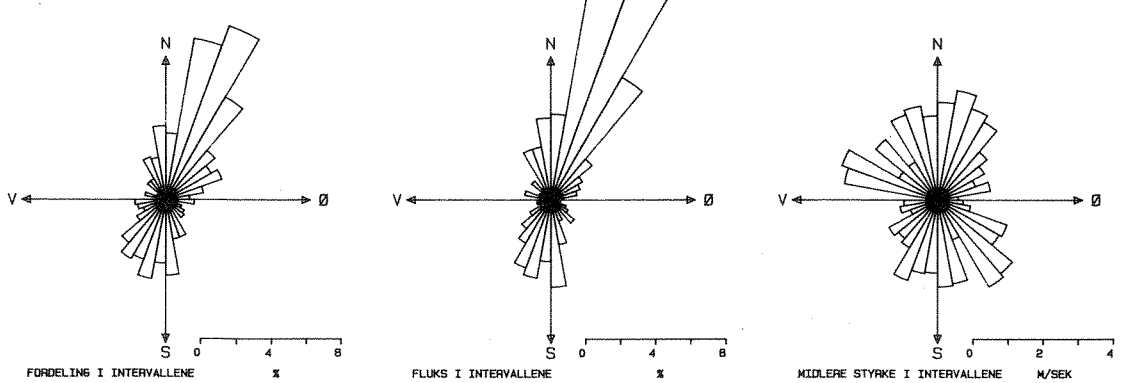
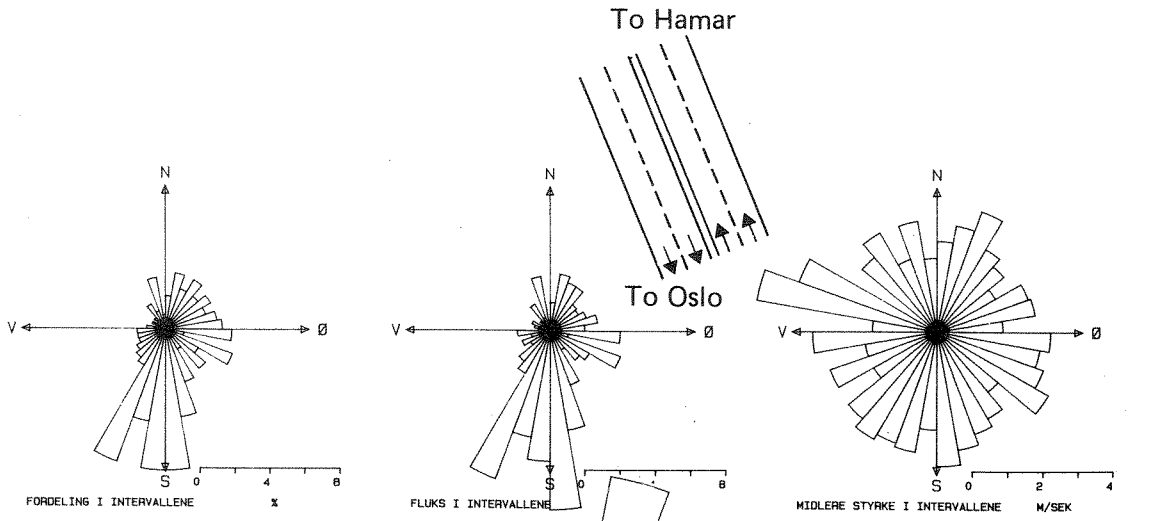
STASJON : MOTORVEIEN SLUTTDATO : 19811112 KL.: 0.00

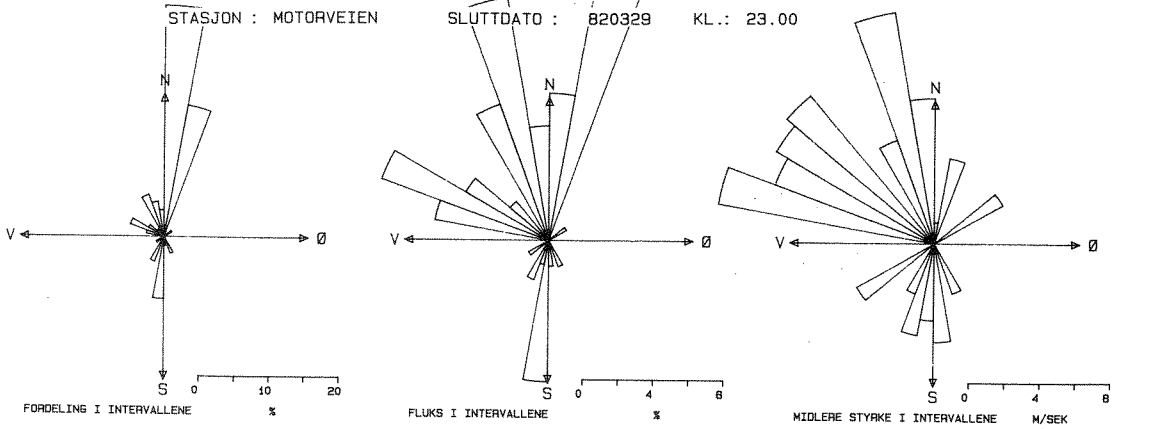


LOKALISERING : JESSHEIM STARTDATO : 811112 KL.: 19.30
STASJON : MOTORVEIEN SLUTTDATO : 820212 KL.: 4.30

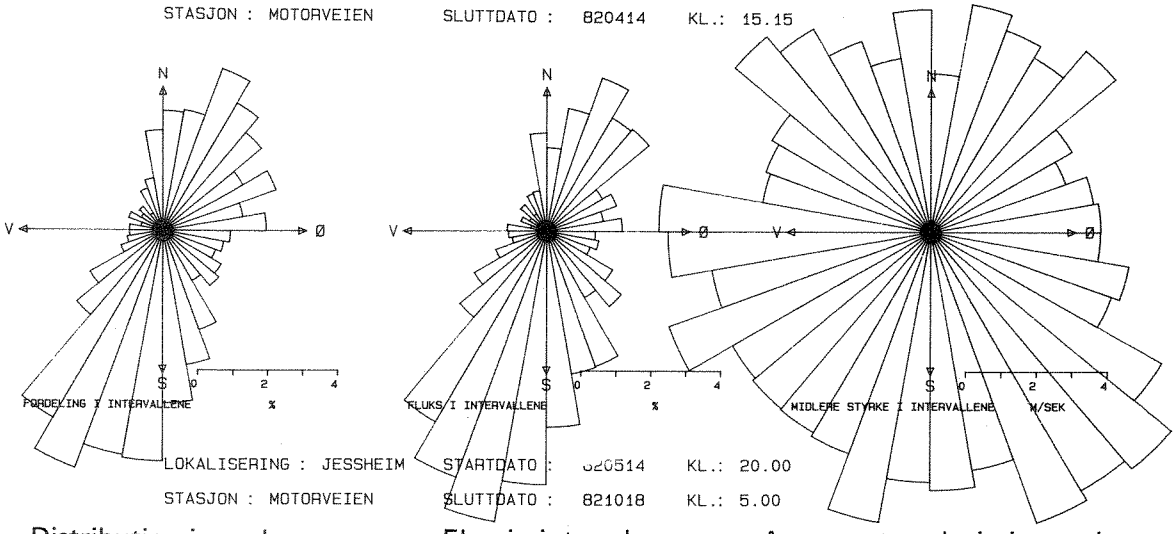
Distribution in each interval (amount) | Flux in interval | Average strenght in intervals



LOKALISERING : JESSHEIM STARTDATO : 820212 KL.: 2.00
STASJON : MOTORVEIEN SLUTTDATO : 820329 KL.: 23.00



LOKALISERING : JESSHEIM STARTDATO : 820405 KL.: 0.15
STASJON : MOTORVEIEN SLUTTDATO : 820414 KL.: 15.15



LOKALISERING : JESSHEIM STARTDATO : 820514 KL.: 20.00
STASJON : MOTORVEIEN SLUTTDATO : 821018 KL.: 5.00

Distribution in each interval (amount)

Flux in interval

Average strenght in intervals

A P P E N D I X B

Drinking water quality standards in different countries (in Norwegian)

DRIKKEVANN STANDARDS (Se også omstående side)

Land		USSR x)	WHO 3. utgave		Japan 1968	India 1975	Tanzania midlert. 1974	Israel 1974	Polen	Danmark 1980		Norge xxx) gen. krav 1976
Parametre			maks.	anbefalt	maks.					maks.	anbefalt	maks.
1.												
Farge Pt	mg/l	20	50	5	5		50	50		15	5	15
Turbiditet FTU	mg/l	1,5	25	5	2		30	25		0,5	0,3	1
Temperatur	°C											10
2. Fysisk-kjemiske parametre												
pH		6,5-8,5		6,5-9,2	5,8-8,6	6,5-9,2	6,5-9,2	6,5-9,5	6,5-9,0	8,5	7,0-8,0	8,0-8,5
Ledn.evne	µS/cm									100	>30	
Hårdhet	dH	1,0	2,0	1,5						Avherding ulovlig		
Kalsium	mg/l											35
Magnesium	mg/l				-	150		150		30z)	-	10
Natrium	mg/l									175	20	
Kalium	mg/l									10		
Aluminium	mg/l	0,5								0,2	0,05	0,1
Sulfater SO_4^-	mg/l	500	400	200	-	400	600	400	150	250z)	50	100
Klorid Cl	mg/l	300	600	200	200	1000	300	600	215	300	50	100
Fritt klor	mg/l											
Nitrater NO_3	mg/l	45	45		45	45	100	90		50	25	11
Nitritt NO_2	mg/l									0,1	Θ	0,05
Ammoniakk NH_4^+	mg/l									0,5	0,05	0,08
Kjeldahl N	mg/l									1,0		
Silisium	mg/l											
Kloroform ekstrakt	mg/l										0,1	
3. biologiske parametre												
Fritt oksygen	mg/l											>70%
$KMnO_4$ perm O_2	mg/l									2,4	1,2	
Tørrstoff 110 °C	mg/l									1500	-	
4. Uønskede el. giftige kompon.												
Sølv	mg/l									0,01	Θ	0,05
Arsen	mg/l	0,05	0,05		0,05	0,05	0,05	0,05	0,05	0,05	-	0,01
Barium	mg/l	2,0								-	0,1	
Bor	mg/l									1,0		0,3
Kadmium	mg/l	0,01	0,01		0,01	0,01	0,05	0,01		0,005	Θ	0,005
Cyanid (CN)	mg/l	0,1	0,05		0	0,05	0,20	0,05		0,05	Θ	0,01
Total krom	mg/l									0,05	Θ	
Krom VI	mg/l				0,05	0,05	0,05	0,05				0,05
Kobber	mg/l	1,0	1,5	0,05	10	1,5	3,0	1,4	1,0	0,1-3,0		0,05
Fluorid	mg/l	0,7-1,5	0,8-1,7		0,8	1,5	8,0	1,4-1,7	1,0	1,5		1,5
Jern	mg/l	0,3	1,0	0,1	0,3	1,0	1,0	1,0	0,3	0,2	0,05	0,2
Kvikksølv	mg/l	0,005	0,001	-	0	0,001		0,01		0,001	Θ	0,0005
Mangan	mg/l	0,1	0,5	0,05	0,3	0,5	0,5		0,1	0,05	0,02	0,1
Nikkel	mg/l									0,050	Θ	
Fosfor	mg/l									0,15	Θ	
Bly	mg/l	0,1	0,1		0,1	0,1	0,1	0,05	0,1	0,05	Θ	0,05
Hydrogensulfid	mg/l											
Thiosulfat	mg/l											
Antimon	mg/l									0,01	-	
Selén	mg/l	0,001	0,01			0,01	0,05	0,01		0,010	Θ	0,01
Sink	mg/l	5,0	15	5,0	1,0	15		15	5,0	0,1-5,0	-	0,3

Land		Internat normer	USA	Kanada	Vest-Tyskland	Sveits	Belgia	Spania	Italia	Sverige	Frankrike	Finland	Nederland
Parametre		Maks.kons. eller min-maks.	Maks.kons. eller min-maks.	Maks.kons. eller min-maks.	Maks.kons. eller min-maks.	Maks.kons. eller min-maks.	Maks.kons.	Maks.kons. eller min-maks.	Analyse eks.	Maks.kons. eller min-maks.	Maks.kons. eller min-maks.		
1.													
Farge Pt	mg/l		15	15	20	15	20	20		20-40		15	20
Turbiditet SiO_2	mg/l		5	5		0,5	4	6			(1) 5	1	0,5
Temperatur	°C			15							12		
2. Fysisk-kjemiske parametre													
pH				6,5-8,5	8,5-9,5		9,5	6,5-9,5	7,0-8,3	7,0-9,5	7,0-8,5	>8,3	
Ledn.evne	µS/cm										2 000		
Hårdhet										2 (anbef.)		3-4	
Kalsium	mg/l							200	160	100			
Magnesium	mg/l					50		50	160				
Natrium	mg/l												
Kalium	mg/l												
Aluminium	mg/l				0,2	0,2		0,2		0,15		0,30	
Sulfater $SO_4^{=}$	mg/l	200-400	250	500	240			200-400	100	100-200	250	100	
Klorid Cl	mg/l		250	250				250-350	35	100-300	200-600	50	
Fritt klor	mg/l		0,2-0,3		0,3-0,6				0,2				
Nitrater NO_3	mg/l	45	45	45	50-90	50	50	50	10		50-100	50	100
Nitritt NO_2	mg/l			1,0		0,1	0,1	0,1	0				
Ammoniakk NH_4^+	mg/l			0,6		0,5	0,5	0,5	0 (en N)	0,05(enN)	0,05	1,0	0,1
Kjeldahl	mg/l											0,5	0,2
Silisium	mg/l												
3. biologiske parametre													
Fritt oksygen	mg/l												
$KMnO_4$ perm	mg/l					12	5	5			0,3	3	20
Tørrstoff 110 °C	g/l						1,5	1,5			0,1-0,2		
4. Uønskede el. giftige kompon.													
Sølv	mg/l		0,05	0,05	0,1	0,01							
Arsen	mg/l	0,05	0,05	0,05	0,04	0,05	0,05	0,05	0		0,5	0,05	0,20
Barium	mg/l		1	1									
Bor	mg/l			5									
Kadmium	mg/l	0,01	0,01	0,05	0,006	0,005	0,005	0,005	0		0,005	0,005	
Cyanid	mg/l	0,05	0,2	0,2	0,05	0,050	0,050	0,050	0		0,05	0,05	0,01
Total krom	mg/l					0,05	0,05						
Krom VI	mg/l		0,05	0,05	0,05			0,05	0		0,05	0,05	0,05
Kobber	mg/l		1	1				1,5		0,05	0,05	0,3	3,0
Fluor	mg/l	1,5		1,5	1,5	1,5	1,5	1,5		1,5	1,5	3,0	1,2
Jern	mg/l		0,05-0,3	0,3	0,2	0,2	0,2	0,2	0,5	0,2-0,4	0,1	0,3	1,0
Kvikksølv	mg/l	0,001	0,002	0,001	0,004	0,001	0,001	0,001	0			0,002	
Mangan	mg/l		0,05	0,05	0,1	0,05	0,05	0,05	0,2	0,1	0,05	0,10	0,05
Nikkel	mg/l					0,05	0,05	0,05					
Fosfor	mg/l			$0,002PO_4$		0,15	2,0	2,15	0 PO_4		$(3)0,3PO_4$		
Bly	mg/l	0,1	0,05	0,05	0,04	0,05	0,05	0,05	0		0,05	0,05	0,30
Hydrogensulfid	mg/l			0,05					100				
Thiosulfat	mg/l				0,5								
Antimon	mg/l					0,01	0,01	0,01					
Selén	mg/l	0,01	0,01	0,01	0,008	0,01	0,01	0,02	0		0,01		0,05
Sink	mg/l	1,5-5	5	5,0	2		5	5		1		1,0	1,5

Følgende drikkevannsstandarder er anvendt:

- ISWA, Paris, Sept. 1980
- National interim primary drinking water regulations.
- EPA-57019-76-003
- Guidelines for Canadian Drinking Water Quality 1978
- ISWA, Zürich, Sept. 1982
- WHO ETS/80.3 (Geneva, 1980)
- Bekjentgjørelse av kvalitetskrav m.v. til overflatevann som anvendes til fremtstilling av drikkevann. Miljøministeriets bekjentgjørelse nr. 162, 29. april 1980
- Sarja, 1980; The Corrosion at the water works in the water distribution networks and in taps water fittings. (Finland)