2535

HÜMOR

HUMEX

HUMIC LAKE ACIDIFICATION EXPERIMENT

Status September 1990, one week before start of the treatment

Report NO 1/91

from

H U M E X

Norwegian Institute for Water Research NIVA

HUMOR

Humic substances, modifiers of the response
of aquatic of ecosystems to acidification

Sponsors

- Commision of European Communities (Directorate General XII, Science, Research Development.
- Various national institutions in Finland, Germany The Netherlands, Norway, Spain, and United Kingdom.

Background and goal

It is now firmly established that in many parts of Europe acidification of surface waters is proceeding due to atmospheric deposition of sulphur and nitrogen compounds. Despite a considerable research effort aimed at understanding the impact of surface water acidification on aquatic biota, many of the published results have been inconsistent or even contradictory.

There are strong reasons to believe that part of this inconsistency is attributable to the varying amounts and functional properties of brown dissolved organic matter (humic substances, HS) in surface waters undergoing acidification. Edvidence is becoming available that HS can;

- contribute directly to acidification
- interact with other dissolved materials
- influence microbial enzyme processes
- directly influence aquatic biota.

The purpose of the "HUMOR" project is to strengthen the scientific knowledge of humic substances influencing the acidification of surface waters and its reversibility, and altering the impact of acidification on aquatic organisms.

The work is carried out in both lakes and rivers in Finland, The Netherlands, Norway, Spain, Sweden, United Kingdom and West Germany by 7 contractors. The main body of the research will be carried out in the home country of each participant with a cooperative effort by all members at the HUMEX lake in western Norway. Each participant provides one part of an overall holistic approach which can be listed in hierarchical order;

(1) chemical characterization including lipid and fatty acid composition of acidified and naturally acidic humic lakes,

(2) effect of pH and HS on iron and phosphorus complex formation and nutrient availability,

(3) effect of pH and HS on microbial enzymatic processes,

(4) effect of pH and HS on lipid solubility and invertebrate membrane transport,

(5) effect of artificial acidification on geochemistry and biological processes in an experimental watershed in western Norway.

Participants

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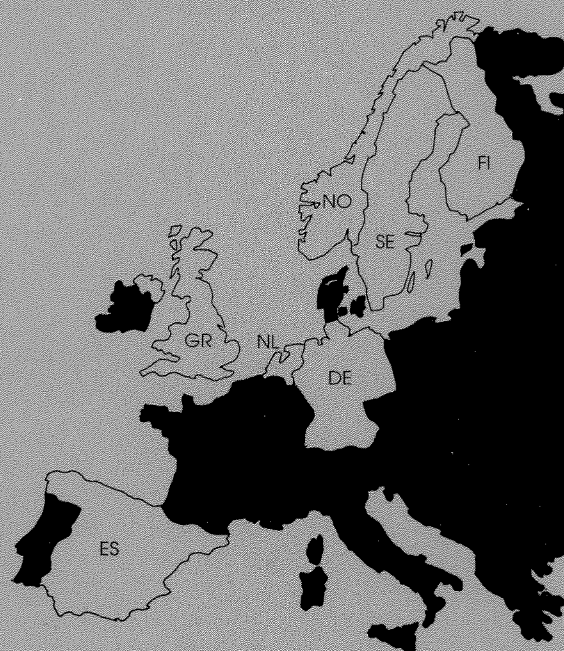
Spain:	Consejo Superior de Investigaciones Cientificas, Barcelona. Responsible: Dr. Juan Grimalt.
Sweden:	University of Lund, Limnology Institute, Lund. Responsible: Dr. Robert C. Petersen Jr.
United Kingdom:	University of Lanaster. Department of Biological Sciences, Lancaster. Responsible: Dr. Roger I. Jones.



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Abstract:

An important conclusion from the acid rain research during the late 1970's and the early 1980's, was that humic substances (HS) in the water affected the response of acid rain. HS acts as a modifier on both the chemical composition and on the biological activity of acidified surface water. The Humex project will, by artificial acidification of a whole catchment, study the role of HS on the acidification and the role of acidification on the biological properties of HS.
In fall 1988, a dystrophic lake was divided in two halves by a plastic curtain, from the middle of the natural outlet to the opposite side. During the following two years, through September 1990, the water chemistry of the two lake halves has been monitored and a number of scientists from Europe and North America have been studying the organic matter and the biota in the water, and in the catchment area prior to the artificial acidification, which started October 6th 1990.

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For the Administration

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INTRODUCTION

The lake Skjervatjern was divided into two halves already during fall 1988, initiated and sponsored by Norwegian Institute of Water Research. The lake was divided by a plastic curtain from the middle of the natural outlet to the opposite shore side. The outflowing water from these two outlets has been monitored by weekly water samples, and analyzed for major cat- and anions. During 1989 the planning and preparation for gaging the water flow from the two outlets took place, and in 1990 necessary funds were available from The Ministry of Environment and from NIVA, to start preparing for the artificial acidification of the one lake half and the corresponding catchment.

As a base for future studies, the participating scientists have been collecting as much information as possible about differences and similarities between the half to be acidified and the control catchment, during this pre-acidification period.

As this project is the first of its kind, and as expensive installations are necessary,we have emphasised on information about the project and invited scientists to participate with their expertise. There are a number of unanswered questions of ecological importance concerned with acidification of surface water containing humic substances.The HUMEX project is dealing with an environmental problem that needs an interdisciplinary approach.

In connection with the invitation from EC to participate in the STEP program, we contacted colleagues in England, Finland, Germany, Spain, Sweden and The Netherlands and suggested a joint application to Brussels. Today there are all together 10 institutions connected to the HUMEX activities and there are reasons to believe that additional scientists will join in the near future.

THE SITE

Skjervatjern is situated on the west coast of Norway, about 10 km east of Førde. In this part of Norway the deposition of acid rain is low. Mean concentration of major ions in precipitation and wet deposition at Nausta is given in Table 1. The sampling station Nausta is situated only 20 km north-west of the Humex site.

Table 1 Weight yearly mean concentrations of ions in precipitation and the total yearly wet deposition at Nausta, about 20 km north-west of Skjervatjern.

Mean concentration (mg/l)						Year	Year	Wet deposition			
Year	SO_4-S	NO_3-N	NH_4-N	Ca	Mg	mean pH	precip. mm	SO_4-S mg/m^2	NO_3-N mg/m^2	NH_4-N mg/m^2	H^+ meq/m^2
1985	0.29	0.13	0.09	0.09	0.12	4,70	1943	561	246	177	39
1986	0.27	0.10	0.08	0.09	0.16	4,74	2314	614	227	176	42
1987	0.27	0.12	0.11	0.09	0.11	4,72	1969	523	236	213	37
1988	0.21	0.13	0.09	0.14	0.23	4,68	2253	476	302	193	47
1989	0.21	0.12	0.07	0.10	0.23	4,80	3330	708	407	227	53

Lake Skjervatjern- morphology

Fig.1 illustrates the depth profile and the surface area/volume relationship of the two basins. Some physical and morphological data are given in Table 2.

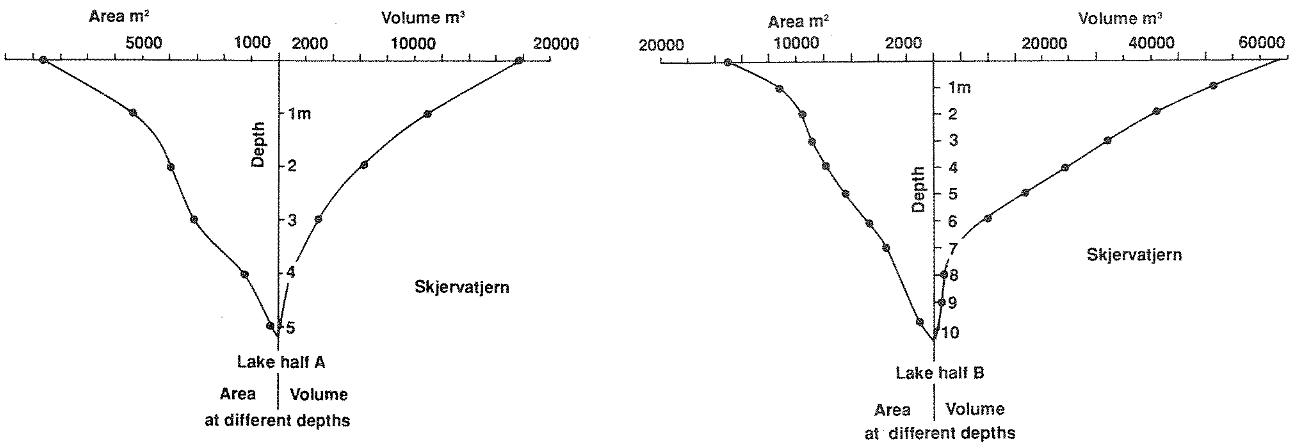


Fig. 1. Area and volumes at different depths in the two lake halves.

Table 2. Lake Skjervatjern; physical and morphological data.

	Experiment. half (A)	% of total	Refer half (B)	% of total
Lake area (ha)	0.9	38	1.5	62
Catchment (ha	2.5	19	10.9	81
Maximum depth (m)	5.2	-	10.4	-
Mean depth (m)	2.0		4.2	
Volume (m^3)	17800.0	22	63109.0	78
Theoretical retention time;	0.4	-	0.3	-

TECHNICAL INSTALLATIONS DURING 1990

The two lake halves

The lake was divided into two halves in November 1988 by a plastic curtain from the middle of the natural outlet to the opposite side. The length of this crossing is105 m and maximum depth 4.5 m. The profile of the curtain was adjusted more or less according to the profile of the cross section, however, 3 to 4 m wider. This extra plastic curtain was pressed into the sediments by large numbers of sand bags. As the depth of the "soft" sediments generally are 0.5 - 1 m, these bags will secure a good physical separation of the water-masses. The position of the dividing curtain is shown on Figure 2.

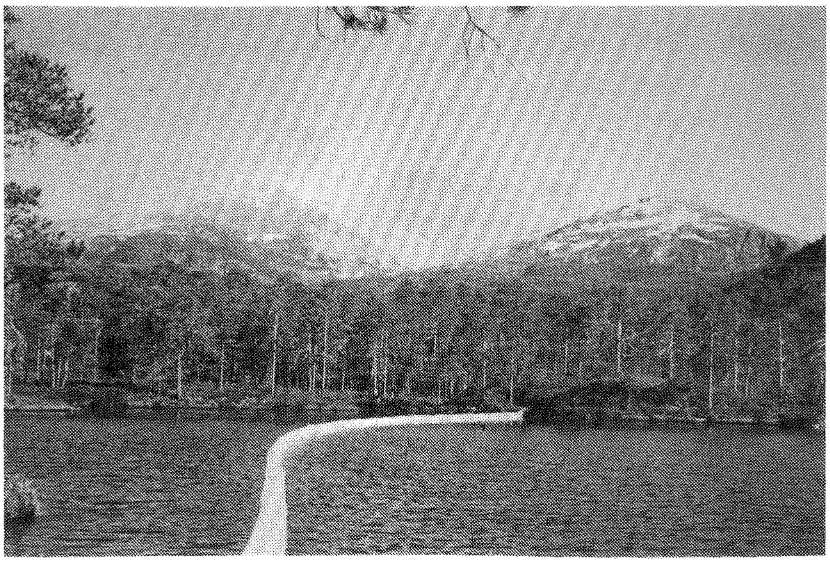


Fig.2. A plastic curtain divides the Lake into two separate basins

Facilities for biological studies downstream the lake

The project will as much as possible relate changes in chemical composition of the water from the two basins with change in biological activity. As will be seen from Figure 3, the two " artificial" outlets are piped into two separate tanks from where experimental water can be led into the field station which is shown on Figure 4. This is planned to house set-ups for fish experiments. The water-flows from the two lake halves are recorded. The device for flow-measurement is installed outside on the tubes (see Figure 5). This is based on acoustic measurement of water flow.

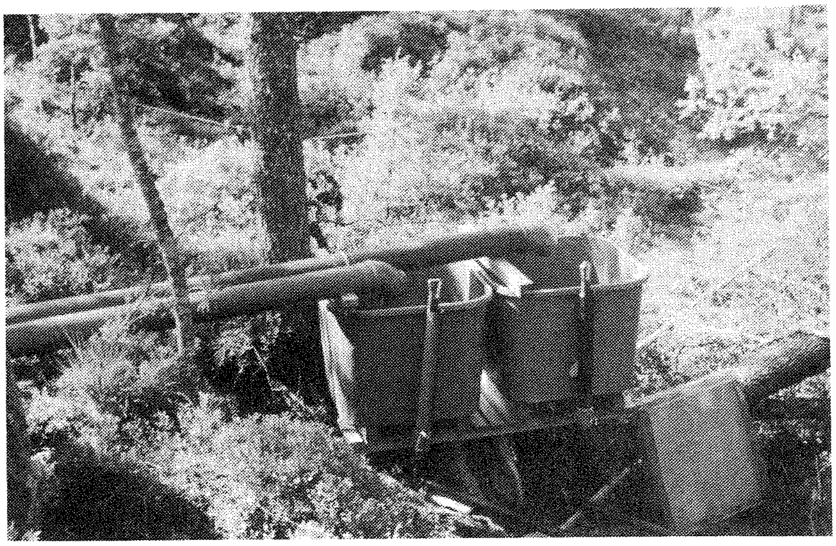


Fig.3. The outlets are piped into two separate "streams"

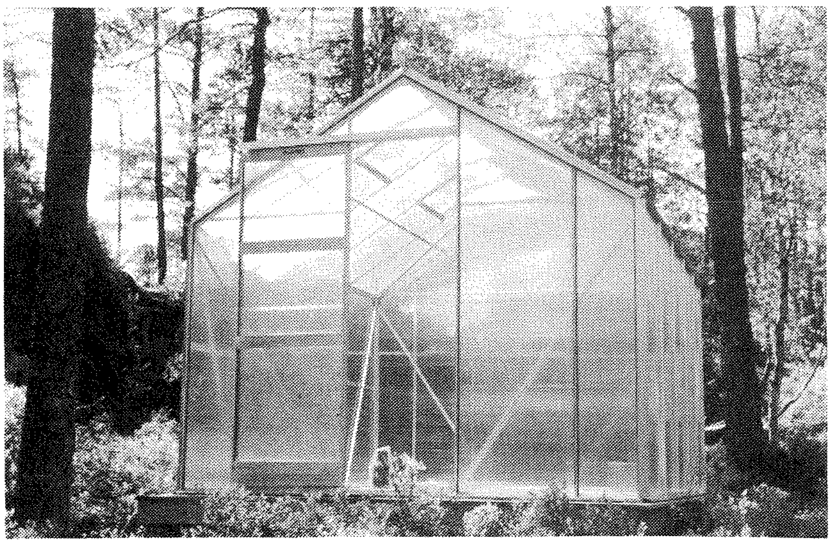


Fig. 4. The field station for biological experiments

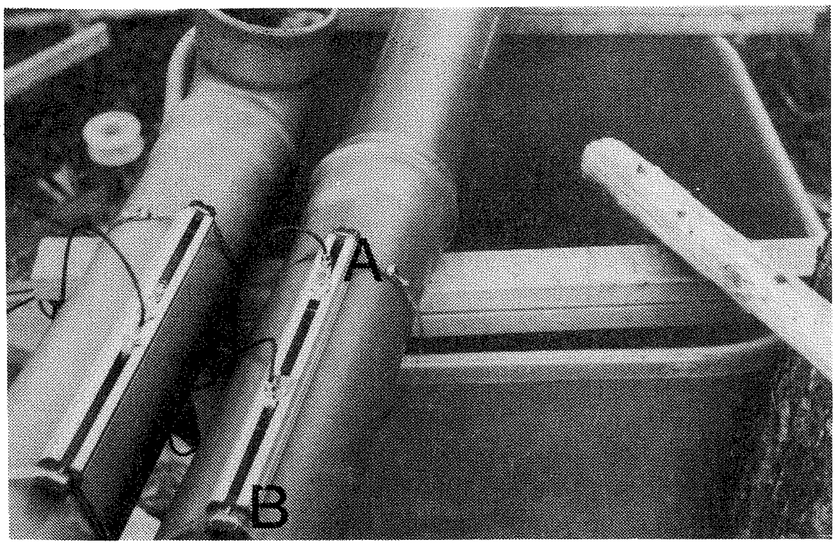


Fig.5. Devices for recording water flow from the two outlets.The pipe must be filled with water. An acoustic signal, sent down into the flowing water at B, is received at A after a certain time t_1. Similarly a signal sent from A, is received at B, after a time t_2. Depending on the flow rate, t_1 - t_2 will differ, and this time-difference is proportional to the water flow.

Sprinkler system

The artificial acidification is carried out by a sprinkling system that is mounted at the top of the highest trees in the catchment. Each of the sprinklers (Fig. 6) has a distribution radius of 15 m. In order to be able to acidify the 2.5 hektar experimental area properly, there is a need for 50 of these sprinklers. For the lake half itself , which is 0.9 ha, two bigger sized sprinklers are used, placed at the shore side. The sprinkling system will be activated manually when a certain amount of precipitation has been accumulated.The amount of artificial acid rain will be 5 to 10 percent of this natural precipitation, with a pH of 3.0. Some ammonium nitrate is also added to this acidified precipitations (0.8 mg NH_4NO_3/ mg SO_4).

Fig.6. Fifty sprinklers are mounted at the top of the highest trees in the area to be acidified.

The annual precipitation in this region is in the range of 2000 mm. This means that about 5000 m^3 of acidified water is to be sprinkled out during a year (see Table 3).The water used for the acidification is taken from Åsvatn, which is a part of the Jølster watercourse. Some chemical characteristics of this water are shown in Table 4.

Table 3. Precipitation at Nausta (mm).

	Jan	Feb	Mars	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Year	% of Norm
1985	122	137	130	75	41	55	106	209	289	261	197	302	1943	
1986	100	47	289	9	210	35	66	81	230	345	587	316	2314	112
1987	119	284	69	93	59	89	139	156	386	199	106	269	1969	88
1988	189	149	45	173	71	21	200	163	337	183	271	451	2253	111
1989	788	398	341	20	287	208	116	274	275	263	145	218	3330	151

Table 4. Chemical composition of Åsvatn during an study in 1972 - 73. (Mean of 13 samples).

pH	Cond mS/m	Turb NTU	TOT-N mg N/l	COD Perm mg O/l	Ca mg/l
5.76	1.63	0.49	146	1.46	0.78

The water is pumped from a point 3-4 m depth, 50 m from the shore of Åsvatn. After addition of acid, the water is pumped through a distribution device (see Fig. 7), to the different sub-areas. The artificial acidification system is operating as follows: Depending on the amount of natural precipitation, the time needed to distribute 10 percent of this amount of acidified water, is read from a table. When activating the electronic device (see Figure 10) "pure" lakewater is pumped to sub-area No I, corresponding to 1.5 mm precipitation. When vegetation and soil are soaked with this water, x mm of acidified water at pH 3 (containing NH_4 NO_3) are added. With for example 50 mm precipitation accumulated, 5 mm of acidified water are added. Before the electronic device allows to switch to sub-area No II, 1.5 mm of "pure" lakewater is added in order to rinse off the acid water from the vegetation.

The time needed to distribute 1.5 mm artificial rain, is 25 minutes; consequently the time needed to distribute 5 mm acid of pH 3, is 108 minutes for each of the 4 sub-areas. Regarding the fifth sub-area, which is the lake-half, the initial "pure"-water addition, is omitted. During winter there are freezing temperatures in this part of the country, and some of the precipitation will be in the form of snow. As the climate changes rapidly during the winter season, with mild periods between frost, we expect technical problems regarding proper acidification. Normally there will be some snow accumulated during winter; in these cases sufficient amount of acid will be added manually (see Figure 8).

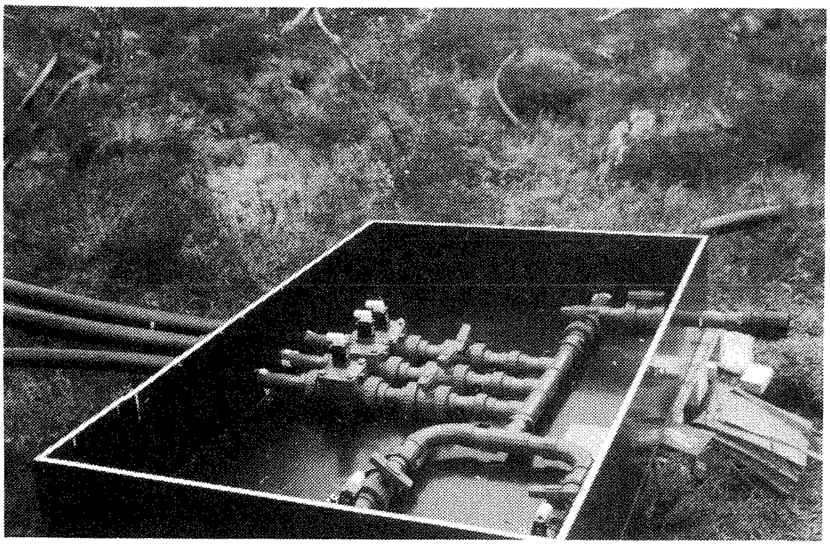


Fig.7. The water is pumped to a set of electronically operated magnetic valves, and distributed to the different sub-areas.

Fig.8. Manual acidification of a snow covered catchment.

Field laboratory

Presently there are about two dozens scientists involved in the project, and we expect that there will be extensive fieldwork, particularly during the period of May through September. For practical reasons, therefore, we have put up two barracks for laboratory work and with cooking and sleeping facilities.The barracks were transported to the lot by helicopter (see Figure 9). Between these barracks the water pump, the acidification device and other electronic devices are installed (Figure 10).

Fig. 9. The barracks were transported from a nearby road by helicopter

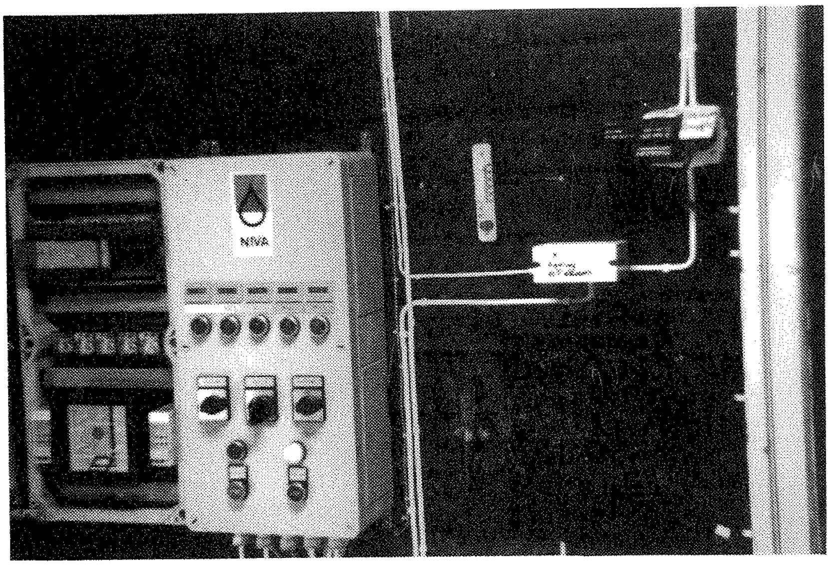


Fig.10. The operating panel for the water acidification and for the sprinkling system.

PREACIDIFICATION STUDIES

Hydrological studies

In the summer of 1990 the spatial pattern of subsurface water flow into each side of Skjervatjern was mapped, and samples for chemical analyses were taken at the land/water interface. Two different source areas and types of discrete source entry points were identified and found to supply water of different chemistry to the lake. One source is from the ombrotrophic bogs and the other from the shallow podzolic soil areas. The effect of catchment acidification on these two different sources will be followed during the project (Lena Petersen, Lund).

Chemical studies

During the period from November 1988 , when the lake Skjervatjern was divided, till early October 1990, when the acidification part of the experimental part started, water samples have been collected weekly from the outlets. In addition, 8 series of water samples have been taken from various depths in the two basins. Figure 11 illustrates the variation of pH. Figures 12 and 13 illustrates the corresponding variation of sulphate(SO_4), UV-absorption and colour. Figure 14 illustrates oxygen and temperature in vertical profiles in the two lake halves during 3 different seasons. All chemical data are given in Appendix 1.

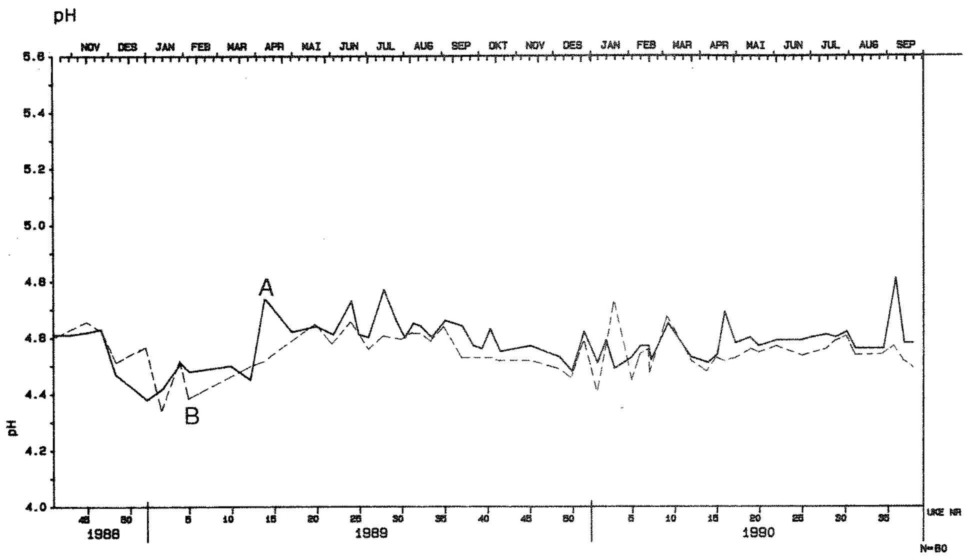


Fig.11. pH as a function of time in the outflowing water from the two basins.

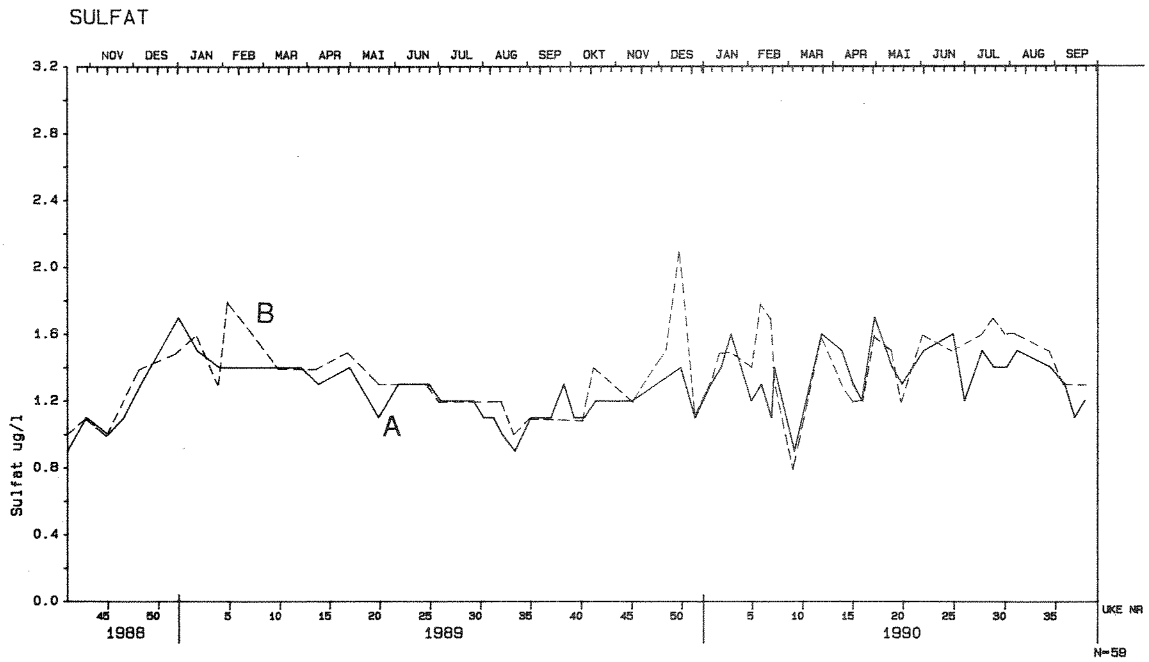
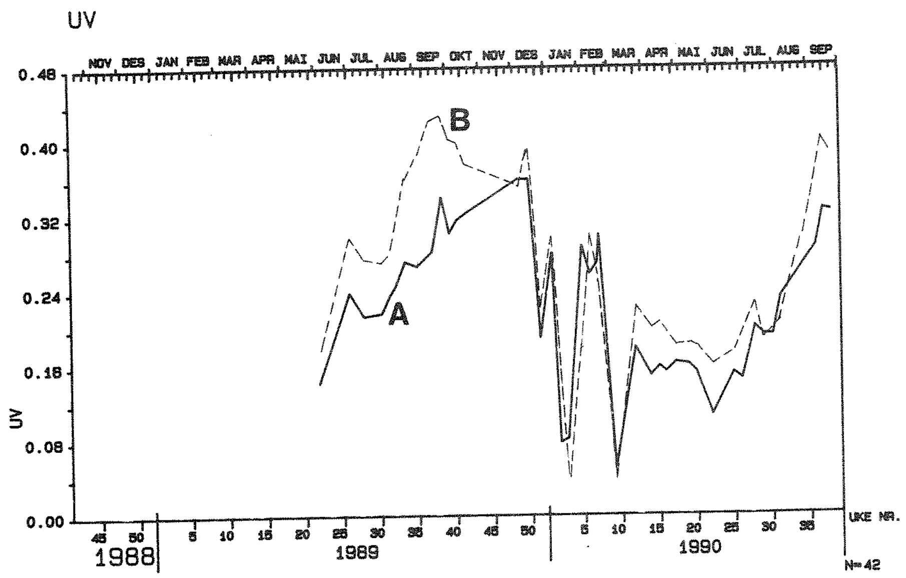


Fig.12. Change of sulphate concentration with time at two outlets.



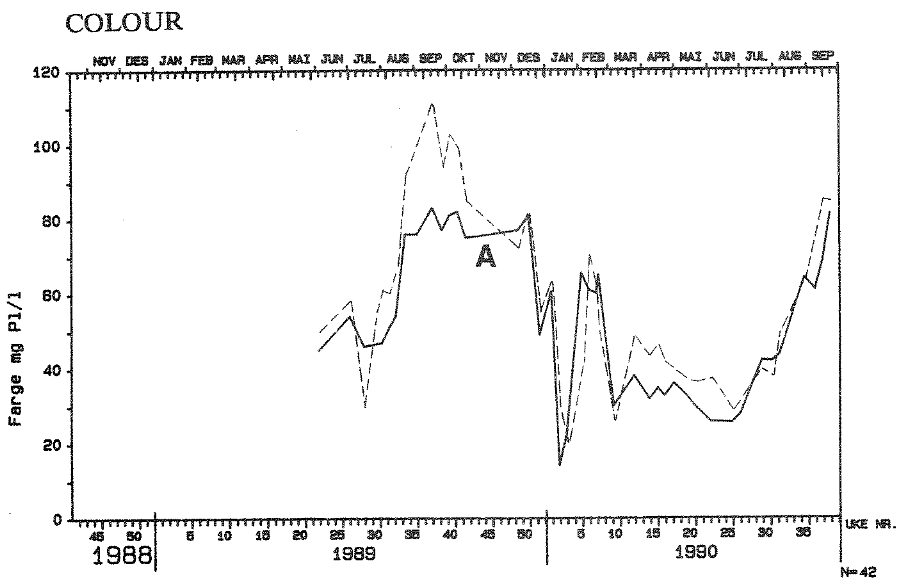


Fig. 13. Variation in the absorption of UV (254 nm./1 cm) and in colour with time in the water from the two outlets.

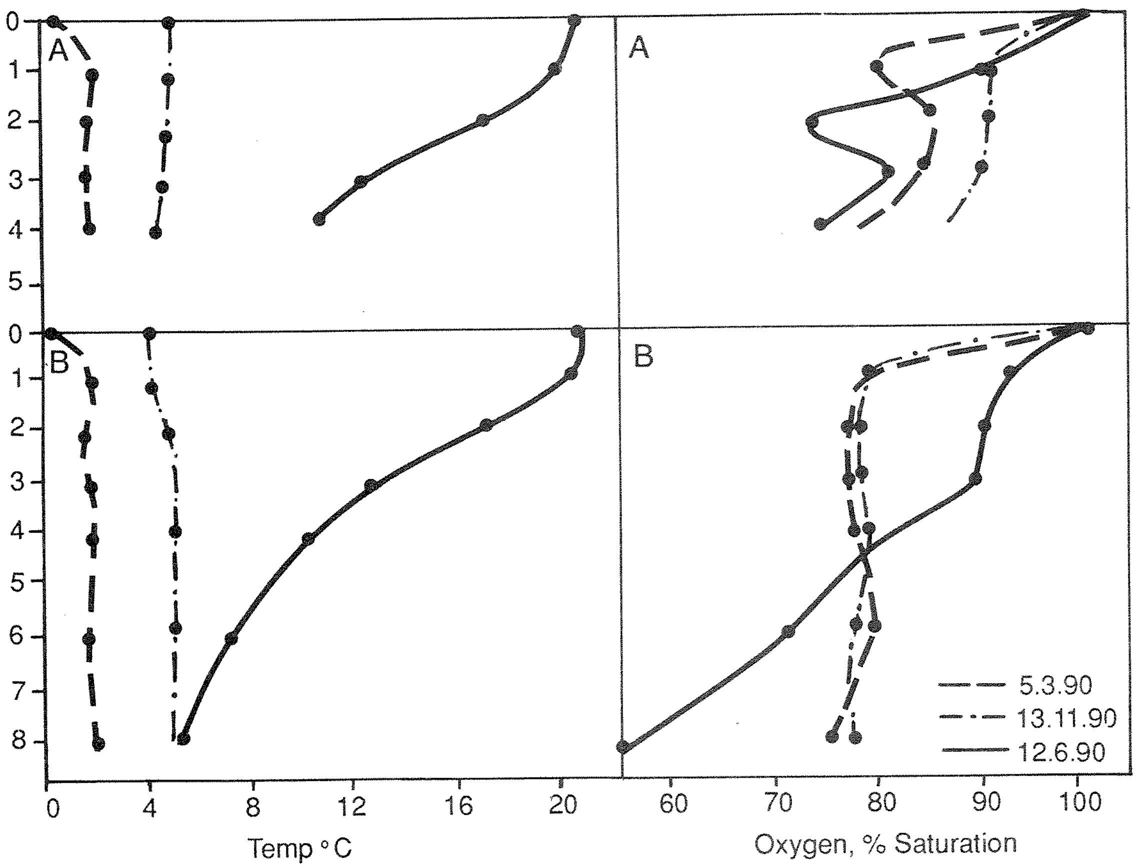


Fig.14. Temperature and % O_2- saturation in the two basins. Changes with depth, during winter, summer and fall.

Table 5 gives the mean concentration of all chemical characterization data that have been collected prior to acidification, and Table 4 shows the Secchi-depth in the two basins at seven different dates during this period.

Table. 4. Secchi-depth in Lake Skjervatjern prior to acidification.

Date	A (m)	B (m)
18/6-89	2,2	2,3
13/7-89	2,8	2,8
06/5-90	2,3	2,5
12/6-90	2,2	2,2
08/7-90	2,6	2,6
21/8-90	2,6	2,6
30/9-90	2,3	2,3
Mean	2,43	2,47

Table 5. Composition of water from Lake Skjervatjern's basin A (to be acidified), and basin B. Mean values from the period 1/1-1989 to 30/9-1990. Vertical profile data are included.

	A 1)				B 1)			
	Mean Value	St. Div.	Min	Max	Mean Value	St. Div.	Min.	Max.
pH	4.60	0.08	4.38	4.81	4.55	0.07	4.34	4.76
Cond mS/m	3.15	0.48	2.10	4.66	3.33	0.40	2.15	4.44
Ca	0.20	0.03	0.10	0.33	0.21	0.03	0.11	0.33
Mg	0.30	0.07	0.16	0.63	0.30	0.05	0.20	0.54
Na	2.58	0.50	1.26	4.11	2.71	0.42	1.31	4.13
K	0.13	0.03	0.06	0.20	0.15	0.04	0.08	0.48
Cl	4.88	1.31	1.30	8.70	4.94	1.36	1.20	8.20
NO_3-N	7.20	9.44	1.00	63.00	9.50	12.90	1.00	89.00
SO_4	1.34	0.44	0.80	5.10	1.57	0.83	0.80	5.60
TOC	5.54	1.94	1.33	12.00	5.91	2.18	0.90	13.10
RAL	65.70	17.70	10.00	127.00	76.40	19.30	12.00	138.00
ILAL	35.70	14.70	10.00	85.00	42.90	16.40	10.00	84.00
LAL	30.00	9.70	0.00	61.00	33.50	9.60	2.00	85.00
NH_4-N	15.50	9.00	6.00	67.00	16.20	8.20	5.00	42.00
TOT-N	223.00	64.30	87.00	363.00	208.00	64.20	90.00	407.00
Colour	50.8 3)	18.30	14.00	87.00	57.6 4)	20.70	20.00	112.00
UV abs	0.225 5)	0.068	0.051	0.360	0.257 6)	0.079	0.037	0.429

1) member of observations (n) = 91

2) n = 111 (including vertical profile)

3) n = 74

4) n = 94

5) n = 69

6) n = 87

Octanol/water partition coefficient

In the summer of 1990 the octanol/water partition coefficient of HS was determined in soil water, at the soil/water interface and in the lake. Differences in the coefficient were found to be related to hydrological source. It is expected that, following acidification, there will be additional changes in the lipid solubility of HS (Kullberg, Lund). The technique is also being used in a Master of Science degree programme at the University of Oslo to study the changes in lipid solubility of HS in different kinds of pretreated samples.

Isolation of HS by XAD-8

A representative from U.S. Geological Survey, Denver (Malcolm), has collected 1000 L of water from each of the two outlets (Sept. 19.-90) From these volumes were isolated 8 and 12 grams HS from A and B respectively. Dr. Malcolm used the well established XAD- technique for this isolation. This technique is identical with that used for "producing" the Intentional HS and the Nordic HS. The two isolates are to be characterized at USGS in Denver. The plans are to repeat this sampling and isolation probably next fall (1 year after the start of the acidification).

Biological studies

Fish: During the early 1980's some trout was transplanted in lake Skjervatjern. By intense net-fishing the last two summers the 55 individuals that were stocked, have probably been caught or have died out. The planned fish experiments will take place in the "greenhouse" downstream from the lake (see Figure 4), and preparations have been made to test the effects on several different fish-species. (Lien, NIVA).

Phytoplankton: Quantitative samples have been taken from each of the two basins during the seasons of 1989 and 1990. The samples are stored and will be analyzed during 1991.(Brettum, NIVA).

Zooplankton: Quantitative and qualitative samples have been analyzed from both halfs in 1989 and 1990. Metal content in zooplankton will be analyzed in a representative number of samples.(Hessen, NIVA)

Zoobenthos: During the summers of 1989 and 1990 the species composition and density of the macroinvertebrate benthic fauna of both sides of Skjervatjern have been measured. The findings show that there is a rich species diversity consisting of mostly dragonflies, damselflies and beetles. Samples have been saved for an analysis of the chemical composition of the major taxa. It is hypothesized that acid stress on the experimental side of the lake will alter their chemical composition (Hargeby, Lund).

Microbial activity: The microbial respiration associated with the coarse (>5mm) organic debris has been measured at the land/water interface in the summers of 1989 and 1990 (Petersen, Lund).

Macrovegetation: Photos of the lake bottom have been taken during 1989 and 1990 as a base for studying changes in the macrovegetation. Figure 15 shows Sphagnum at the bottom of basin A (Brandrud, NIVA).

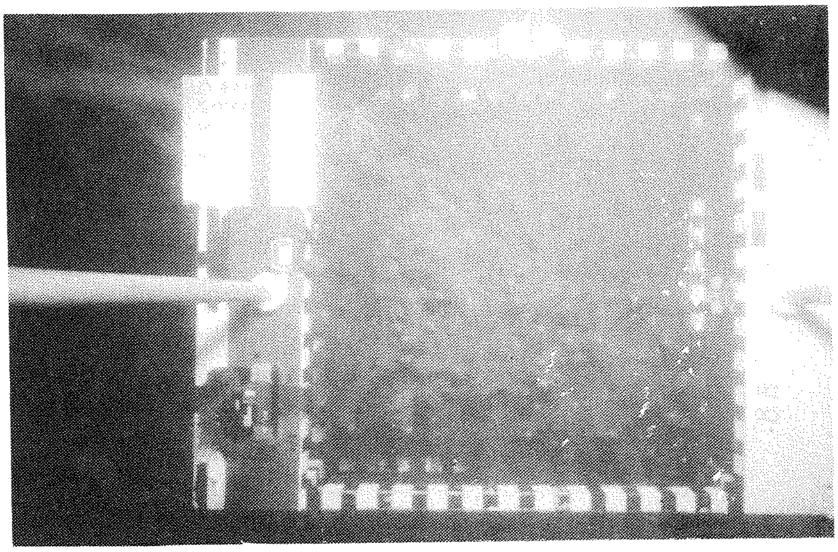


Fig.15. Photos of the Sphagnum - cover in the two basins have been taken.

Soil studies

Soil water sampling devices (ceramic cup lysimeter) have been installed in 3 plots in the catchment to be acidified and in 3 plots in the control-area. These 3 plots are located in the mineral soil in the seepage zone, in bog-area close to the lake, and in bog further up in the catchment.These sites were selected in order to capture the range of different soils in the catchment. The flasks (see Figure 16) have a negative pressure (vacuum) and will suck water up from the different depths in the soil profile. Altogether there are installed 30 "samplers"of this kind. Prior to acidification, 5 series of samples have been collected, all of which have been analyzed on pH, conductivity, inorganic and organic aluminium, and total organic carbon. In addition, a selected number of samples from these and future series will be characterized using XAD-8 separation, membrane dialyzation, HPLC-size fractionation, and determination of octanol/water partition coefficient (see page 13).

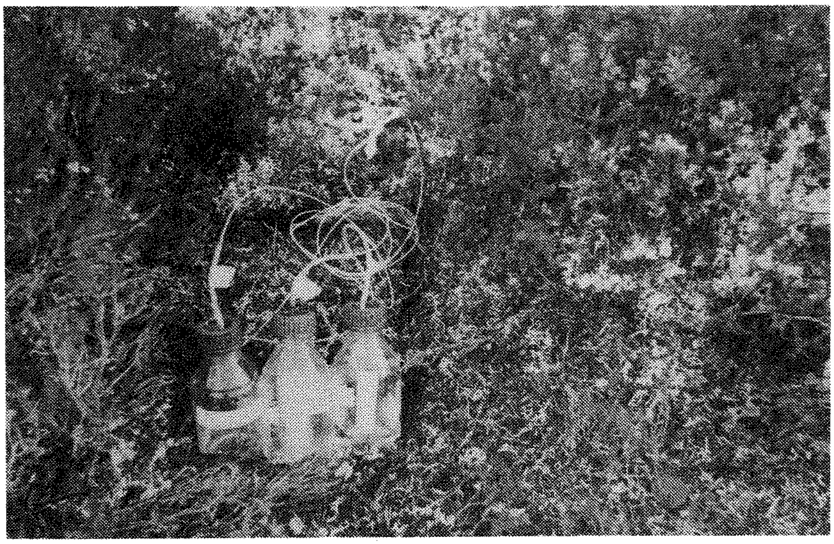


Fig. 16. Vacuumed glass bottles sucks up the soil water from different depths.

CLOSING REMARKS

It is now generally realised and accepted that HS play a major role for the chemical and biological response pollutants in water. The interest that scientists from both Europe and North America have showed the HUMEX project clearly indicate that HS is "discovered" as an element of environmental importance. We strongly believe that there is a demand for more knowledge about HS in general and that catchment manipulation of the kind that is used in the HUMEX project is good approach. We hope therefore that a similar project could be established elsewhere ,for instance in North America.; this will increase the communication between scientists, but first of all it will give us an idea of to which extent one should expect regional differences in the response of acid rain to surface water containing HS.

APPENDIX

A

Appendix Table 1. Chemical composition of water from Skjervatjern's basin A during 1988 and 1989. UNITS: Temp: centigrades, Depth: cm. Cond. mS/m. SO_4, Cl, Ca, Mg, Na, K, TOC: **mg/l**. NO_3-N, NH_4-N, TOT-N, RAL ("Reactive" Al), ILAL ("Non labile" Al):. **ug/l**. UV: absorption at 254 nm with 10 mm light path. Colour: mg Pt/l.

AR	DATO	DYP	TEMP	OKS mg O2/l	PH	K25	SULF	CL	NO3N	CA	MG	NA	K	TOC	RAL	ILAL	NH4N	TOTN	FARG mg PL/1	UV
1988	1017				4.61	2.10	.9	2.1	7	.19	.22	1.52	.1	10.06	127	79	12	231		
1988	1030				4.61	2.36	1.1	2.1	7	.18	.22	1.51	.08	10.28	101	68	14	249		
1988	1114				4.62	2.17	1	2	8	.18	.21	1.26	.06	9.36	86	66	11	260		
1988	1125				4.63	2.11	1.1	2.1	14	.18	.21	1.43	.07	9.36	84	68	23	266		
1988	1207				4.47	2.91	1.3	2.7	20	.21	.26	1.95	.14	11.98	111	85	24	288		
1989	0102				4.38	4.44	1.7	8.5	21	0.33	0.63	3.89	0.16	4.33	104	43	25	180		
1989	0115				4.42	4.66	1.5	8.7	19	0.23	0.57	4.02	0.14	2.16	34	26	10	102		
1989	0130				4.51	3.36	1.4	5.7	16	0.26	0.43	2.81	0.14	4.61	72	44	11	183		
1989	0206				4.48	4.09	1.4	6.3	12	0.23	0.44	3.48	0.17	4.15	54	25	9	174		
1989	0312				4.50	3.52	1.4	6.0	13	0.24	0.38	2.93	0.15	4.22	61	26	12	210		
1989	0328				4.45	3.56	1.4	5.6	17	0.24	0.35	2.72	0.15	4.87	70	36	12	179		
1989	0409				4.74	3.25	1.3	5.7	4	0.23	0.34	2.66	0.14	3.60	68	28	10	144		
1989	0501				4.62	3.19	1.4	5.4	1	0.24	0.35	2.54	0.15	4.31	61	30	16	177		
1989	0521				4.64	2.92	1.1	4.8	1	0.21	0.31	2.32	0.13	5.96	69	33	29	210		
1989	0604				4.61	2.48	1.3	4.7	M 1	0.21	0.30	2.25	0.12	4.98	56	30	17	171	45.0	0.143
1989	0618	100	19.6	8.5	4.73	2.78	1.2	4.9	M 1	0.20	0.30	2.39	0.10	5.10	69	25	14	206	40.0	0.182
1989	0618	200	14.4	9.4	4.65	2.94	1.3	4.8	M 1	0.20	0.30	2.39	0.11	4.77	64	25	12	158	44.0	0.201
1989	0618	300	11.1	8.3	4.61	3.21	1.3	4.9	M 1	0.20	0.32	2.51	0.14	5.16	74	36	10	137	52.0	0.249
1989	0618	400	8.8	7.1	4.57	3.35	1.4	5.0	7	0.21	0.32	2.58	0.16	5.03	71	33	12	144	51.0	0.239
1989	0619				4.73	2.82	1.3	4.7	M 1	0.21	0.29	2.39	0.19	4.87	65	27	67	363		
1989	0625				4.61	2.97	1.3	4.6	1	0.20	0.28	2.36	0.10	5.32	65	27	22	288		
1989	0703				4.60	2.75	1.2	4.1	1	0.17	0.28	2.22	0.09	5.74	63	36	15	239	54.0	0.239
1989	0713	100	17.3	9.2	4.57	2.76	1.1	4.3	1	0.19	0.25	2.25	0.06	5.33	81	35	7	221	46.0	0.230
1989	0713	200	15.8	9.2	4.61	2.84	1.1	4.3	M 1	0.22	0.26	2.25	0.08	5.66	87	42	7	236	51.0	0.250
1989	0713	300	11.2	7.8	4.50	3.06	1.3	5.1	M 1	0.22	0.30	2.54	0.14	5.60	90	50	7	194	59.3	0.282
1989	0713	400	9.7	6.4	4.49	3.47	5.1	1.3	9	0.25	0.31	2.64	0.17	4.99	79	45	11	207	55.0	0.256
1989	0716				4.77	2.70	1.2	4.2	M 1	0.17	0.25	2.42	0.08	5.57	65	33	9	236	46.0	0.214
1989	0726				4.66	2.79	1.2	4.4	2	0.20	0.25	2.45	0.13	5.46	62	29	13	258	38.0	
1989	0802				4.60	2.65	1.1	4.2	M 1	0.18	0.25	2.33	0.07	6.25	58	37	11	177	47.0	0.217
1989	0809				4.65	2.40	1.1	4.1	4	0.18	0.24	2.34	0.11	6.31	64	40	26	260	51.0	0.235
1989	0815				4.64	2.57	1.0	3.7	1	0.18	0.26	2.08	.09	5.78	64	36	24	305	54.0	0.246
1989	0824				4.60	2.65	0.9	3.3	2	0.16	0.24	2.08	0.09	9.71	70	51	13	263	76.0	0.272
1989	0904				4.66	2.59	1.1	3.6	2	0.16	0.26	2.20	0.20	7.83	72	52	16	324	76.0	0.267
1989	0918				4.64	2.60	1.1	3.9	1	0.23	0.28	2.35	0.18	7.88	68	45	15	339	83.0	0.283
1989	0927				4.57	2.67	1.3	3.6	3	0.17	0.27	2.22	0.11	7.47	81	52	23	228	77.0	0.341
1989	1004				4.56	2.91	1.1	3.8	3	0.21	0.31	2.35	0.15	7.88	83	52	18	279	81.0	0.303
1989	1011				4.63	2.89	1.1	3.8	2	0.21	0.30	2.23	0.13	7.53	91	57	20	230	82.0	0.317
1989	1019				4.55	2.95	1.2	3.8	3	0.22	0.30	2.21	0.10	7.73	72	50	12	239	75.0	0.324
1989	1113				4.57	2.85	1.2	3.9	7	0.18	0.27	2.19	0.11	7.07	75	45	12	204		
1989	1207				4.53	3.01	1.4	4.0	18	0.19	0.29	2.30	0.11	6.65	67	48	10	228	77.0	0.360
1989	1217				4.48	3.40	1.4	4.2	29	0.19	0.29	2.47	0.11	6.47	73	45	20	335	81.0	0.360
1989	1227				4.62	2.79	1.1	3.7	38	0.14	0.25	2.08	0.12	3.49	36	21	20	186	49.0	0.190

Appendix Table 2. Chemical composition of water from Skjervatjern's basin A during 1990. UNITS: Temp: centigrades, Depth: cm. Cond. mS/m. SO_4, Cl, Ca, Mg, Na, K, TOC: **mg/l**. NO_3-N, NH_4-N, TOT-N, RAL ("Reactive" Al), ILAL ("Non labile" Al):. **ug/l**. UV: absorption at 254 nm with 10 mm light path. Colour: mg Pt/l.

A

AR	DATO	DYP	TEMP	OKS mg O2/1	PH	K25	SULF	CL	NO3N	CA	MG	NA	K	TOC	RAL	ILAL	NH4N	TOTN	FARG mg PL/1	UV
1990	0107				4.51	2.80	1.3	3.5	63	0.13	0.22	1.91	0.12	5.14	67	35	26	258	60.5	0.280
1990	0114				4.59	4.23	1.4	7.5	28	0.18	0.47	3.88	0.13	1.33	10	M 10	24	102	14.0	0.078
1990	0121				4.49	4.54	1.6	8.6	7	0.22	0.47	4.11	0.14	2.15	15	11	11	102	22.5	0.082
1990	0204				4.53	3.13	1.2	4.3	12	0.17	0.26	2.32	0.14	5.22	66	35	12	186	65.5	0.288
1990	0211				4.57	2.76	1.3	4.0	17	0.19	0.25	2.24	0.14	5.28	69	39	10	176	61.0	0.258
1990	0218				4.57	2.66	1.1	4.1	17	0.22	0.25	2.36	0.11	5.05	75	43	8	164	60.0	0.270
1990	0220				4.52	3.23	1.4	4.9	16	0.18	0.28	2.73	0.11	4.23	56	31	8	158	65.0	0.300
1990	0305	100	2.0	10.8	4.63	3.13	1.4	5.1	12	0.18	0.26		0.16	4.61	52	31	6	222	49.0	0.235
1990	0305	200	1.7	11.1	4.56	3.21	1.4	5.0	13	0.20	0.27		0.15	4.62	55	31	6	188	51.0	0.248
1990	0305	300	1.7	11.3	4.51	3.30	1.3	5.0	15	0.20	0.27		0.13	6.56	67	39	6	264	57.5	0.283
1990	0305	400	1.8	10.2	4.56	3.22	1.3	5.1	14	0.18	0.27		0.17	5.09	61	34	8	222	54.5	0.266
1990	0306				4.65	2.57	0.9	4.0	5	0.10	0.16	2.12	0.10	2.57	16	11	11	87	30.0	0.051
1990	0325				4.53	3.91	1.6	7.1	16	0.19	0.36	3.40	0.16	3.39	40	21	9	161	38.0	0.179
1990	0408				4.51	3.92	1.5	6.6	10	0.21	0.34	3.08	0.16	2.83	47	17	9	116	31.8	0.149
1990	0416				4.54	3.70	1.3	5.9	2	0.19	0.32	2.88	0.13	2.81	50	20	7	113	34.7	0.159
1990	0422				4.69	3.69	1.2	5.9	2	0.19	0.32	2.86	0.12	3.44	52	24	7	126	32.6	0.153
1990	0501				4.58	3.38	1.7	5.6	9	0.18	0.29	2.68	0.18	3.60	44	22	12	173	36.0	0.163
1990	0506	10			4.57	3.42	1.5	5.7	9	0.17	0.29	2.72	0.13	3.26	48	20	10	150	34.5	0.164
1990	0506	100	15.0	8.0	4.65	3.21	1.5	5.7	8	0.18	0.29	2.74	0.12	3.48	48	20	14	150	35.5	0.166
1990	0506	200	11.2	9.9	4.59	3.42	1.8	5.8	8	0.18	0.29	2.81	0.13	3.71	50	24	16	150	40.0	0.213
1990	0506	300	9.7	9.9	4.56	3.39	1.5	5.8	8	0.18	0.29	2.82	0.13	3.70	55	28	14	150	46.0	0.207
1990	0513				4.60	3.39	1.4	5.9	2	0.19	0.30	2.78	0.15	3.45	55	17	8	189	32.5	0.161
1990	0520				4.57	3.56	1.3	5.9	2	0.21	0.30	2.74	0.11	4.00	57	22	11	161	30.0	0.153
1990	0604				4.59	3.41	1.5	5.9	M 1	0.22	0.33	2.82	0.14	3.65	50	18	15	185	25.7	0.107
1990	0612	10			4.71	3.42	1.4	6.0	M 1	0.23	0.31	2.84	0.15	4.04	52	18	19	267	25.0	0.145
1990	0612	100	20.5	11.2	4.66	3.43	1.5	6.0	M 1	0.23	0.30	2.83	0.14	3.83	58	18	23	221	26.0	0.145
1990	0612	200	17.0	10.4	4.71	3.42	1.4	6.0	M 1	0.23	0.31	2.84	0.15	4.04	52	18	19	267	25.0	0.145
1990	0612	300	12.8	9.8	4.58	3.36	1.5	5.8	1	0.21	0.30	2.76	0.15	4.29	52	29	23	197	39.0	0.190
1990	0624				4.59	3.34	1.6	5.9	7	0.22	0.31	2.90	0.17	4.40	65	24	12	305	25.5	0.152
1990	0702				4.60	3.23	1.2	5.6	3	0.23	0.31	3.07	0.14	4.79	59	24	14	254	27.9	0.145
1990	0708	100	14.1	9.0	4.75	3.28	1.4	5.6	2	0.23	0.30	3.00	0.17	5.16	65	23	44	350	31.3	0.151
1990	0708	200	14.0	7.4	4.60	3.39	1.4	5.6	1	0.23	0.30	3.00	0.15	5.25	61	23	12	267	29.9	0.155
1990	0708	300	11.8	8.5	4.57	3.49	1.4	5.7	1	0.22	0.29	3.00	0.17	4.88	71	31	12	206	39.2	0.183
1990	0708	400	9.2	8.2	4.55	3.50	1.4	5.8	1	0.21	0.30	3.00	0.17	4.68	69	34	6	188	42.8	0.202
1990	0714				4.61	3.38	1.5	5.5	2	0.22	0.29	2.95	0.15	5.60	71	35	34	275	36.6	0.201
1990	0722				4.60	3.38	1.4	5.6	2	0.21	0.29	2.96	0.15	5.94	68	32	19	251	42.2	0.192
1990	0731				4.62	3.38	1.4	5.4	1	0.23	0.30	2.96	0.20	5.70	63	31	19	344	42.0	0.192
1990	0807				4.56	3.76	1.5	5.1	9	0.23	0.29	2.78	0.15	6.22	67	30	19	281	43.6	0.232
1990	0821	10			4.71	3.19	1.4	4.7	M 1	0.21	0.26	2.64	0.12	6.86	83	37	20	275	58.4	0.247
1990	0821	100	14.8	8.1	4.62	3.26	1.5	4.7	1	0.22	0.26	2.66	0.12	6.71	71	37	24	281	61.0	0.259
1990	0821	200	13.5	8.1	4.63	3.25	1.5	4.8	M 1	0.22	0.26	2.68	0.13	7.08	71	43	28	297	63.6	0.265
1990	0830				4.56	3.27	1.4	4.6	M 1	0.21	0.26	2.59	0.12	7.01	73	37	10	281	64.2	0.270
1990	0909				4.81	3.08	1.3	4.5	8	0.21	0.23	2.52	0.19	6.81	73	37	9	333	61.0	0.287
1990	0916				4.58	3.09	1.1	4.6	2	0.20	0.25	2.52	0.14	6.74	80	45	13	257	68.8	0.326
1990	0923				4.58	3.12	1.2	4.4	1	0.20	0.24	2.44	0.17	7.93	70	48	7	270	81.3	0.324
1990	0930	10			4.59	2.92	0.8	4.1	5	0.17	0.28	2.32	0.13	8.02	83	57	9	284	78.0	0.337
1990	0930	100	10.2	9.5	4.74	2.76	1.0	4.3	3	0.19	0.29	2.49	0.18	7.75	74	57	33	330	87.4	0.341
1990	0930	200	8.8	9.2	4.66	2.84	0.8	4.1	2	0.18	0.29	2.34	0.15	8.09	78	57	19	302	83.9	0.340
1990	0930	300	8.7	10.0	4.61	2.89	1.0	4.1	2	0.17	0.28	2.34	0.13	7.68	76	59	19	249	79.2	0.335

B

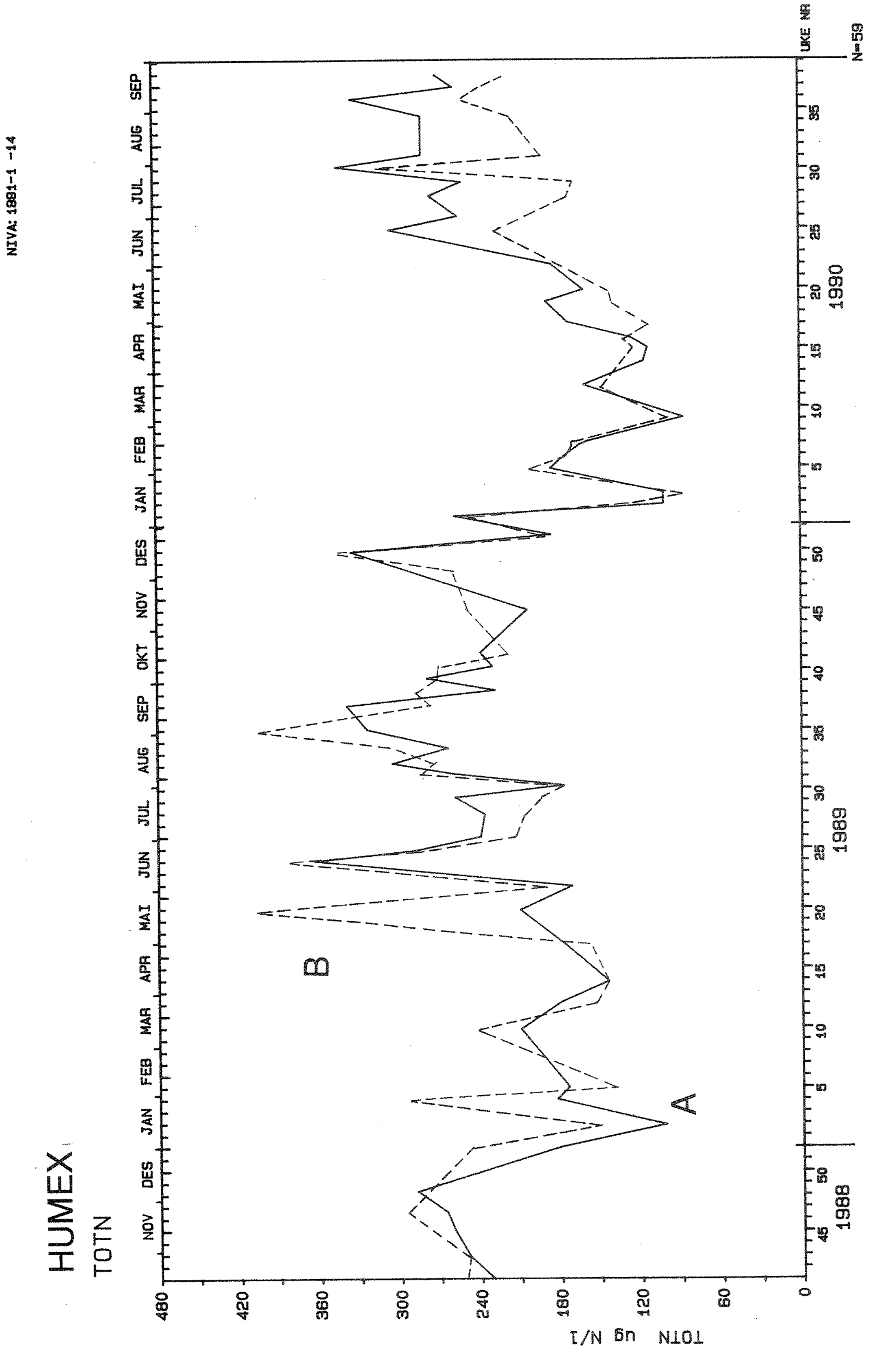
Appendix Table 3. Chemical composition of water from Skjervatjern's basin B during 1988 and 1989. UNITS: Temp: centigrades, Depth: cm. Cond. mS/m. SO_4, Cl, Ca, Mg, Na, K, TOC: **mg/l**. NO_3-N, NH_4-N, TOT-N, RAL ("Reactive" Al), ILAL ("Non labile" Al):. **ug/l**. UV: absorption at 254 nm with 10 mm light path. Colour: mg Pt/l.

AR	DATO	DYP	TEMP	OKS mg O2/1	PH	K25	SULF	CL	NO3N	CA	MG	NA	K	TOC	RAL	ILAL	NH4N	TOTN	FARG mg PL/1	UV
1988	1017				4.6	2.15	1	2.2	8	.19	.22	1.58	.13	10.56	118	77	12	251		
1988	1030				4.63	2.31	1.1	2.3	13	.19	.22	1.54	.1	9.49	120	77	22	249		
1988	1114				4.66	2.22	1	2.2	11	.19	.22	1.31	.08	9.19	97	73	17	278		
1988	1125				4.63	2.15	1.2	2.2	54	.19	.22	1.57	.15	9.74	99	75	32	296		
1988	1207				4.51	2.85	1.4	2.7	18	.22	.26	1.94	.16	13.09	118	84	20	282		
1989	0102				4.57	3.81	1.5	8.2	34	0.29	0.54	4.13	0.23	3.30	71	23	36	246		
1989	0115				4.34	4.44	1.6	7.4	12	0.25	0.50	3.39	0.17	3.99	69	40	12	150		
1989	0130				4.52	3.31	1.3	5.1	17	0.33	0.41	2.54	0.22	6.70	85	57	30	293		
1989	0206				4.39	4.10	1.8	6.0	15	0.23	0.40	3.25	0.15	5.27	72	35	9	137		
1989	0312				4.46	3.64	1.4	5.8	22	0.25	0.37	2.81	0.22	5.76	76	39	12	242		
1989	0328				4.50	3.46	1.4	5.7	3	0.21	0.35	2.79	0.13	3.94	53	26	12	153		
1989	0409				4.52	3.43	1.4	5.7	4	0.22	0.35	2.66	0.15	4.71	77	41	6	144		
1989	0501				4.59	3.10	1.5	5.4	2	0.24	0.36	2.53	0.17	4.78	73	35	14	158		
1989	0521				4.65	3.18	1.3	5.2	M 1	0.27	0.33	2.51	0.48	7.06	75	38	29	407		
1989	0604				4.58	2.97	1.3	4.9	M 1	0.21	0.31	2.40	0.15	5.76	75	39	19	189	50.0	0.177
1989	0618	100	20.1	8.3	4.60	3.21	1.3	4.9	M 1	0.20	0.29	2.49	0.11	5.61	78	30	12	158	47.0	0.239
1989	0618	200	15.8	9.1	4.58	3.28	1.2	4.8	M 1	0.19	0.30	2.45	0.12	5.70	76	36	10	137	53.0	0.258
1989	0618	300	10.7	8.6	4.55	3.31	1.2	4.4	M 1	0.18	0.28	2.43	0.12	7.54	82	52	14	198	78.5	0.364
1989	0618	400	10.1	8.8	4.55	3.49	1.2	5.0	M 1	0.20	0.31	2.55	0.13	5.66	71	36	10	135	57.0	0.271
1989	0618	600	6.2	8.7	4.55	3.50	1.3	5.3	7	0.23	0.35	2.62	0.14	4.27	69	30	14	149	47.5	0.226
1989	0618	800	5.1	7.5	4.60	3.57	1.5	5.4	24	0.27	0.36	2.64	0.18	4.36	80	36	37	236	51.5	0.235
1989	0619				4.66	2.92	1.3	4.8	M 1	0.20	0.30	2.44	0.13	5.07	79	32	37	383		
1989	0625				4.62	3.10	1.3	4.7	1	0.22	0.28	2.45	0.15	5.66	81	32	34	282		
1989	0703				4.56	3.02	1.2	4.4	M 1	0.18	0.30	2.37	0.11	6.52	81	46	13	213	58.5	0.300
1989	0713	100	17.1	9.1	4.60	2.82	4.4	1.3	M 1	0.23	0.26	2.43	0.10	6.60	138	53	7	276	56.2	0.286
1989	0713	200	13.7	8.2	4.50	2.86	4.3	1.2	3	0.20	0.26	2.40	0.10	7.09	90	53	7	249	66.5	0.331
1989	0713	300	11.0	8.6	4.49	3.21	4.3	1.3	1	0.19	0.26	2.41	0.10	7.19	87	55	7	194	69.2	0.337
1989	0713	400	9.1	8.5	4.45	3.62	5.2	1.4	4	0.23	0.32	2.66	0.14	5.57	75	42	17	161	58.1	0.277
1989	0713	600	6.1	8.5	4.50	3.43	5.5	1.5	15	0.28	0.34	2.72	0.15	5.00	83	40	11	207	50.3	0.245
1989	0713	800	5.5	6.9	4.49	3.81	5.6	1.6	23	0.30	0.35	2.76	0.16	4.58	77	40	22	215	50.3	0.240
1989	0716				4.61	2.85	1.2	4.4	M 1	0.18	0.27	2.60	0.12	6.17	87	45	15	207	30.0	0.275
1989	0726				4.60	2.91	1.2	4.5	1	0.21	0.27	2.60	0.11	6.25	82	43	9	195	53.0	
1989	0802				4.60	2.84	1.2	4.4	M 1	0.20	0.26	2.55	0.13	7.07	84	52	13	177	61.0	0.272
1989	0809				4.62	2.70	1.2	4.3	5	0.20	0.26	2.56	0.18	7.08	85	51	18	285	60.0	0.280
1989	0815				4.62	2.83	1.2	4.1	1	0.21	0.27	2.45	0.16	6.99	91	54	33	273	65.5	0.310
1989	0824				4.59	2.79	1.0	3.6	M 1	0.19	0.26	2.38	0.15	9.41	103	76	15	302	92.5	0.361
1989	0904				4.64	2.68	1.1	3.6	1	0.20	0.27	2.35	0.19	10.21	101	75	31	405	100.0	0.384
1989	0918				4.53	2.76	1.1	3.6	1	0.21	0.27	2.39	0.10	10.70	101	73	13	276	111.5	0.423
1989	0927				4.53	2.85	1.1	3.5	4	0.18	0.27	2.37	0.18	9.77	105	70	27	288	94.5	0.429
1989	1004				4.53	3.05	1.1	3.8	4	0.21	0.29	2.43	0.12	9.79	107	75	12	272	103.1	0.405
1989	1011				4.53	3.16	1.1	3.9	5	0.21	0.31	2.37	0.15	9.53	109	70	27	270	100.0	0.401
1989	1019				4.52	3.16	1.4	4.1	11	0.24	0.31	2.43	0.11	8.75	94	62	14	218	85.0	0.376
1989	1113				4.52	3.19	1.2	4.4	14	0.22	0.29	2.42	0.14	7.92	89	55	12	248		
1989	1207				4.49	3.41	1.5	4.8	42	0.21	0.34	2.66	0.15	6.34	73	51	18	260	72.5	0.352
1989	1217				4.46	3.77	2.1	4.8	34	0.29	0.33	2.77	0.14	6.97	86	55	12	347	82.0	0.390
1989	1227				4.59	3.06	1.1	4.1	43	0.17	0.28	2.31	0.10	4.57	50	32	20	192	55.0	0.220

Appendix Table 4. Chemical composition of water from Skjervatjern's basin B during 1990. UNITS: Temp: centigrades, Depth: cm. Cond. mS/m. SO_4, Cl, Ca, Mg, Na, K, TOC: **mg/l**. NO_3-N, NH_4-N, TOT-N, RAL ("Reactive" Al), ILAL ("Non labile" Al):. **ug/l**. UV: absorption at 254 nm with 10 mm light path.

B

AR	DATO	DYP	TEMP	OKS mg O2/l	PH	K25	SULF	CL	NO3N	CA	MG	NA	K	TOC	RAL	ILAL	NH4N	TOTN	FARG mg PL/l	UV
1990	0107				4.41	3.04	1.3	3.6	89	0.14	0.23	1.95	0.11	5.60	69	40	17	251	63.5	0.300
1990	0114				4.57	4.22	1.5	7.5	35	0.17	0.46	3.92	0.15	3.07	27	19	17	131	31.0	0.148
1990	0121				4.73	3.83	1.5	7.9	27	0.18	0.47	3.95	0.16	0.92	12	M 10	17	90	19.5	0.037
1990	0204				4.44	3.82	1.4	6.2	14	0.17	0.31	2.81	0.13	3.56	44	20	14	203	41.0	0.187
1990	0211				4.54	3.01	1.8	4.4	18	0.22	0.27	2.43	0.14	5.92	90	54	14	176	71.0	0.303
1990	0218				4.56	2.85	1.7	4.2	32	0.21	0.26	2.45	0.10	5.20	80	43	12	170	60.5	0.260
1990	0220				4.48	3.29	1.3	4.9	19	0.21	0.28	2.78	0.11	5.65	75	47	10	170	51.5	0.240
1990	0305	100	2.0	10.4	4.48	3.36	1.3	5.0	15	0.18	0.27		0.14	5.65	73	44	10	194	62.5	0.306
1990	0305	200	1.6	10.2	4.49	3.35	1.3	5.0	18	0.20	0.27		0.14	6.03	71	44	8	194	63.0	0.307
1990	0305	300	1.8	10.5	4.49	3.36	1.3	5.0	18	0.19	0.27		0.13	5.92	73	44	10	188	63.0	0.310
1990	0305	400	1.8	10.3	4.48	3.33	1.4	5.0	19	0.20	0.27		0.14	5.82	73	42	8	176	64.0	0.307
1990	0305	600	1.8	10.1	4.46	3.39	1.3	5.0	18	0.20	0.27		0.13	5.96	73	42	8	182	63.5	0.308
1990	0305	800	1.9	10.1	4.47	3.38	1.4	5.0	18	0.22	0.27		0.13	5.94	71	42	8	182	63.5	0.309
1990	0306				4.68	2.79	0.8	4.6	9	0.11	0.20	2.37	0.14	2.66	19	11	11	99	26.0	0.039
1990	0325				4.52	3.94	1.6	6.5	21	0.18	0.32	3.10	0.14	4.46	59	31	9	149	49.0	0.225
1990	0408				4.48	3.92	1.3	6.3	10	0.22	0.32	2.98	0.15	3.63	71	28	22	132	43.4	0.200
1990	0416				4.53	3.73	1.2	5.9	3	0.21	0.31	2.88	0.16	3.65	67	27	9	123	46.7	0.207
1990	0422				4.52	3.79	1.2	5.8	M 1	0.20	0.31	2.85	0.15	4.23	61	30	5	132	42.0	0.197
1990	0501				4.53	3.54	1.6	5.7	6	0.18	0.29	2.74	0.13	3.47	58	24	14	114	39.5	0.182
1990	0506	10			4.54	3.33	1.6	5.8	6	0.18	0.29	2.82	0.14	3.55	62	22	12	156	41.0	0.192
1990	0506	100	14.7	9.5	4.59	2.96	1.7	5.8	5	0.19	0.29	2.81	0.14	3.79	55	22	12	150	40.5	0.239
1990	0506	200	12.0	9.9	4.58	3.33	1.6	5.7	5	0.18	0.29	2.78	0.14	3.68	56	30	18	168	47.5	0.221
1990	0506	300	10.8	10.4	4.57	3.25	1.7	5.5	3	0.17	0.28	2.75	0.16	4.43	58	35	14	174	55.5	0.251
1990	0506	400	12.8	10.3	4.58	3.44	1.6	6.0	3	0.19	0.30	2.93	0.15	4.27	60	32	14	168	47.5	0.233
1990	0506	600	12.6	10.0	4.57	3.22	1.5	6.2	4	0.19	0.31	2.97	0.16	3.90	53	28	10	150	44.0	0.220
1990	0506	800	14.0	9.5	4.57	3.57	1.5	6.3	14	0.20	0.32	3.00	0.16	3.81	64	30	10	144	45.5	0.205
1990	0513				4.56	3.49	1.5	6.0	2	0.19	0.29	2.80	0.12	3.76	66	24	12	140	37.0	0.183
1990	0520				4.55	3.57	1.2	5.9	2	0.21	0.30	2.71	0.13	4.17	67	28	13	143	36.6	0.181
1990	0604				4.57	3.39	1.6	5.9	2	0.21	0.31	2.84	0.15	3.92	67	26	15	179	34.5	0.161
1990	0612	10			4.57	3.59	1.4	6.0	M 1	0.22	0.31	2.86	0.16	4.46	65	23	15	173	32.0	0.172
1990	0612	100	20.3	11.4	4.72	3.40	1.6	6.0	1	0.21	0.31	2.82	0.18	3.98	63	21	21	203	33.0	0.156
1990	0612	200	17.0	9.2	4.69	3.48	1.5	5.9	M 1	0.22	0.30	2.84	0.23	4.38	54	29	17	291	39.0	0.196
1990	0612	300	12.5	11.9	4.57	3.44	1.4	5.5	M 1	0.20	0.28	2.71	0.15	4.64	59	39	15	173	55.0	0.252
1990	0612	400	10.0	12.6	4.60	3.52	1.2	5.9	1	0.19	0.31	2.80	0.15	3.84	54	32	42	197	46.0	0.206
1990	0612	600	7.0	13.6	4.56	3.54	1.3	6.1	M 1	0.22	0.30	2.89	0.15	3.93	63	31	15	185	43.0	0.208
1990	0612	800	5.6	14.0	4.57	3.63	1.5	6.1	11	0.25	0.32	2.86	0.18	3.80	77	39	19	185	47.0	0.217
1990	0624				4.54	3.41	1.5	5.8	8	0.20	0.31	2.90	0.16	3.97	65	24	19	228	29.0	0.174
1990	0702	800			4.58	3.27	1.3	5.6	2	0.21	0.30	3.08	0.17	4.91	67	30	12	224	32.3	0.167
1990	0708	100	14.1	9.2	4.56	3.45	1.5	5.6	1	0.20	0.29	3.10	0.15	5.21	71	29	12	194	32.1	0.181
1990	0708	200	14.0	8.9	4.55	3.51	1.5	5.6	1	0.21	0.30	3.10	0.15	5.31	75	31	8	176	35.0	0.189
1990	0708	300	10.8	9.5	4.53	3.37	1.4	5.6	1	0.20	0.28	3.10	0.15	4.73	69	40	14	158	48.9	0.239
1990	0708	400	6.0	9.5	4.51	3.80	1.3	6.4	1	0.21	0.32	3.10	0.15	4.11	63	31	6	126	41.4	0.204
1990	0708	600	4.9	8.8	4.51	3.83	1.5	6.5	6	0.23	0.33	3.10	0.16	3.91	61	31	6	120	39.8	0.201
1990	0708	800	4.1	7.0	4.55	3.65	1.4	6.2	15	0.26	0.32	3.10	0.18	3.88	69	34	14	188	42.4	0.212
1990	0714				4.56	3.50	1.6	5.6	3	0.20	0.29	3.06	0.14	5.45	73	40	19	173	37.8	0.228
1990	0722				4.59	3.50	1.7	5.7	2	0.20	0.29	3.07	0.14	5.46	73	36	12	168	40.2	0.188
1990	0731				4.61	3.33	1.6	5.4	M 1	0.20	0.29	3.06	0.15	5.02	70	33	14	315	38.0	0.197
1990	0807				4.54	3.26	1.6	5.2	5	0.21	0.29	2.87	0.14	5.87	79	35	14	192	49.1	0.217
1990	0821	10			4.54	3.55	1.6	4.9	1	0.20	0.26	2.87	0.12	7.67	101	53	12	203	62.0	0.289
1990	0821	100	17.0	8.3	4.76	3.50	1.6	5.0	10	0.25	0.27	2.92	0.20	7.94	87	53	26	309	67.0	0.307
1990	0821	200	15.6	8.1	4.63	3.37	1.6	4.9	M 1	0.22	0.26	2.90	0.17	8.04	85	53	36	269	65.0	0.301
1990	0821	300	14.0	7.2	4.52	3.68	1.6	5.0	M 1	0.22	0.27	2.98	0.15	9.45	97	69	26	263	98.0	0.415
1990	0821	400	12.0	7.5	4.54	3.72	1.5	5.9	M 1	0.22	0.28	3.04	0.16	4.36	59	30	14	144	47.0	0.210
1990	0821	600	7.5	7.9	4.54	3.82	1.5	6.0	6	0.24	0.29	3.10	0.17	3.98	61	33	16	144	45.0	0.208
1990	0821	800	6.5	5.1	4.59	3.69	1.6	6.0	14	0.28	0.30	3.13	0.21	3.79	63	33	36	209	47.0	0.209
1990	0830				4.54	3.43	1.5	4.8	M 1	0.20	0.26	2.63	0.12	7.88	95	51	8	215	64.4	0.306
1990	0909				4.57	3.36	1.3	4.6	19	0.20	0.23	2.71	0.12	8.31	99	55	9	251	76.6	0.362
1990	0916				4.52	3.39	1.3	4.6	2	0.21	0.26	2.75	0.14	8.70	105	66	17	239	85.8	0.404
1990	0923				4.50	3.42	1.3	4.6	1	0.22	0.26	2.67	0.14	8.97	98	62	9	222	85.4	0.389
1990	0930	100	9.9	8.6	4.62	3.17	1.2	4.6	3	0.19	0.31	2.70	0.21	9.25	95	67	31	354	88.5	0.389
1990	0930	200	9.9	8.8	4.57	3.22	1.2	4.5	2	0.19	0.30	2.59	0.15	9.19	95	67	19	284	85.8	0.392
1990	0930	300	8.9	9.4	4.56	3.20	1.1	4.5	2	0.18	0.30	2.58	0.14	9.16	97	69	11	237	87.8	0.393
1990	0930	400	8.3	8.3	4.56	3.25	1.2	4.5	2	0.18	0.30	2.59	0.13	9.52	95	75	11	225	89.7	0.397
1990	0930	600	7.2	7.0	4.54	3.66	1.3	5.8	9	0.21	0.34	2.87	0.17	4.65	61	40	19	150	98.3	0.210
1990	0930	800	6.0	3.9	4.60	3.52	1.4	5.9	15	0.25	0.35	2.89	0.21	4.37	66	44	33	206	104.0	0.202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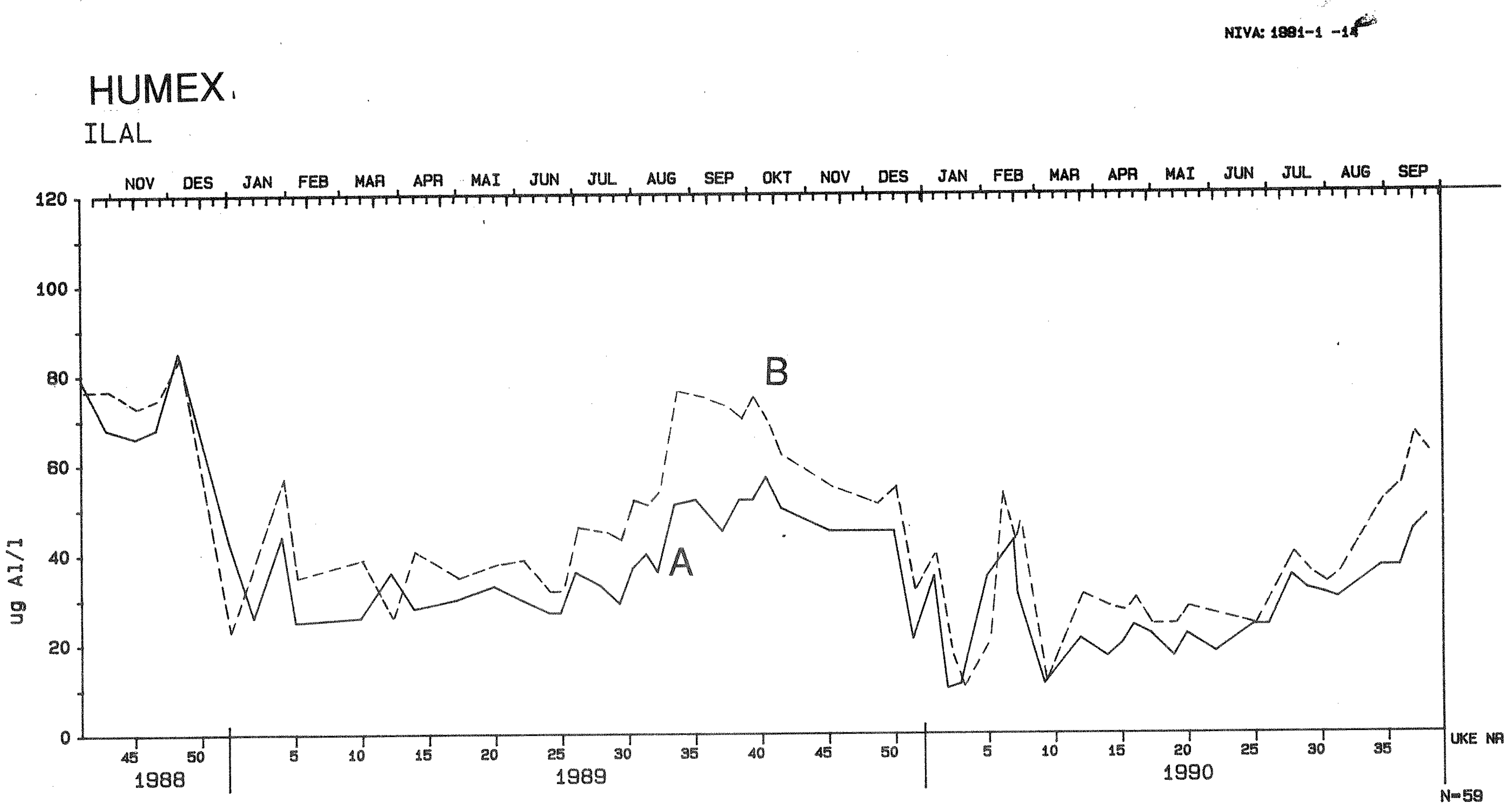
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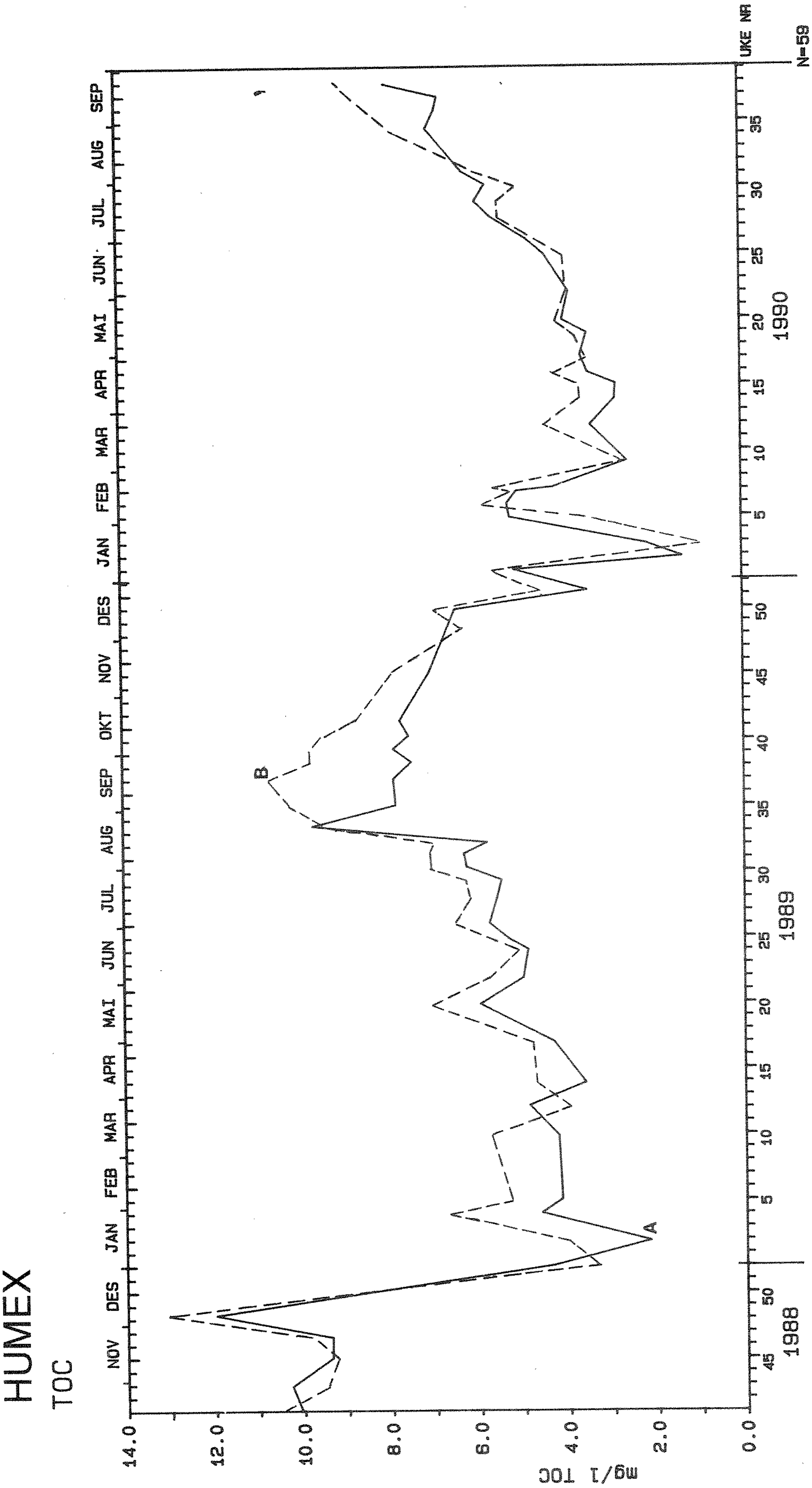
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HUMEX

Humic lake acidification experiment

Sponsors

- Norwegian Ministry of Environment, Oslo.
- Norwegian Institute for Water Research, Oslo.

Background and goal

Research on the acidification of lakes and rivers has focused mainly on clearwater systems. Acid deposition also affects colored waters with high concentrations of dissolved organic matter. Here the biological and chemical effects may be substantially influenced by the presence of high levels of humic matter. Humic acids comprise a significant natural buffer system in softwaters, and by complexing aluminium the dissolved organic carbon renders acidified waters less toxic to fish and other aquatic organisms.

Colored waters comprise an important fraction of the surface waters in regions of Europe and north America currently receiving high levels of acid deposition. International negotiations aimed at reducing the emissions of acidifying compounds to the atmosphere are in part based on the premise that such reductions will restore acidified aquatic ecosystems. The interaction of acidic deposition with natural organic acids must be understood before predictions of future acidification of colored lakes can be made. The HUMEX project addresses this question directly by providing experimental information at the ecosystem level.

The Site

Skjervatjern is a small (2.4 ha), pristine, naturally acidic humic lake located near Førde, western Norway. The lake has a pH value of 4.6 with concentrations of total organic carbon (TOC) of about 7 mg C/l, nonmarine base cations of about 30 µeq/l, and monomeric labile aluminium of less than 50 µg Al/l. The lake supports brown trout when stocked, but no recruitment occurs due to the lack of spawning streams.

The terrestrial catchment to Skjervatjern (13.4 ha) is on granitic bedrock covered with thin organic-rich soils. Vegetation is a sparse forest of pine and birch interspersed with patches of *Sphagnum* moss.

Skjervatjern should thus be extremely sensitive to inputs of acid deposition.

The Lake

In October 1988 Skjervatjern was divided in two halves by means of a 105-m long and 5-m deep plastic curtain.

The outlet is also split into two halves and drainage from each is gauged.

Project plan

On one half (A) artificial acid precipitation will be applied to the lake and entire terrestrial catchment. The second half will serve as untreated reference. Acid application will be means of a permanent sprinkling system. Water from a nearby lake (cond. 1.4 m S/cm, pH 6, TOC: 1.5 mg/l), acidified to pH 3 by a mixture of sulfuric acid and ammonium nitrate will be sprayed during and immediately following natural rain events. The volume of water added will be equivalent to about 5 % of the natural precipitation. Loadings of pollutant ions H^+, SO_4^{2-}, NO_3^- and NH_4^+ will be similar to those received in the highly impacted areas of southernmost Norway. The experimental design is similar to that used in the large-scale acidification experiments of the RAIN project.

Participants (in addition to the HUMOR participants)

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Finland: National Board of Water and Environment, Helsinki: Pirrko Kortelainen, Irma Mäkinen.

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United States: The State University of New Jersey, Rutgers, Dept. of Biology: Camden. Mark D. Morgan. U.S. Geological Survey, Denver Colorado: Ronald Malcolm.

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