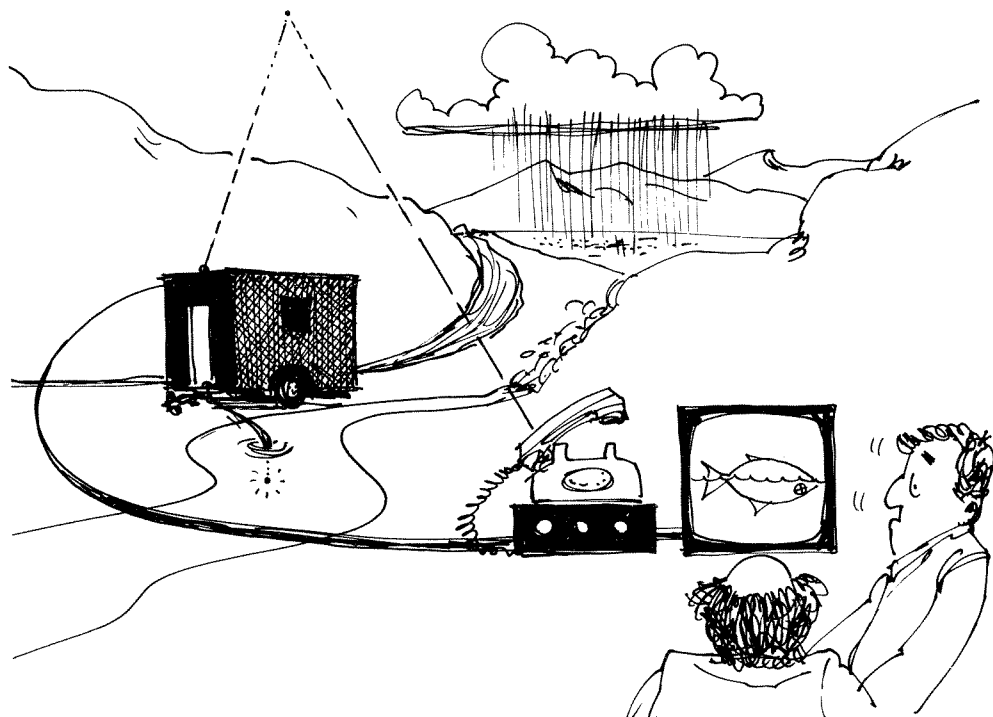


Acid 19/8 Rain Research

REPORT 11/1986

MOBILLAB-NIVA, a complete station
for monitoring water quality



NIVA - REPORT

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Abstract:	<p>MOBILLAB-NIVA is a complete mobile station for monitoring water quality with tele-metric transmission of recorded data to a central receiving station. It is intended for use in studies of rapid changes in water quality and its effects on aquatic life and short term studies to decide on water quality monitoring strategy.</p> <p>The present version of MOBILLAB-NIVA is specially designed to study effects of acid inputs on water chemistry, fish and invertebrates. The station is equipped with physical and chemical sensors for continuous measurement of these parameters: pH, conductivity, water temperature, uv-absorbtion, turbidity, reactive aluminium, non-labile aluminium and labile aluminium.</p> <p>MOBILLAB-NIVA is equipped with experimental and reference tanks for fish and invertebrates. Shell sand filters are used to obtain the reference water quality.</p>
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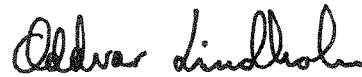
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Project leader



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For the Administration



Oddvar Lindholm

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MOBILLAB-NIVA - a complete station for
monitoring water quality

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SUMMARY

MOBILLAB-NIVA is a complete mobile station for monitoring water quality with telemetric transmission of recorded data to a central receiving station. It is intended for use in studies of rapid changes in water quality and its effects on aquatic life and short term studies to decide on water quality monitoring strategy.

The present version of MOBILLAB-NIVA is specially designed to study effects of acid inputs on water chemistry, fish and invertebrates. The station is equipped with physical and chemical sensors for continuous measurement of these parameters:

Sensor	Measurement
pH electrode	Acidity
Conductivity cell	Ionic content
Thermistor	Water temperature
UV-absorbtion	Colour (humic substances)
Turbidity	Particles and colloids
Reactive aluminium (1)	"Total" aluminium
Non-labile aluminium (2)	"Organic" aluminium
Labile aluminium (1-2)	"Toxic" aluminium

MOBILLAB-NIVA is equipped with experimental and reference tanks for fish and invertebrates. Shell sand filters are used to obtain good reference water quality for fish.

1. BACKGROUND

Today it is generally agreed that acidification of freshwaters reduces the hatching of fish and the continuance of fish populations. Previous work in North America and Scandinavia has identified conditions that are critical to many species: pH, calcium, and aluminium are considered the most critical parameters. Also, aquatic invertebrates show a sequence of disappearance along a gradient of increasing acidity. Such broad patterns are now well documented and generally accepted, but the controlling mechanisms are not well known.

A recent investigation carried out in the river Vikedalselva (Henriksen et al. 1984), western Norway, showed that Atlantic salmon are killed during short acidic episodes, when pH decreases and the concentrations of labile aluminium increases rapidly (fig. 1). Labile Al is the fraction of total dissolved Al that is considered toxic to fish. The result obtained in that study pointed to the importance of studying episodes, including meteorology, hydrology, water quality changes and biological responses in watersheds undergoing acidification. To do this a much better resolution of variations in Al-concentrations (and other components) than those recorded through daily sampling was considered desirable to relate fish kills directly to changes in water quality. To approach this problem, chemical constituents influencing the fish (pH, Ca, Al. etc.) must be monitored continuously.

A pH, conductivity, and temperature monitor (assembled at NIVA) recorded in 1983 large pH fluctuations in river Vikedalselva that were related to water flow. This study was partly financed by the Norwegian Council for Scientific and Industrial Research (NTNF). A grant from the Norwegian Ministry of Environment made it possible for us to carry out a study of aluminium speciation methods (as described by Driscoll 1980 and modified by Wright and Skogheim 1983). This method was

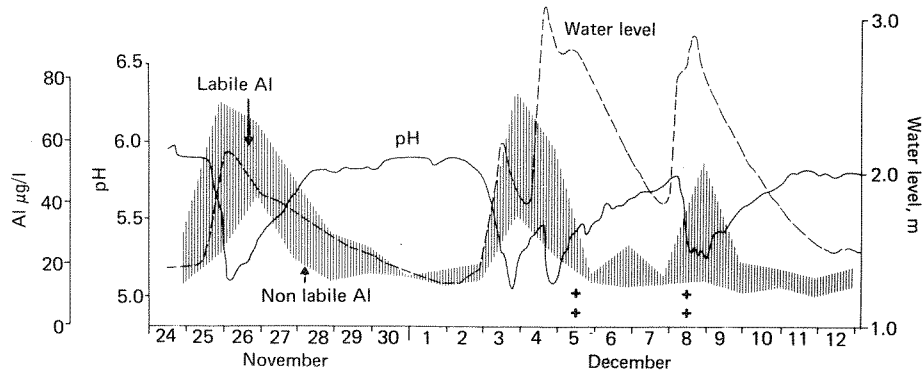


Fig. 1 Variations in pH, water level and labile monomeric aluminium (shaded in area) in Vikedal river, Nov. 24 - Dec. 12, 1983. pH curve is plotted on readings every second hour from continuous pH-monitor. Water levels from 4 h. readings of limnigraph records. Aluminium data are from daily samples. (Sampled at 2300 h.). Time of death of salmon presmolt (1+) are indicated (+ = 1 fish). Total amount of precipitation from Nov. 21 - Dec. 5 (weekly samples) were 136 mm with a weighted average pH of 4.35. Corresponding values for the week Dec. 5 til 12 were 56 mm and 4.75. (From Henriksen et al 1984).

adapted to the Technicon AutoAnalyzer with great success (see Røgeberg and Henriksen 1985). This work was carried out during the studies in river Vikedalselva referred to above. By courtesy of Technicon AB we modified the laboratory method for use on the Technicon Monitor 650, an industrial version of the laboratory AutoAnalyzer (Røgeberg and Henriksen 1985). The aluminium fractionation method (Driscoll 1980, Seip et al. 1984) adapted to this instrument fulfilled our requirements for monitoring use: stable operation unattended for 3-4 weeks (see Røgeberg and Henriksen 1985 for details).

Based on this experience and on many years of experience with sensors for parameters, such as pH, conductivity, temperature and turbidity we sought funding for construction of a mobile station for monitoring changes in water quality and the biological consequences. We presented the project to the parties we thought were interested, and a complete financial plan was developed in autumn 1984. Subsequently the following institutions contributed to the construction of MOBILLAB-NIVA:

Norwegian Ministry of Environment (MD)
Norwegian Institute for Water Research (NIVA)
Norwegian Council for Scientific and Industrial Research (NTNF)
Norwegian Water and Electricity Board (NVE)
Surface Water Acidification Project (SWAP)

We thank the sponsors for making the completion of the MOBILLAB-NIVA possible.

2. CONSTRUCTION

There are two practical approaches to automatic continuous monitoring of water quality:

1. To place the sensors in the water.
2. To bring the water to the sensors.

Although the first approach is the simplest, it restricts the choice of sensors to those which can be placed directly into the water. Also, varying water flow conditions and freezing during the winter may create problems.

The design of MOBILLAB-NIVA was based on the second approach. Although this concept increases the complexity of the system, the choice and design of sensors are far more flexible. Also, biological test systems can easily be incorporated in a system like MOBILLAB-NIVA.

MOBILLAB-NIVA has been constructed as a complete mobile station equipped with sensors for physical and chemical parameters and tanks for studying fish and invertebrates. The collected data are transmitted telemetrically (mobile telephone) to a central receiving station located at NIVA.

2.1 MOBILLAB - specifications

The station is housed in a standard trailer (Scandicell) with enforced floor and roof (fig. 2).

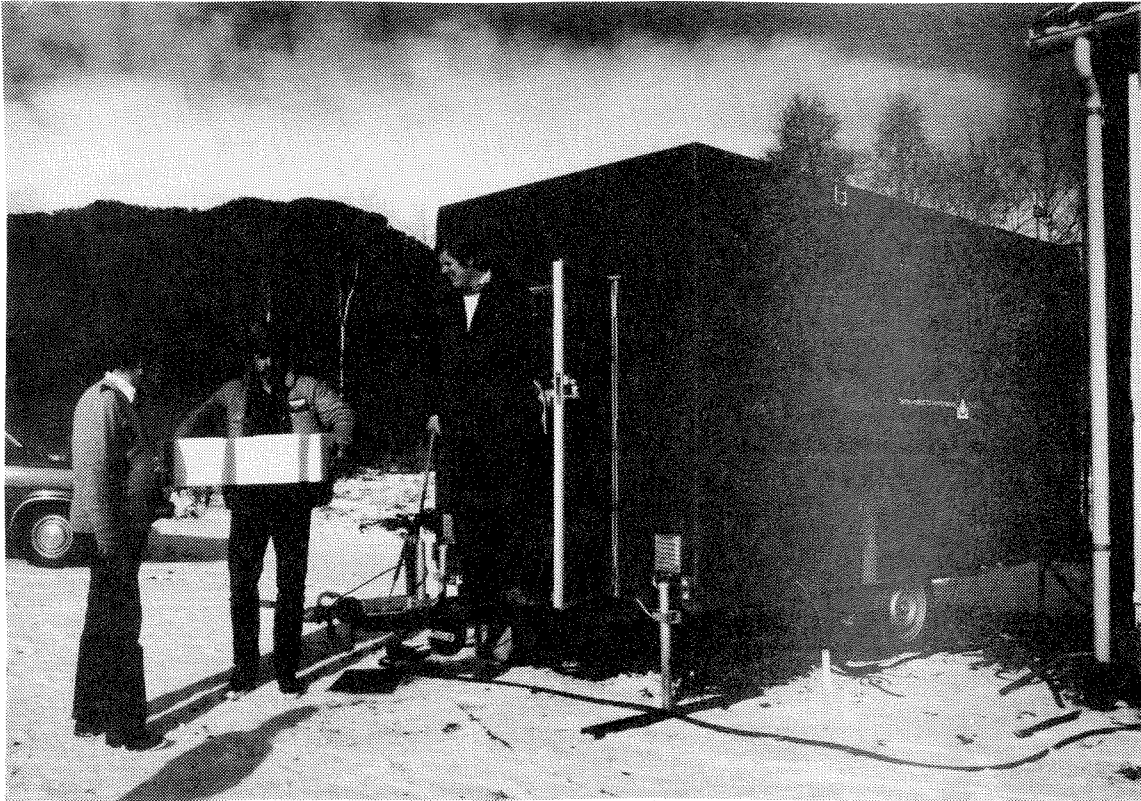


Fig. 2 MOBILLAB-NIVA-exterior.

Dimensions:	Inner length	4.2 m
	" width	2.0 "
	" height	2.1 "

Weight: Empty with frame: 635 kg.

Frame: Rectangular steel, A-shaped: 40x80 mm.

Roof, wall and floor constructions:

Inside made of glass fiber enforced polyester with glossy surface of gelcoat. Traction on the floor is achieved by mixing sand into the surface layer.

Intermediate made of polystyrene foam.

Outside made of glassfibre enforced polyester.

The thickness of the floor, walls and roof are 50, 30 and 50 mm, respectively.

Connections for transportations. Trailer hitch and 4 "ears" for helicopter transportation, crane lift or simply for guying.

Wheels and support. 2 wheels, 185x14" with brakes (80 km/h) + 4 supporting legs and a nose wheel. Maximum load: 1300 kg.

Windows. One window on left long side, 700x900 mm, to open. One roof window 475x475 mm, double, to open.

Ventilation. Two manually operated air vents at lower end of front short wall. One ventilation fan at upper end of back wall operated automatically by a humidity meter.

Light. Splash proof bathroom fittings,
4x20W on wall,
2x50W on roof.

Heating. Splash proof thermostated electric heaters
1x500W mounted on the wall,
1x2000W movable fan heater.

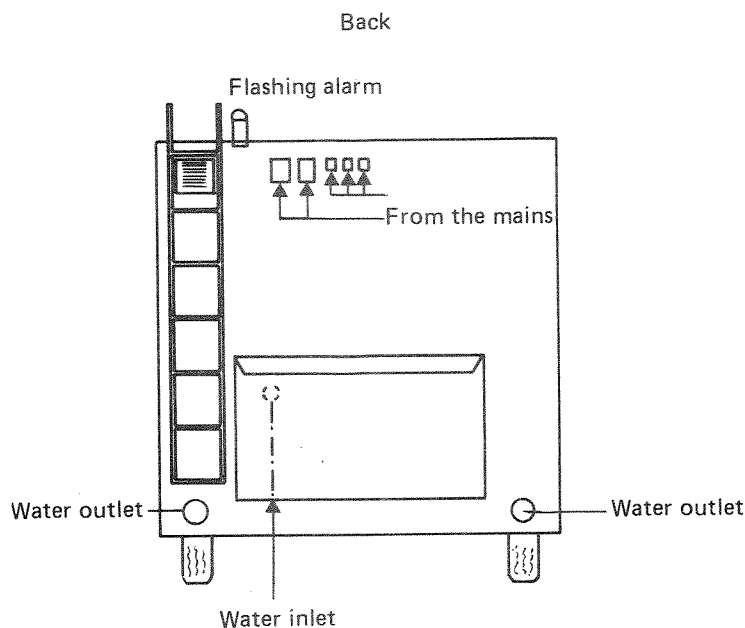


Fig. 3 MOBILLAB-NIVA as seen from the back.

Water supply. The water enters the back of the trailer (fig. 3) through stainless steel lockable fast couplings (5/4"). Inner pipes and valves are made of grey PVC, 32 mm .

The main water supply pipes (fig. 4) are mounted in the ceiling. Water pressure is regulated by a manually operated PVC valve. A pressure transducer signals rupture or pressure reduction to a light and sound alarm mounted on the roof of the lab (fig. 3). A number of junctions are mounted on the pipelines for easy exchange of components. All inside water pipes are insulated against condensation with 9 mm Armaflex insulating material.

The water is lifted from the source under study by two deep well pumps (Grundfos type SP) one operating at a time to ensure continuous water supply in case of pump failure.

Waste system is made of 75 mm black ABS-pipes mounted at the lower end of inside walls (fig. 4). They are insulated with 9 mm Armaflex. There is a drain with grating in the floor that can be

connected to a tube underneath the trailer.

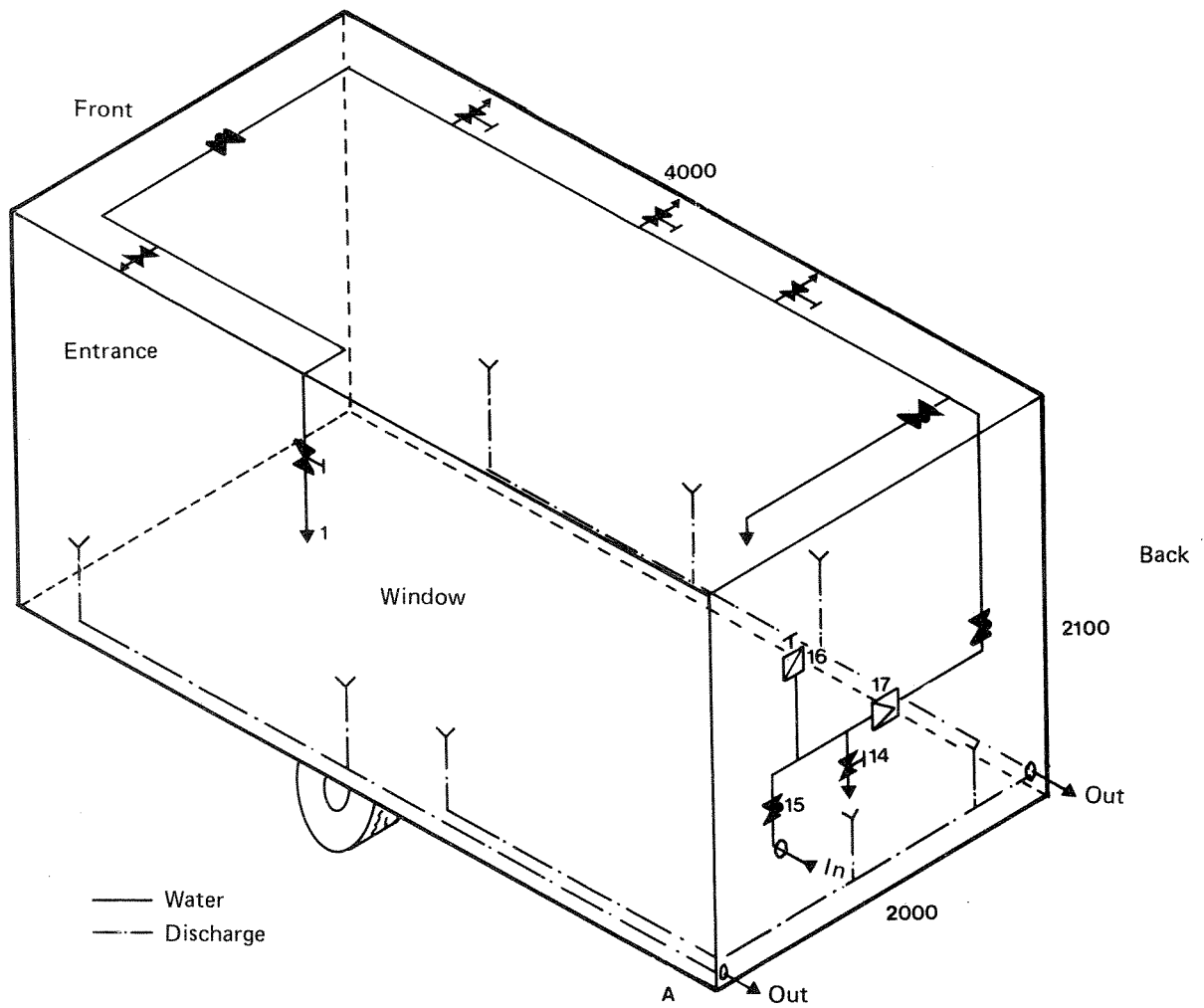


Fig. 4 MOBILLAB-NIVA - water and waste system.

Interior. The bench is made of sandwich material (1500x650 mm, height 900 mm) with a sink made of stainless steel. Shelves and connections for heavy equipment and instruments are composed of Dexion aluminium profiles screwed to ceiling and floor. These are easily changed to fit other equipment and instruments.

Electric current. The trailer is connected to the main (220V - A1 phase AC) at the outside of the back wall (fig. 3). The supply is protected with a 32A fuse and connected to a watt meter in the fusebox. There are 3 exterior outlets for use of electricity outside the trailer (16A). For inside electricity use, 9 circuits have been installed, 6@16A and 3@10A.

Only splash-proof sockets have been used and all power lines are mounted in cablechannels uppermost on the walls.

Safety equipment

Safety switches for protection against lightning, etc. are connected directly to pumps and ahead of other electrical equipment. Failure in water supply is indicated by a blinking alarm light and/or sound. The alarm system is activated through a pressostat and is connected to a 12V/20Ah battery giving a 15 h continuous alarm.

The electrical system is grounded through a copper rod in the ground.

In case of fire a 5 kg manually operated fire extinguisher is mounted inside the trailer.

Flow diagram

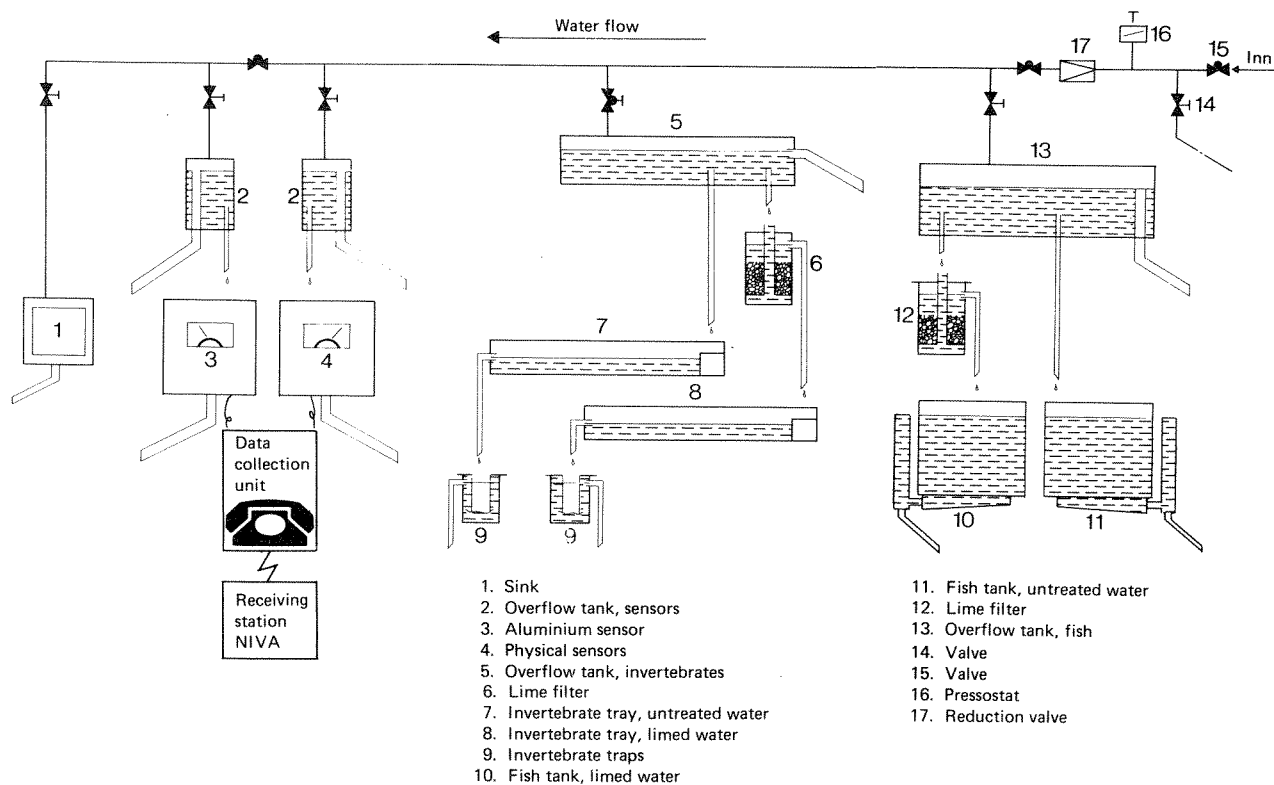


Fig. 5 MOBILLAB-NIVA - flow diagram.

The flow diagram of MOBILLAB-NIVA is shown in fig. 5. The water enters through a valve system (14-17) and is distributed to overflow tanks feeding the experimental fish tanks (fig. 5a) imvertebrate trays (fig. 5b) and analytical instruments. The analytical data are recorded on a 12 channel strip chart recorder. The data are also collected in a data collection unit and transmitted automatically via a mobile telephone to a central receiving station at NIVA (see below for details).

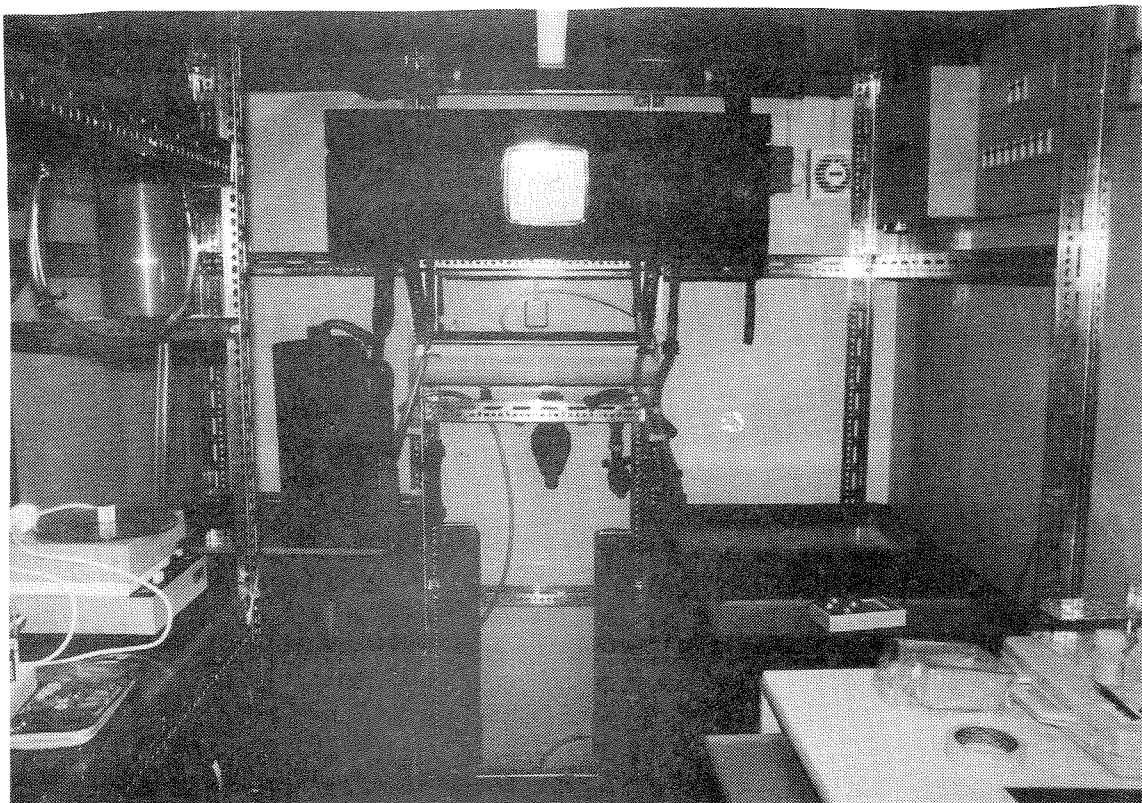


Fig. 5a Fish tanks, overflow tank and lime filter.

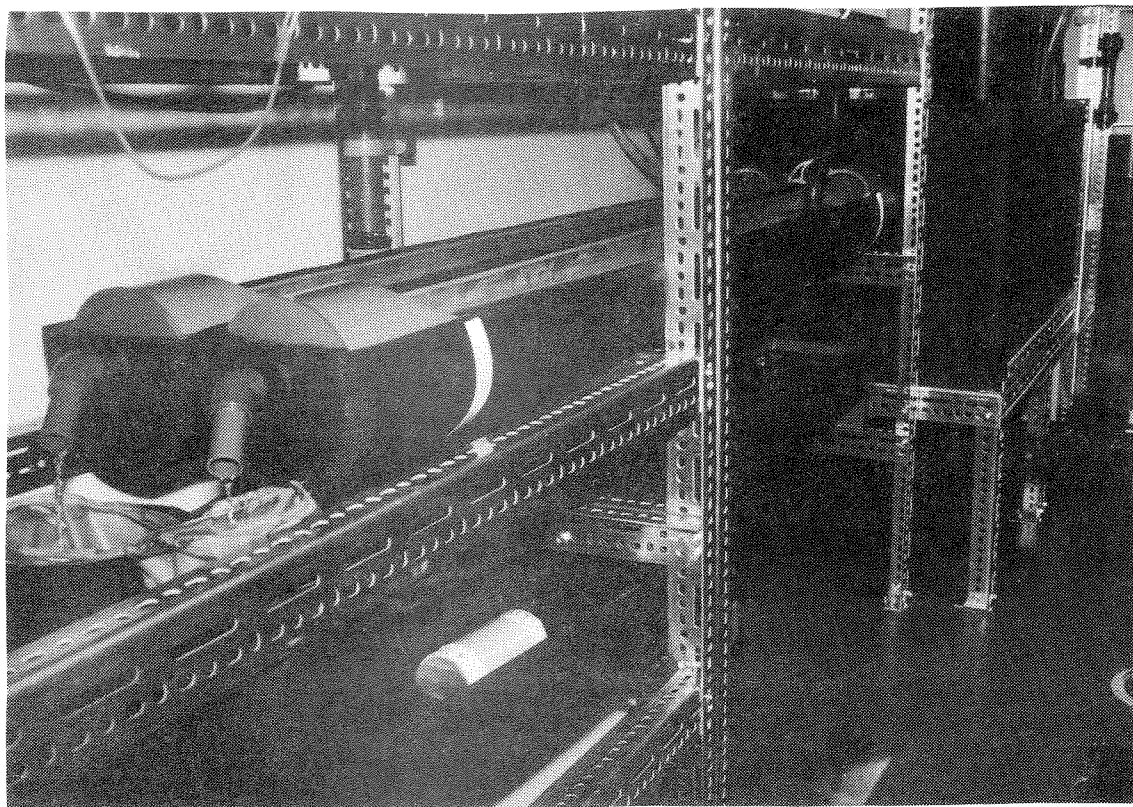


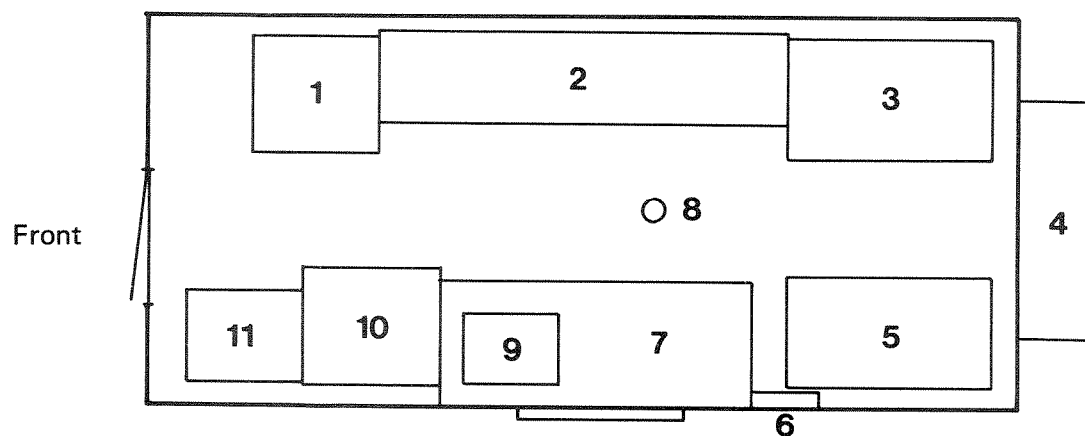
Fig. 5b Invertebrate trays and traps.

2.2 Instrumentation

The present version of MOBILLAB-NIVA is equipped with physical and chemical sensors for continuous measurement of these parameters:

<u>Sensor</u>	<u>Measurement</u>
pH electrode	Acidity
Conductivity cell	Ionic content
Thermistor	Water temperature
UV-absorbtion	Colour (humic substances)
Turbidity	Particles and colloids
Reactive aluminium (1)	"Total" aluminium
Non-labile aluminium (2)	"Organic" aluminium
Labile aluminium (1-2)	"Toxic" aluminium

Fig. 6 shows the positioning of the components inside the trailer.



- | | |
|--------------------|-----------------------------------------------|
| 1 Physical sensors | 7 Bench |
| 2 Bench/shelf | 8 Drain |
| 3 Fish tank | 9 Sink |
| 4 Toolcase | 10 Aluminium sensor |
| 5 Fish tank | 11 Data collection and
transmission system |
| 6 Freeze box | |

Fig. 6 Inside positions of instruments and components seen from above.

pH- conductivity-temperature sensors

All sensors are placed in a flow-through cell (fig. 7).

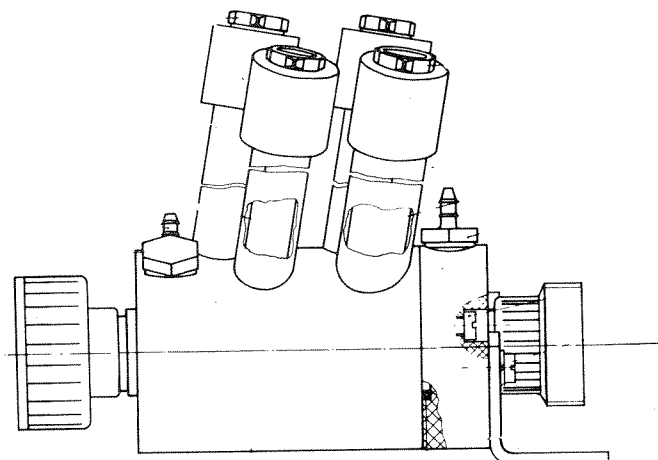


Fig. 7 Hartmann & Braun flow through cell for pH and temperature.

These sensors are made by Hartmann & Braun. The pH-sensor is equipped with separate glass and reference electrodes with automatic temperature compensation. The glass electrode is made by EIL (type 3310.72130), the reference electrode by Leeds & Nortrup (type 117392). The pH-range can be selected in steps of 2, 5, 10 and 14 pH-units with output signal of 0-20 mA or 4-20 mA.

The temperature sensor has two ranges, 0-25 °C and 0-100 °C. The signal output is either 0-20 mA or 4-20 mA.

The conductivity sensor is of the Pt-electrode type with automatic temperature compensation and is constructed as a flow-through cell (fig. 8).

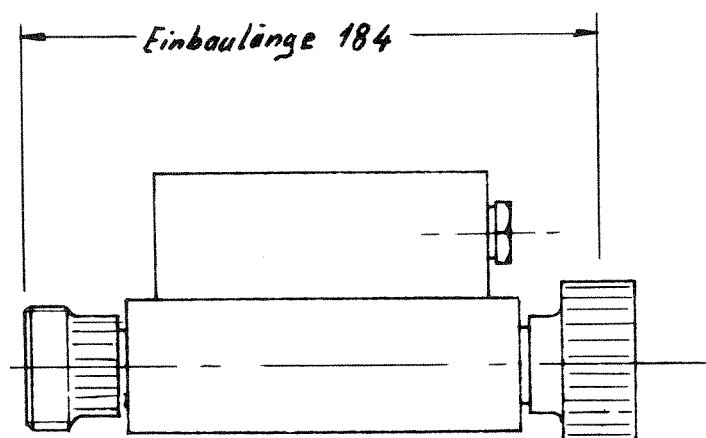


Fig. 8 Hartmann and Brown flow through cell for conductivity.

The measuring ranges are: 0-6 $\mu\text{S}/\text{cm}^2$, 0-20 $\mu\text{S}/\text{cm}^2$, 0-60 $\mu\text{S}/\text{cm}^2$, 0-200 $\mu\text{S}/\text{cm}^2$, 0-600 $\mu\text{S}/\text{cm}^2$ and 0-2000 $\mu\text{S}/\text{cm}^2$. Also here the output signal is either 0-20 mA or 4-20 mA.

UV-sensor

The UV-sensor is of the LKB type Uvicord II 8300. The output is either 0-10 mV or 0-100 mV. The lightpath of the flow cell is 5 mm. The sensor measures the relative changes in UV-absorption.

Turbidity sensor

The turbidity meter Type 5 "Surface Scatter" made by Hach (fig. 9). The flow cell is "open" so that growth is not a problem. Output ranges: 0-1 NTU, 0-10 NTU, 0-100 NTU and 0-1000 NTU.

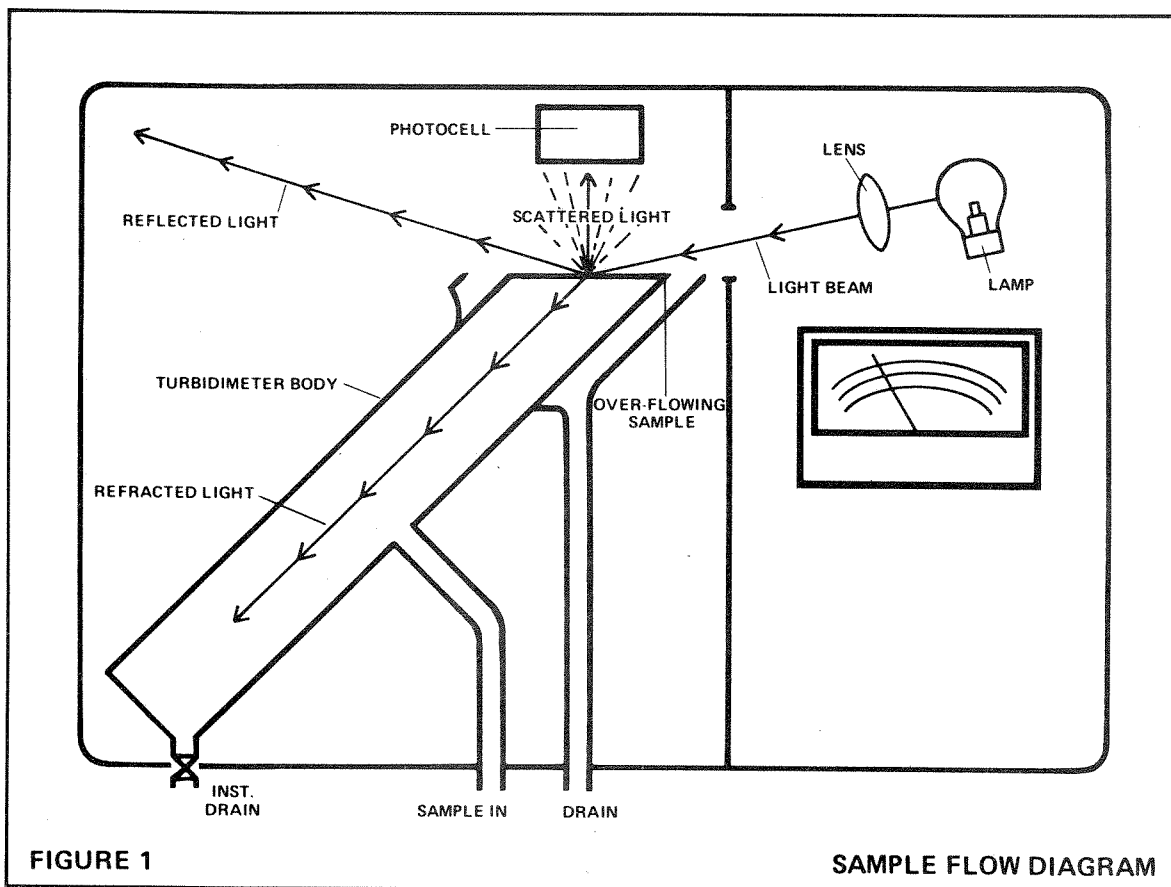


Fig. 9 The Hatch turbidimeter, type 5, "Surface scatter".

2.3 Aluminium sensor

The Technicon Monitor 650 provides automated wet chemical analysis of a wide range of parameters in process, effluent or other liquid streams. The system employs continuous-flow technology to measure concentration by constantly aspirating sample, adding appropriate reagents for development of a chromophore and reading out absorbance with a colorimeter.

The system is under control of an integral microprocessor, which converts electro-optical information to concentration units, digitally displayed on the front panel.

The system consists of a cabinet, hydraulics module and microprocessor. Various options for use with the system are also available from the Technicon including a dual-stream option, six-stream option, digital printer, recorder, weight option and

purge option. In addition, the system can be interfaced with external electronic devices at the user's facility in an analog fashion, or digitally via an optional RS-232C computer interface.

The aluminium fractionation method was adapted to this instrument (Røgeberg and Henriksen, 1985). The monitor 650 version used here was equipped with the dual-stream option. During continuous monitoring the water stream is switched alternately through an ion exchange column and directly into the system. Each stream is sampled for 15 minutes and the average value from the last two minutes is recorded.

A detailed description of the monitor and its operation is given in the appendices.

2.4 Automatic data collection and transmission system

This system (fig. 10) was installed by EDAS (Environmental Data Acquisition System, Eidsvoll, Norway). The signals from the sensors

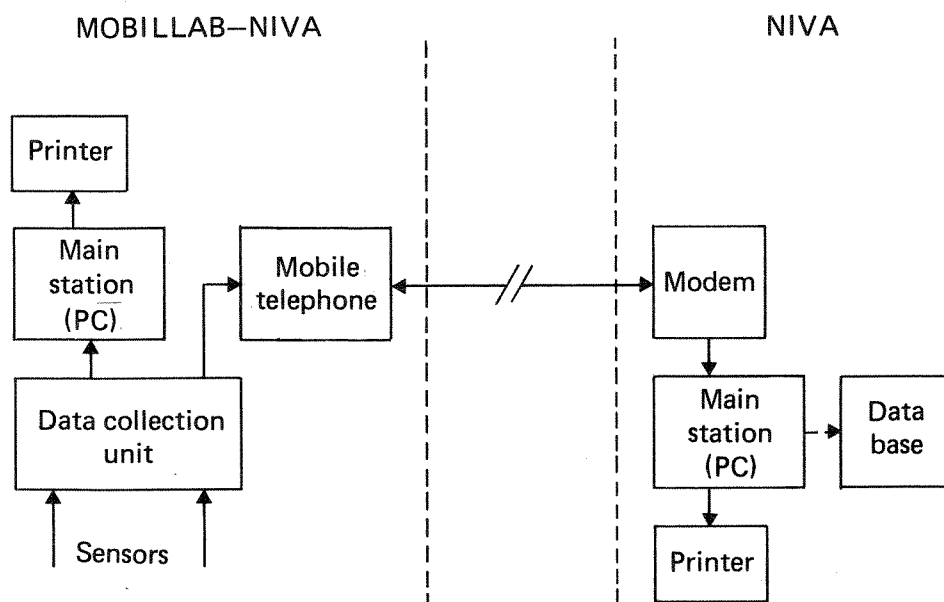


Fig. 10 Schematic diagram of the EDAS data collection and transmission system.

are collected at 3 min. intervals and stored with time identification in the data collection unit. This unit is supplied with battery backup. A mobile telephone is coupled to the data collection unit and the collected data can be transferred to the main station at NIVA by either manual or automatic calling.

At the main station transmitted data can be treated and presented in tables and/or by graphics. The MOBILLAB-NIVA is also equipped with a main station to facilitate data presentation and treatment when it is manned.

2.5 COST

The total cost of MOBILLAB-NIVA was NOK 1.025.000,- distributed as follows:

Trailer, fully equipped	NOK	250.000,-
Instrumentation	"	300.000,-
Labour	"	300.000,-
Automatic data collection and transmission system	"	175.000,-

3. EXPERIENCE

1. MOBILLAB-NIVA was completed in March 25, 1985, and immediately put into operation at river Vikedalselva from March 29 to June 12. pH, conductivity, UV-absorbtion and aluminium speciation were recorded continuously during this period without major breaks. Smolts of Atlantic Salmon and invertebrates were placed in their respective experimental and reference tanks. The invertebrates were collected from a nearby river. Every fourth week all the sensors were checked and recalibrated. This took about 8 hours. Most of the time was spent on recalibrating the aluminium sensor. All sensors showed very good stability during the whole period of operation. Breaks in the electrical current are "inevitable" in our country. However, after current interruptions, all the sensors stabilized to the previous values after a short time. At Vikedal the station was located near the house of our observer (fig. 11) who looked after the fish and the invertebrates. It was not necessary for him to adjust any of the sensors at any time.

The Vikedal operation was concluded with a 2-day experiment to artificially acidify a small tributary to the river. The station was moved about 2 km and brought into operation at the new location within 3 hours.

The results from the Vikedal operation will be published elsewhere.

2. MOBILLAB-NIVA was transported back to NIVA for maintenance and for installation of the Environmental Data Acquisition System (EDAS) as described above. The station was then moved to Trondheim for the Aqua-Nor exhibition August 12-15 1985. Here it was demonstrated during the whole exhibition without any problems. The collected data were transmitted to NIVA's stand inside the exhibition rooms.

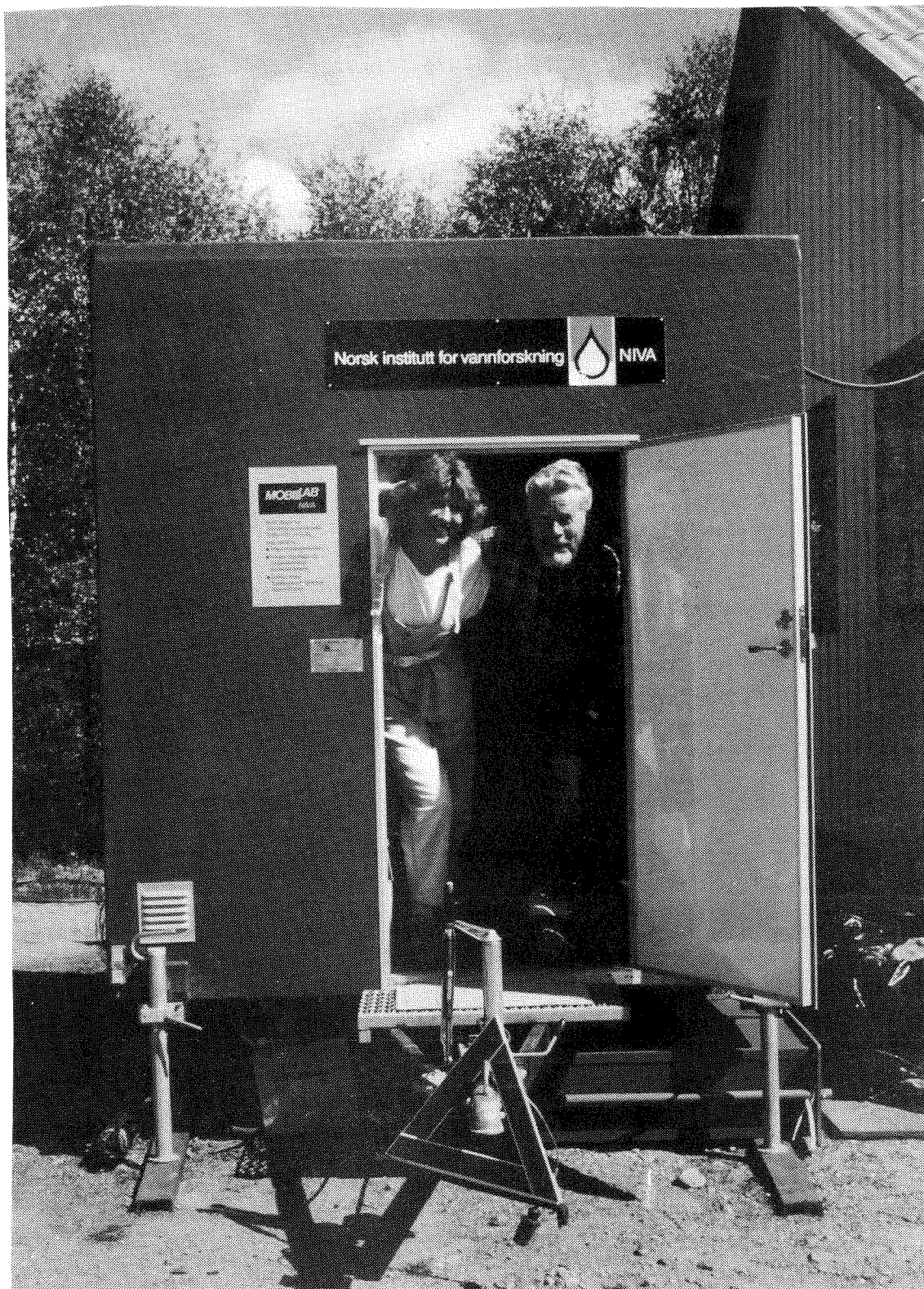


Fig. 11 MOBILLAB-NIVA in operation at Vikedal river. Our local observer is smiling in company with his favorite scientist.

The station was received with great interest, especially among aquaculture people, and there is evidently a market for a simpler version of the station for use in studies and control of smolt production units.

3. After the closing of the exhibition in Trondheim MOBILLAB-NIVA was transported to Sogndal (figs. 12 and 13) where the RAIN-project



Fig. 12 MOBILLAB-NIVA transported to research site at Sogndal.

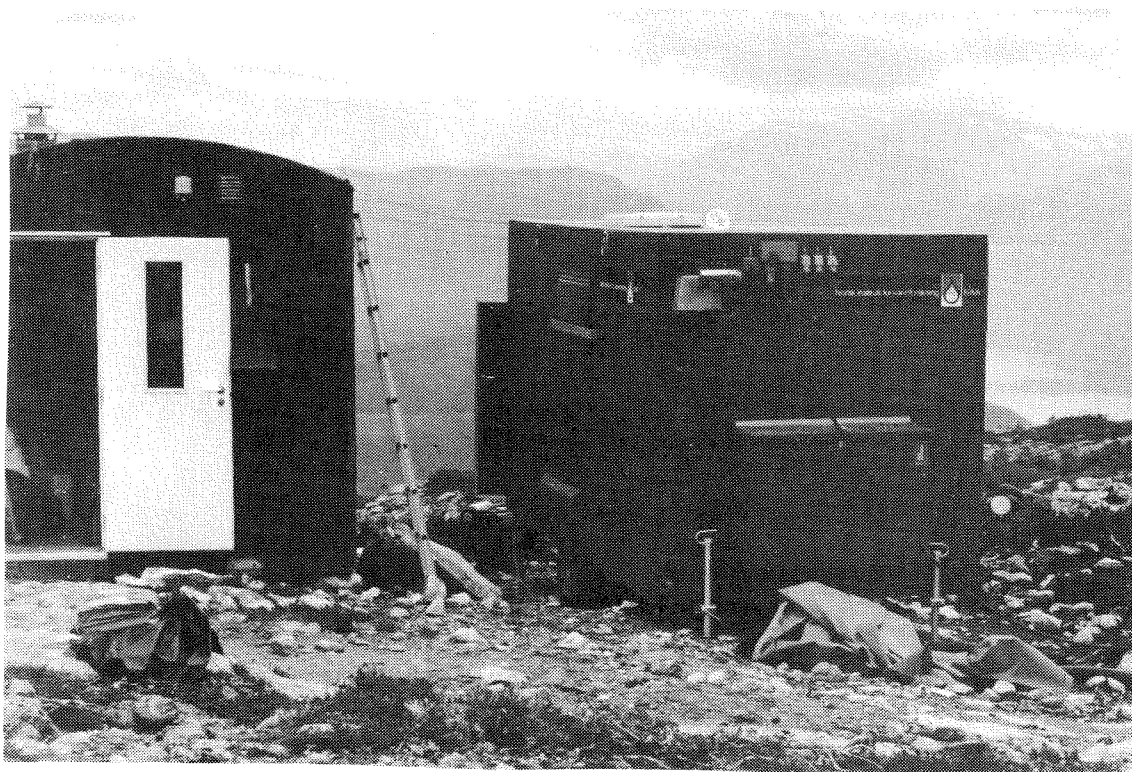


Fig. 13 MOBILLAB-NIVA at Sogndal.

adds acid to a pristine area. We followed the change in water chemistry during an acidification experiment carried out during the period August 21-31 1985. Results from the first period of acid addition are shown in fig. 14. Acid was added for about 6 hours on August 21. The pH in runoff decreased rapidly from 5.4 to 4.35 and the labile Al-fraction increased correspondingly from 10 $\mu\text{g Al/l}$ to 130 $\mu\text{g Al/l}$. The small "peak" in the steep part of the curves is due to an hour's stop in acid addition because of pump failure! This illustrates the sensitivity of the system. A more detailed description of these experiments will be published elsewhere.

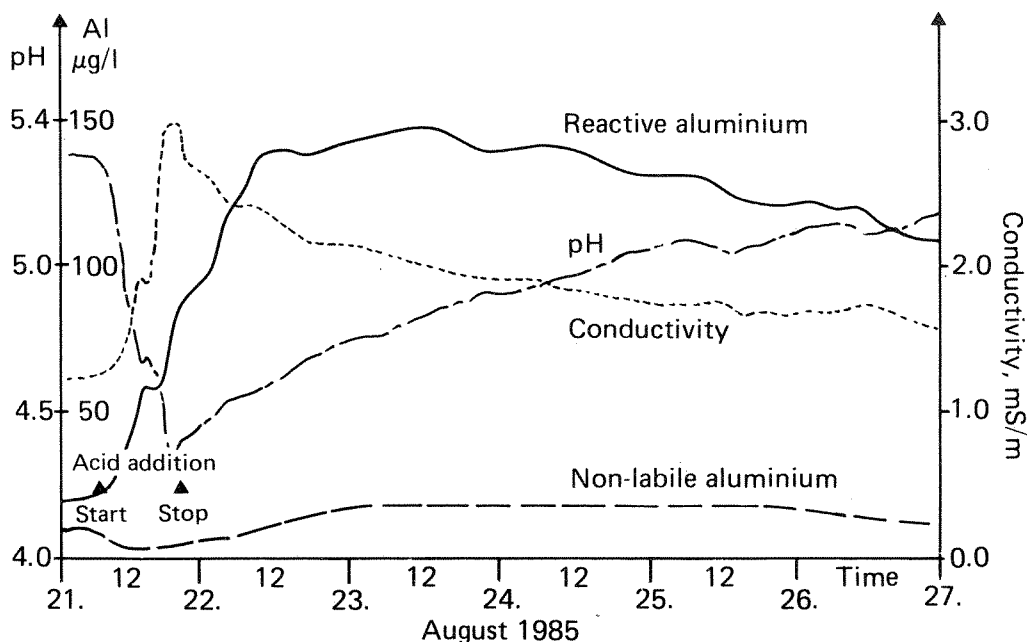


Fig. 14 Artificial acidification at Sogndal, western Norway (RAIN-project). Variation in pH, conductivity, reactive and non-labile Al after sulphuric acid addition to the catchment.

The power supply used during these experiments was a gasoline electric generator that had to be refilled every 11 hour. The station worked satisfactorily during the whole period with this power supply system. The current frequency produced by this power supply, was not stable enough for the chopper motor of the aluminum monitor, which is very sensitive in this respect. Consequently, the monitor could not be run in the automatic mode with automatic switching between the two sample streams. However, this did not represent a great problem in this particular experiment as the monitor could be run satisfactorily in the manual mode. This was possible as the non-labile Al- fraction was very low and constant ($< 10\text{-}20 \mu\text{g/l}$) during the whole experiment, and it was sufficient

to measure this fraction occasionally by manual switching of the sample streams.

The last kilometer of the road to the experimental area is not accessible by ordinary cars. The station was moved the last bit by a belt car (snowmobile) (see fig. 12). This worked out very well, but we would hesitate to do it again!

4. The effectiveness of two drinking water purification plants using aluminium coagulation have also been studied by means of MOBILLAB-NIVA. For this purpose the turbidity sensor was installed. As an example fig. 15 shows the results obtained the

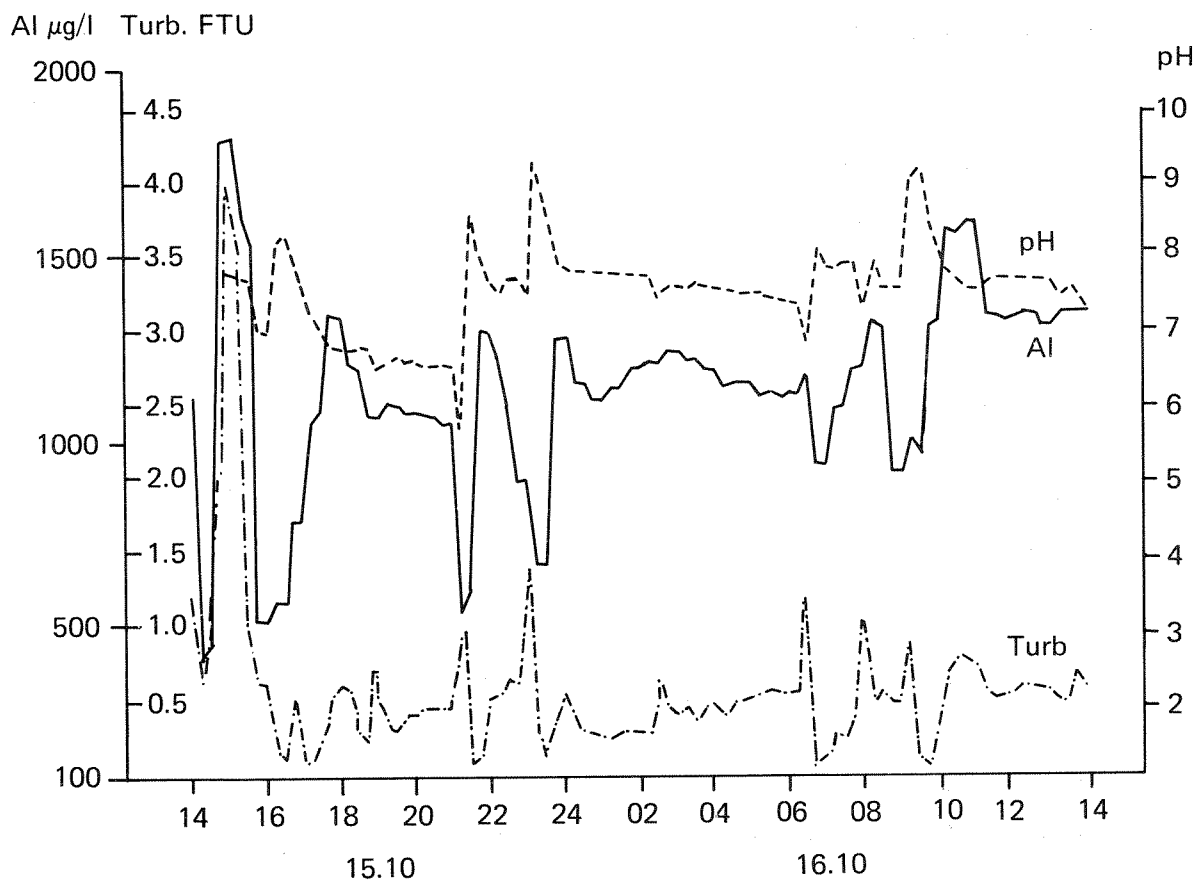


Fig. 15 Results from a water purification plant.

first day of operation at one of the plants. The figure is drawn on the basis of data transmitted from the plant to the central receiving station at NIVA. The continuous measurements of water chemistry make it possible to trace the operational stability of the plants. The MOBILLAB-NIVA can quickly detect the effects of controlled variations of the operational parameters which makes it a useful tool for obtaining optimum conditions in water purification processes.

5. The effect of pH on aluminum fractions in humic water samples was studied in the laboratory by continuous measurements of these fractions during gradually changing pH conditions. The results indicate a maximum of the non-labile aluminum fraction and a corresponding minimum of the labile aluminum fraction between pH 6 and 7.

The results summarized here illustrate the ability of MOBILLAB-NIVA, to trace rapid changes in water quality either naturally or artificially induced.

The trailer itself is very well constructed. It is stable and the construction is waterproof. The equipment mounted inside to roof, walls and floor have not dislodged even during the very brutal transport to Sogndal. All sensors have functioned according to the specifications given for the instruments. MOBILLAB-NIVA is easy to put into operation when satisfactory power supply is available.

Experiences with the aluminum monitor 650

Even though our experience with the Al Monitor is generally satisfactory, some problems have arisen:

- 1) Particles in the water may cause clogging of the system, and a filtering device outside the monitor should be considered in order to reduce this problem.
- 2) During long periods of electric current disruption the pump tubings may be permanently compressed and subsequent reagent flow prevented, disturbing the chemistry of the reaction solution. In this case it is necessary to replace the pump tubings and recalibrate the system manually.
- 3) Automatic recalibration performed before the sensor has stabilized after current disruption may lead to an erroneous calibration curve and hence, erroneous results. In this case a manual recalibration must be performed.

4. FUTURE DEVELOPMENTS

The aluminium sensor (Technicon Monitor 650), a colorimetric analyzer (see Appendix for details), has proved to be very suitable, robust, stable and easy to operate. The monitor has been modified to analyze two aluminium fractions: total monomeric aluminium (reactive Al) and non-labile monomeric aluminium (the Al not retained on a strong cation exchange column). The difference between the two Al fractions is the species (labile aluminium) thought to be toxic to fish. The determination of speciation is achieved by either pumping the sample directly into the analytical system (reactive Al) (see Appendix) or first through a strong cation exchange column. The monitor has only one analytical system, but two input channels. Thus either of two different sample streams can be analyzed after two different pretreatments.

Any colorimetric method can be adapted to the Monitor 650 as long as the method and the reagents keep stable for the period of observation. The major work in adapting new colorimetric methods to the Monitor 650 lies in designing a stable chemical system. An analytical method that works well in a laboratory may certainly not work unattended for 4 weeks.

Continuous measurements of phosphorus and nitrogen compounds are of great interest in a variety of cases (unpolluted and polluted watersheds, agricultural runoff, purification plants, industrial effluents). There is no reason why automated laboratory methods based on the AutoAnalyzer cannot be modified for continuous use in a system like MOBILABNIVA. Because of its flexibility MOBILABNIVA can easily be changed to adapt other sensors.

Our plans are to test other types of sensors commercially available, such as ion selective electrode monitors, hardness monitors, and other physical and chemical sensors. Further,

MOBILLAB-NIVA is very suitable for testing prototypes for biological sensors, especially sensors for fish reactions to toxic conditions.

Major applications of the MOBILLAB-NIVA concept are to study short term variations in water quality, the biological response to natural and imposed toxic conditions and to decide on monitoring strategy.

Acknowledgements:

We wish to thank Bjørn O. Rosseland and Odd K. Skogheim for helpful suggestions during the planning period, and Erik Bjerknes, Oddbjørn Pettersen and Frank Sannerud, all from NIVA, for qualified assistance during the construction of MOBILLAB-NIVA.

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APPENDICES

- 1. TECHNICON MONITOR 650 - DESCRIPTION AND SPECIFICATION**
- 2. TECHNICON MONITOR 650 - OPERATION**
- 3. MONITORING OF ALUMINUM SPECIATION**

APPENDIX

1. TECHNICON MONITOR 650 - DESCRIPTION AND SPECIFICATION

General

The system provides automated wet chemical analysis of a wide range of parameters in process, effluent or other liquid streams. The system employs continuous-flow technology to measure concentration by constantly aspirating sample, adding appropriate reagents for development of a chromophore and reading out absorbance with a colorimeter.

The system is under control of an integral microprocessor, which converts electro-optical information to concentration units, digitally displayed on the front panel.

The system consists of a cabinet, hydraulics module and microprocessor. Various options for use with the system are also available from the supplier including a dual-stream option, six-stream option, digital printer, recorder, weight option and purge option. In addition, the system is capable of being interfaced with external electronic devices at the user's facility in an analog fashion, or digitally via an optional RS-232C computer interface.

Overall system specifications

Dimensions (without Purge Option).....	25.7 in. wide x 26.1 in. deep x 54.8 in. high (65 x 66 x 139 cm)
Dimensions (with Purge Option)	Same except 52.8 in. (134 cm) high
Shipping Weight	Approximately 300 pounds (136 kg), without reagents.

Electrical Requirements 100, 115, 200, or 220 V,
50, or 60 Hz, single phase.
(Current: 15A maximum at
115 V).

Hydraulic Requirements

Sample flow 100 to 150 cc/min. at
90⁰ C maximum temperature,
15 p.s.i.g. max press.,
via 1/8 in. I.D. by 1/4 in.
O.D. conn.

Drain 3/8 in. I.D. by 1/2 in.
O.D. conn.

Cooling Water 0.5 gal./min. at 18⁰ C,
required with Purge Option.

Environmental Requirements:

Operating Temperature 10-40⁰ C
Relative Humidity 20-100%, non-condensing.

Air Purge Requirement (with Purge Option)

Air 50 SCFH clean instrument
air or inert gas.

CABINET

The entire system is housed in a cabinet which also contains an air compressor, reagent storage compartment, and isolation transformer. The isolation transformer allows use of different supply voltages.

The cabinet is of rugged construction, suitable for operation in a process environment. An optional purge can be provided to accept purge gas for installation in corrosive environments. The cabinet has an external finish that is resistant to common corrosive fumes.

Reagent storage compartment

The reagent storage compartment can hold up to five 15 litre jugs and four 4-litre containers - adequate for 30 days' operation of the system on selected chemistries.

HYDRAULICS MODULE

The hydraulics module - which is capable of being moved forward in the cabinet along slides - contains an overflow sampler, colorimeter proportioning pump, manifold assembly and auxiliary devices.

Overflow sampler

The overflow sampler, mounted on the front panel, permits continuous sampling of a single stream. A second overflow sampler, for use when the dual-stream option is used, is also available from the supplier.

Colorimeter

The colorimeter measures intensity of light transmitted through the analytical stream (proportional to the concentration of constituent being measured), by looking at light from the flow cell and from reference. The colorimeter is a single-channel, solid-state unit, for greater stability. It is capable of handling flow cells having path-lengths of 10, 50 and 75 mm.

Wavelength Range	400 to 800 nm, fixed
Wavelength at Half-Band Pass .	15 to 20 nm
Photometric Presentation	0.015 to 1.5 A.U.F.S., continuously adjustable
Photometric Linearity	$\pm 1\%$ up to 1.0 A.U.; $\pm 3\%$ up to 1.5 A.U.

Photometric and Electrical	
Drift	(% of full scale per 8 hrs.). Less than 1% above 0.1 O.D.; less than 2% from 0.05 to 0.1 O.D.; less than 5% below 0.05 O.D.
Gain Control	Computer or potentiometer adjustment.
Sensitivity	From less than 1 ppb to more than 100 g/l, depending on chemistry selected.
Source	Tungsten lamp.

Proportioning pump

The system is provided with a peristaltic proportioning pump to continuously and simultaneously propel samples and reagents through the system, and to form air bubbles for segmentation of liquid stream. The pump is capable of being controlled by the microprocessor via keyboard. The microprocessor also provides pump shut-down under alarm conditions.

The pump is capable of handling up to 10 reagent and/or sample streams and up to four air streams from the compressor.

The pump has an interlock mechanism to stop reagent flow in the event of a spill or leak.

Liquid Flow Rate	Proportional to inside diameter of pump tube.
Air Bubbling Rate	60 bubbles/minute.
Speed	5 RPM, synchronously driven.

Manifold assembly

The manifold assembly is a self-contained sub-assembly, capable of being attached to the hydraulics module. It consists of all components required to automatically run the specified chemistry.

Auxiliary devices

The system can be provided with auxiliary devices, depending on the chemistry: UV digester, air purge, distillation unit and heating bath.

MICROPROCESSOR

The microprocessor 1) controls the various components of the system, 2) processes and outputs the data and 3) provides alarms and diagnostics for the entire system.

Data processing

The signal from the colorimeter is, after passing through the pre-amplifier, immediately converted to digital information. All subsequent manipulations are performed digitally, for greater system stability.

Automatic recalibration

The system is provided with automatic two-point recalibration, initiated and controlled by the microprocessor at time intervals preset by the operator at the keyboard.

Data output

The microprocessor provides output data on concentrations and optical density. It also provides an output of raw-data, via digital display or optional recorder or digital printer, for diagnostic or control purposes.

Alarms

The microprocessor provides automatic alarming, either visual or audible for the following faults:

- | | |
|----------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Visual Alert Light | a) Flow meter failure. |
| | b) Reagent pump tube maintenance required. |
| Visual Alert and Audible alarm | c) Purge pressure failure. |
| | d) High-low level (separate contact closures for each) for at least 30 seconds. (Contacts shall remain closed until concentration returns to "Normal Limits".) |
| Visual Alert, Audible Alarm and Automatic Shutdown | e) Colorimeter failure. |
| | f) Pump failure. |
| | g) Leak detector (delayed shutdown). |

Diagnostics

Diagnostics information on all key electronic and mechanical components are displayed digitally. In addition, LED's on printed circuit boards shall indicate which functions are being fulfilled.

OPTIONS

The following options are available from the supplier for use with the system. Dual-stream option, six-stream option, digital printer, recorder, weight option, purge option and RS-232C computer interface.

Dual-stream option

A dual-stream option permits the monitoring of two separate streams through use of two overflow samplers. This option permits keyboard selection of time-per-stream, and contains manual override, locking onto one stream.

Six-stream option

A six-stream option, a separate module provides selection of up to six sample streams by means of solenoids under control of the microprocessor. Time-interval per stream and number of active streams are operator-selectable.

Digital printer

An optional digital printer provides printout of stream selected, concentration time of day and diagnostic information.

Recorder

An optional 4-inch strip chart recorder, mounted in the cabinet, provides a tracing of concentration.

Weight option

A weight option computes weight of analyte in the flowing stream per unit time from concentration data and a 4-20 ma input from a flow controller supplied by the user.

Purge option

A purge option is available to prevent damage to the electronics when operating in a corrosive environment. The purge option permits the cabinet to accept a positive pressure of clean instrument air or inert gas, such as nitrogen. Loss of internal pressure activates an alarm. When the purge option is employed, the totally-enclosed cabinet is cooled by means of a heat exchanger supplied with the purge option.

RS - 232 C computer interface

An optional computer interface permits interfacing (digitally) with external electronic devices.

SERVICE ABILITY

All components of the system are readily accessible for servicing from the front of the cabinet. The hydraulics module is designed for routine maintenance at 30-day intervals, or as specified for the particular chemistry.

Tubings are compatible with acidic, basic and organic sample streams, as required, and are quickly and easily replaced.

The recorder is capable of 30 days continuous operation between servicing.

2. TECHNICON MONITOR 650 - OPERATION

GENERAL

Calibration

Two different types of calibration can be performed depending on the chemistry of the colorimetric method:

- a) two point linear calibration with baseline solution and one standard.
- b) non linear calibration with baseline solution and up to eight standards.

For both calibration procedures a baseline solution and/or one standard are chosen for automatic recalibration. The recalibration frequency can be varied from 1 to 99 hours.

Sample monitoring

The monitor can aspirate up to six different sample streams. The aspiration time of each sample stream can be set to 0-99 mins. It must be checked empirically that the stream sampling time is sufficient for each stream to reach steady state in the flow cell.

The signal from the colorimeter can be averaged over a selected time period between 0-250 seconds (damping).

The average signal can be recorded on a chart recorder. Values can also be printed out on an optional printer or external computer at intervals of 0-250 mins.

3. MONITORING OF ALUMINIUM SPECIATION

Calibration procedure

Before system start-up a manual non-linear calibration is performed. Calibration standard concentrations are 0, 25, 50, 100 and 250 $\mu\text{g/l}$ Al. During the manual calibration cycle each standard is aspirated for 25 minutes. 0 and 250 $\mu\text{g/l}$ Al standards are used for automatic recalibration every 12 hours.

Sample monitoring

During the continuous automatic monitoring the water stream is switched alternately through an ion exchange column and directly into the system outside the column. Each stream is sampled for 15 minutes and the average value from the last two minutes is recorded.

Monthly Maintenance

All pump tubes and reagents are replaced and a new ion exchange column is installed. The system is washed with 1 M sodium hydroxide and rinsed thoroughly with distilled and deionized water. A new manual non-linear calibration procedure is performed.

Reagent consumption

During one month of continuous monitoring the amount of reagents needed are approx:

2	liters	of	hydrochloric	acid
2	"	"	phenanthroline	
3	"	"	pyrocatecholviolet	
4	"	"	buffer (hexamethylenetetramine)	
5	"	"	deionized distilled water	
1	liter	"	250 $\mu\text{g/l}$ Al standard	
100	ml	"	25, 50 and 100 $\mu\text{g/l}$ Al standards.	

ANALYTICAL METHOD

Two aluminium fractions are measured:

- 1) total monomeric Al (reactive Al) which is the Al fraction that reacts directly with pyrocatecholviolet at pH 6.0 - 6.2,

and

- 2) non-labile monomeric Al which is the fraction that reacts with pyrocatecholviolet after passage through cation exchange column.

Labile monomeric Al is the difference between total monomeric and non-labile monomeric Al.

The flow scheme of the method is shown in Figure 1.

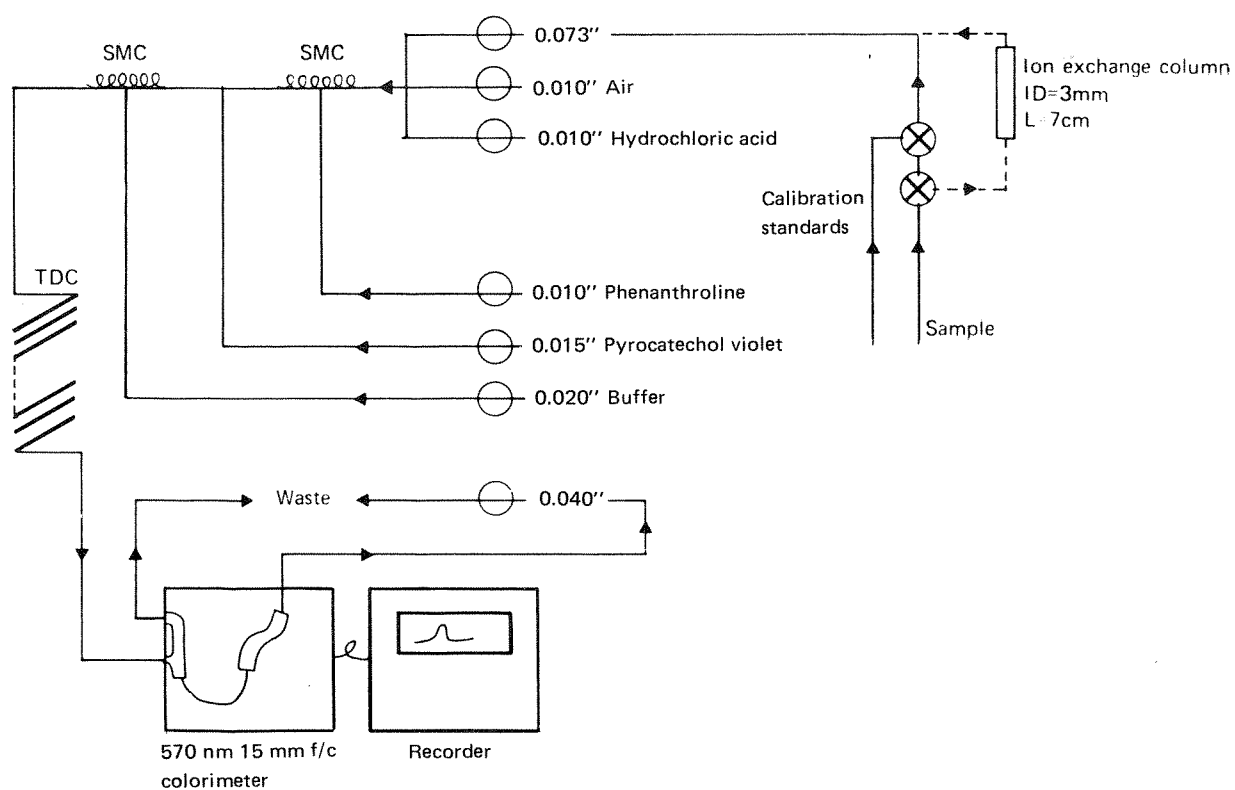


Figure 1. An automatic method for determining aluminium species in freshwater using the Technicon Monitor 650.

STOCK REAGENTS

Hydrochloric acid (Reagent A)

5 M HCL: Dilute 414 ml concentrated hydrochloric acid ($d = 1.19$, 37%) to 1000 ml with deionized distilled water.

1.10 phenanthroline reagent (Reagent B)

Dissolve 100 g hydroxyl-ammonium chloride in deionized distilled water and dilute to 1000 ml. Dissolve 1.0 g 1.10 phenanthroline in this solution. Store in a polythene bottle.

Pyrocatechol violet

Dissolve 0.375 g in 100 ml deionized distilled water. Let the solution stand for about 5 min. with occasional shaking. Dilute to 1000 ml with deionized distilled water. Store in a polyethene bottle.

Buffer

Dissolve 300 g hexamethylene tetramine in 750 ml deionized distilled water. Filter the solution through a Whatman GF/C filter and transfer the filtrate to a 1000 ml volumetric flask. Add 16.8 ml of concentrated ammonia ($d = 0.91$) and dilute to 1000 ml. Mix well and transfer the solution to a polyethene bottle.

STANDARDS

Standard A

Dissolve 1.758 g $KAl(SO_4)_2 \cdot 12 H_2O$ in a little water. Add 20 ml 5M hydrochloric acid and dilute to 1000 ml with deionized distilled water. This solution contains 100 mg Al/l.

Standard B

Mix 25 ml of standard A and 5 ml 5 M hydrochloric acid and dilute to 1000 ml. This solution contains 2.5 mg Al/l. Prepare suitable calibration standards (25-250 µg Al/l) from this solution.

WORKING REAGENTS

Hydrochloric acid

Dilute 100.0 ml of reagent A and 30 ml Brij-35 (30 % solution) to 1000 ml with deionized distilled water.

1.10 phenanthroline

Dilute 710 ml of reagent B and 30 ml of Brij-35 to 1000 ml.

Buffer

The buffer solution is used undiluted, but it should be checked that the pH of the final solution is 6.0 - 6.2.

Ion exchange resin

Mix the sodium form of Amberlite IR 120 (14-52 mesh) with 1% of the corresponding hydrogen form. Wash the resin twice with deionized distilled water, and then with 10^{-3} M sodium chloride until the supernatant becomes clear.