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National long-term surveillance of Swiss rivers

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Introduction

The "National Long-term Surveillance of Swiss Rivers" (NADUF) programme was initiated in 1972 as a cooperative project between three institutes: the Swiss Agency for the Environment, Forests and Landscape (BUWAL), the Swiss Federal Institute for Environmental Science and Technology (EAWAG) and the Federal Office for Water and Geology (BWG). The program conducts the surveillance and evaluation of the chemical–physical state of Swiss rivers.

The goals of NADUF serve both national and international interests. The main national goal is to evaluate the effectiveness of water protection measures. In addition, NADUF provides both basic data and sampling facilities for scientific studies on issues associated with river water. At the international level, several NADUF stations serve as reference stations for other water surveillance programs (e.g. the International Commission for the Protection of the Rhine (IKSR), the Global Environment Monitoring System – United Nations Environment Program/World Health Organization (GEMS-UNEP/WHO)).

The NADUF network of sampling stations includes locations on all the major rivers of Switzerland. Chemical–physical data are collected at 19 stations (Fig. 1) selected to provide a representative overview of Swiss rivers. The locations include all rivers flowing out of Switzerland, the main tributaries to major lakes, and catchment areas at a range of altitudes extending from the Alps to the Swiss Plateau. In addition, several heavily polluted river sections, of particular interest in water protection efforts, are also sampled. The sampling modes employed depend on the parameter group. Selected physical parameters are continuously measured with electrodes. These parameters are: water level, temperature, electrical conductivity, pH and oxygen concentration. Chemical parameters are measured over 14-day periods, in samples continuously col-

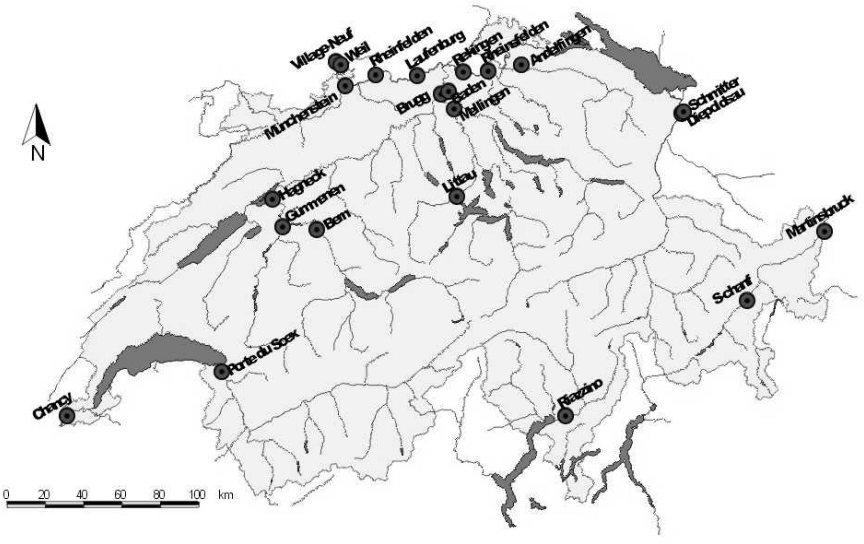

Fig. 1. Locations of sampling stations of the NADUF program.

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lected on a discharge-proportional basis (BINDERHEIM-BANKAY et al. 2000). These parameters include total hardness, carbonate hardness, total suspended solids, calcium, potassium, sodium, magnesium, sulphate, silicic acid, chloride, ortho-phosphate, total phosphorus, nitrate, total nitrogen, dissolved organic carbon, total organic carbon, lead, copper, zinc, cadmium, chromium and nickel. Since the beginning of NADUF, all chemical parameters have been measured in the same laboratory, thus enabling a consistency in the data series. Though the basic set of parameters is given, there are degrees of flexibility for the sampling program: the length of the measuring period and additional parameter possibilities are determined individually for each station; these can be adapted to special data needs for particular water protection issues or for scientific research.

Evaluating water protection measures at a national level

The NADUF databank, comprising almost 30 years of surveillance in an extensive network of sampling stations, is an exceptional source of information on the development of river water quality throughout Switzerland. Evaluations highlight a positive trend in the quality: with the exception of only a few rivers showing marked pollution, all the main rivers in Switzerland meet the criteria set by the water protection ordinance. This can be seen as a successful result of major endeavours for water protection that were undertaken throughout the country. In addition to documenting this general trend, the continuous surveillance program has been an effective instrument for the evaluation of those water protection measures that were initiated during the course of investigation. For example, data evaluations clearly indicated a general decrease in phosphate. This arose from the implementation of phosphate removal in wastewater treatment plants, and from the phosphate-ban initiated in 1986. In addition to such measures, which were implemented to specifically benefit water, it could be seen that some additional measures, aimed at other environmental problems, also led to benefits for water quality. Among documented cases of such benefits were the use of the catalytic converter, as of 1985, which led to a reduction in the use of leaded gasoline and reductions in nitrogen; financial support for organic farming, as of 1993, based on subsidies for specified ecological measures, defined in the agricultural law.

The on-going reduction of water pollution, based on the increase of infrastructure serving wastewater collection and treatment, could be documented by the NADUF data. The major contribution to this reduction had however taken place before the initiation of the NADUF project – 60% of the population was already connected to wastewater treatment plants at the time the program started.

The positive effects of the measures mentioned above are described below for two NADUF stations. One station, Rhine at Basle, represents a very large catchment area, on one of Europe's largest rivers. The other station, Glatt at Rheinsfelden, represents a minor tributary to the Rhine, north of Zurich. The Glatt, being heavily polluted at this location, is thus a critical point to examine, and one at which the effects of water protection measures are readily recognizable. The data obtained at these stations are plotted in two different types of graphs. One represents a qualitative view, showing the development of the concentrations of the selected parameters. The other represents a quantitative view, in that the annual averages of the concentrations are shown in relation to the respective annual discharges (JAKOB et al. 1994). Since concentration is influenced by discharge, a data evaluation looking at possible changes in the amount of pollution benefits from comparing concentrations occurring at similar amounts of discharge. Using these evaluation criteria, the following has been observed at the two stations:

- The phosphate concentrations have significantly decreased since 1986. This is evident both in graphs showing the development along the time course (Fig. 2a, b), as well as in the discharge-related diagram (Fig. 3a, b). This trend is mainly due to the phosphate ban, together with the expanded capacity of wastewater treatment plants, and the increased infrastructure, connecting homes and businesses to the treatment plants. The reduction in phosphate concentration was ca. 50% on the Rhine at Basle, and ca. 80% on the Glatt at Rheinsfelden.

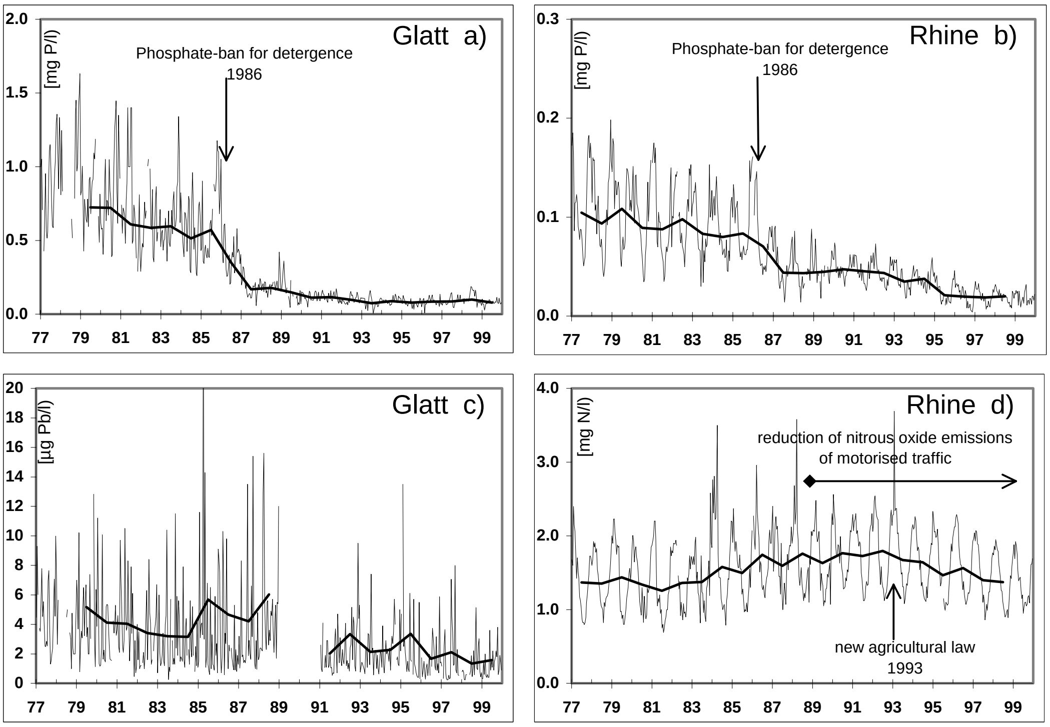

Fig. 2. Development of phosphate and nitrate concentrations in the Rhine at Basle (b and d) and of phosphate and lead concentrations in the Glatt at Rheinsfelden (a and c). The thin line represents the 14-day continuously collected, discharge-proportional samples. The thicker line shows the discharge weighted annual averages. The phosphate ban had an immediate influence on the phosphate concentration in water; in contrast, the reduced lead and nitrogen emissions from motorised traffic have only gradually influenced the concentrations of these substances in water.

- The lead concentrations have decreased significantly since 1989. This is seen both in the graph representing the development of concentration over time (Fig. 2c), and in the discharge related graph (Fig. 3c). This reduction is considered the result of the decrease in use of leaded gasoline, an effect stemming from the introduction of catalytic converters. According to the BUWAL (1997), the lead emission from traffic decreased ca. 90% between the early 1970s and 1996. The reduction in lead concentration is particularly marked in the Glatt, reflecting the high proportion (24%) of densely populated land in the catchment area.

The development of the nitrate concentration shows an increasing trend through the 1980s and a decreasing trend during the 1990s. The maxima occurred between 1986 and 1993 (Fig. 2d). The same pattern is seen in the discharge related graph (Fig. 3d). These changes are possibly due to the intensification in agricultural methods before 1993, followed by the adoption of measures furthering a more ecologically oriented agriculture. There is however most likely an additional factor contributing to the decrease in nitrate in water: as of the late 1980s there has been a decrease in nitrogen emissions from vehicles. This resulted in reduced deposition, and thus a lower nitrate loading of waters. According to information

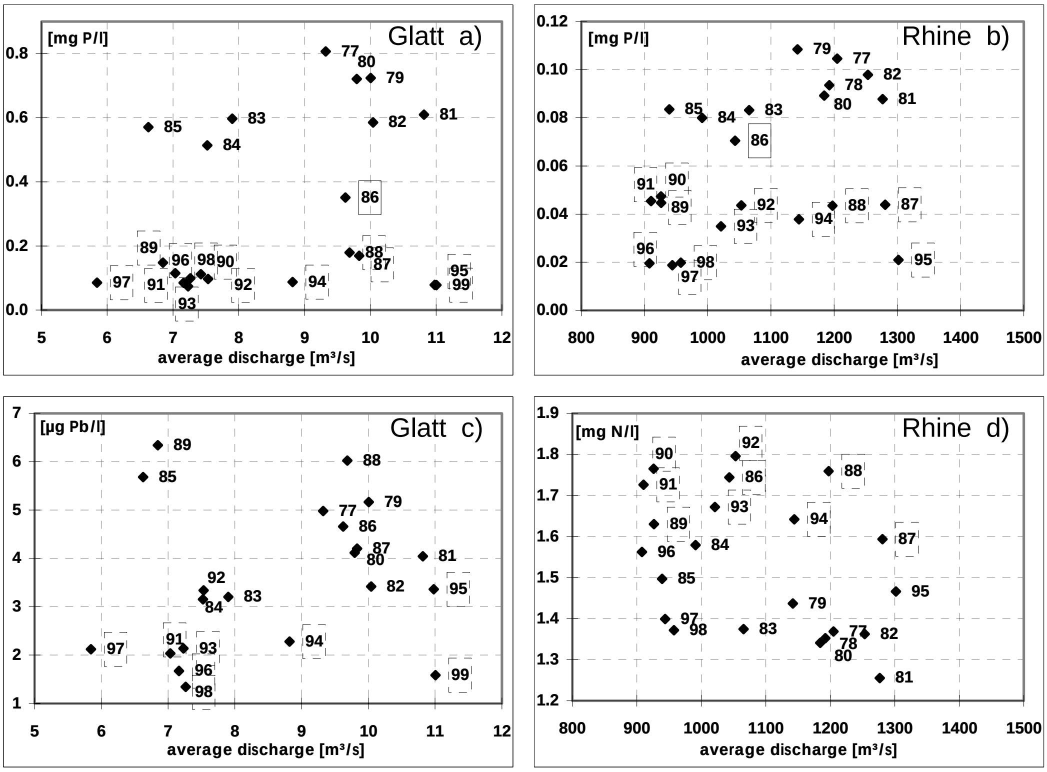

Fig. 3. Discharge weighted annual averages of concentrations, plotted in relation to discharge. The graph shows phosphate and nitrate for the Rhine station at Basle (b and d), and phosphate and lead for the Glatt station at Rheinsfelden (a and c). The phosphate and lead concentrations are considerably lower after 1986 (1989 for lead; the data points in both cases are marked). The nitrate concentrations clearly show a maximum between 1986 and 1989 (data points marked).

from the BUWAL (2000), since the end of the 1980s there was a general decrease in nitrogen deposition from a variety of sources, including trans-border sources. The maximum nitrate concentrations on the Rhine at Basle were approximately 20–30% higher than the values observed before 1986 and after 1993 (Fig. 3d). The same picture is seen for the nitrate values in the Glatt at Rheinsfelden, except that here, due to the high proportion of waste water, the reduction was only 10–20%.

The NADUF data, which provide a significant base for the evaluation of water protection measures, are made generally available in two ways – they are published in the Hydrological Yearbook and they are accessible on the Internet (www.bwg.admin.ch). This accessibility supports the cooperation and coordination with those in official positions associated with water protection, with other monitoring programs and in research institutes.

Significance of NADUF at an international level

NADUF participates in various international monitoring programs, in that several of its stations also serve for the sampling in other networks (e.g. IKSR). The NADUF stations, particularly in the alpine region, represent a low level of anthropogenic pollution. Data from them thus serve as reference values for ‘natural’ water. The case of the Rhine clearly illustrates how the quality of this river changes along its path from Lake Constance to the North Sea. In recent years the concentrations of heavy metals, upon reaching the North Sea, have been 4–10 times higher than they are at Lake Constance. The nitrate concentrations were three times higher (IKSR). The NADUF station Rhein-Rekingen serves as the reference station. The station in Basle measures the total load coming from Switzerland via the Rhine.

Among the international organizations, there is an intensive exchange of data and understanding. The long-term data series of NADUF play a particularly critical role in the detection and evaluation of trends in those rivers that cross borders. As a result of this international cooperation, the NADUF data can contribute not only to European environmental reports (European Environmental Agency, EUA), but also to reports in other parts of the world (Global Environment Monitoring System – United Nations Environment Program/World Health Organization (GEMS-UNEP/WHO), Organization for Economic Cooperation and Development (OECD)).

Conclusions and project outlook

The NADUF program, whether in national or international structures, serves both the practical level, such as the evaluation of the effectiveness of water protection measures, and the scientific research level, as in studies on reactions and processes occurring in river water. Both levels are essential for interpreting data on water quality and for the planning and evaluation of water protection measures.

Maintaining the success of this program requires periodic evaluation and adaptation at various levels, in particular concerning the selection of parameters, sampling modes at different locations, cooperative research projects and access to data. The critical tasks of parameter selection include the following aspects: the relevance of continuity for individual parameters, identification of those pollutants that remain of significance and should thus stay in the program, recognition of potentially polluting substances, which should be included for future measurements, cooperative research projects, which can help provide information on the distribution and behaviour of substances in water, utilization of the data to serve the development of new water protection criteria and legal measures.

The following are examples of points to be considered in making decisions for the program's future, in particular as reflects parameter selection:

- The measurement of the nutrients (nitrogen and phosphate) provides a critical evaluation basis for the effectiveness of wastewater treatment plants, and of the ecological measures to be implemented in agriculture.
- The presence of synthetically produced organic substances in water is being increasingly recognized as a significant problem. Some of these substances can have adverse effects at extremely low concentrations, making both detection and removal difficult. Among the wide spectrum of effects being detected, their endocrine-like behaviour has been of particular concern. Detecting and measuring such substances is an immediate task for water quality work. The sampling and analytical infrastructure of NADUF provides a functional basis for cooperation with research projects on the occurrence and behaviour of these substances in water. Such data are pertinent for the development of measures to reduce both the occurrence and use of these critical pollutants.
- Water quality is endangered not only by pollutants, but also by physical intervention, including channelling, which affects the banks and beds of rivers and streams. The protection of waterways to conserve both the quality of water itself, as well as the landscape, is gaining recognition; renaturation and revitalization projects are being initiated. The measurement of nutrients helps in the adherence to the improvement in the self-purification of the waters, resulting from these measures. This in turn aids in the identification of other catchment areas that could benefit from such measures.
- Climate issues are becoming increasingly important. Measurements of temperature and geochemical parameters can help provide more insight into the consequences of changes in weather, temperature and precipitation patterns for surface waters.

In order to effectively utilize the data that will be obtained in future NADUF work, the following two structural points are of major help. They have contributed significantly to the insights gained from the NADUF program.

- **Long-term database:**
  This is essential for both the detection and interpretation of changes in the concentration and behaviour of substances in water systems. A long-term databank provides the basis for comparative evaluations, which draw upon observations from similar hydrological conditions in

other years. In doing so, it enables the essential differentiation between 'real' changes in concentration and/or load, and those mainly reflecting fluctuations in discharge and temperature.

- **Utilizing complementary information in parameter selection:**
  An appropriate evaluation of concentration changes in water quality indicators often depends on measurements of accompanying substances of natural origin. These, e.g. mainly geochemical parameters, can provide pertinent information on the sources, both of the pollutant (e.g. from agriculture or wastewater treatment plant) and of the water itself (e.g. run-off, ground water, glacial and snow water).
  Complementary information contributes to the overall success of monitoring programs in two main ways: by aiding data validation, and thus also evaluation and interpretation, and by providing data that serve as basic links to other water studies. This in turn enables comparative evaluations for research work on the development of water protection measures and the evaluation of their effectiveness.

Summary

NADUF is a major long-term study on the water quality of Swiss rivers. Within the NADUF program, the chemical–physical state of the main Swiss rivers has been measured since 1972. NADUF serves two main purposes: to evaluate the effectiveness of water-protection measures and to provide data for scientific studies on biological, chemical and physical processes occurring in river water. The data and evaluations made available by the NADUF work have relevance for national as well as international studies.

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