FIELD TECHNIQUES: INLAND WATERS

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Summary

The system of inland waters comprises the different compartments of runoff, groundwater, rivers and lakes, including manmade reservoirs, irrigation and other alterations of the natural water system. About half of the world’s standing waters are saline terminal lakes of endorheic river catchments. Rivers from catchments discharging into the sea usually are freshwaters that can be used for human water demands, drinking water supply, irrigation, etc. Basic equipment for sampling and measuring water quality and pollution is described, and the major determinants are listed and referred to that should be assessed to judge about water quality. On national and international levels monitoring systems are designed and developed to systematically survey the major systems of inland waters, groundwater aquifers and the running and standing surface waters. The crucial problem is how to overcome the mismatch among the borders of administrative territories on the one hand and the given areas of natural river catchments on the other hand, referring to a suitable system for survey, administration and management of inland water systems. Actual approaches are described by examples from the European Union and its system of regulations and monitoring design.

1. Introduction

The oceans obviously are the largest global system of waters. The survey of its state and development needs a systematic approach of observation, technical monitoring and data evaluation:

> We currently have a sustained operational atmospheric observing system that has enabled us to dramatically improve atmospheric weather forecasts. We have invested in operational ocean observing systems in the Pacific that have enabled us to provide successful El Niño-based seasonal atmospheric forecasts. This calls on us to take the next step and expand the operational systems to the global ocean. (D. J. Baker, US Undersecretary for oceans and atmosphere)

As it is obvious with the oceans, also the inland waters are subunits of the global and regional water cycles consisting of surface waters, lakes and rivers, and less conspicuous subsurface soil- and groundwaters, that are integral parts of the entire continental systems of water flow and discharge. It is the aim of the present text, firstly, to define the inland water systems, secondly, to describe how they are used, changed and threatened by man, thirdly, how the different kinds of threats, contaminants and effects of misuses can be identified and traced to their sources. Lastly, we refer to how an optimum balance among different kinds of human uses of waters and protection of the respective ecosystems may be achieved with an integrated system of monitoring, weighting of economical, sociological and ecological costs and benefits, managing the entire catchment area of rivers, lakes and aquifers.

2. Objectives: Lakes, Rivers, and Groundwaters

To describe the hydrologic system, the respective pools and flows of the water and of dissolved and suspended constituents must be measured. The given volumes of lake basins, rivers, and groundwater bodies are considered as “pools,” the contents of which are exchanged by the throughflows with typical exchange times. The velocities of turnovers and exchange depend on the water input by rainfall, physical evaporation, biological transpiration including losses by irrigation, recharge and discharge of groundwater bodies, and the surface discharge of rivers into the sea. Further components of the budget are changing pool sizes of lakes and man-made reservoirs, and transbasin diversions. Typical turnover times are 10 days for the water in the atmosphere and in rivers, months to years in lakes, decades to centuries in groundwaters and glaciers. Typical transport distances are 100 km per day in rivers, meters to kilometers per day in lakes horizontally and centimeters to meters vertically, but in groundwater aquifers only meters per year.

	Pool sizes (10^3 km^3)	**Fluxes(10^3 km^3/year)**	**Turnover times**
Ice caps/glaciers	27 500	2.5	11 000 years
Groundwater	8200	12	700 years
Soil moisture	70		?
Freshwater lakes	100		1 month to 500 years
Saline lakes	105		no outflow
Rivers	1.7	38.2	16 days
Atmosphere	13	496	10 days
Oceans	1 350 000		no outflow

Table 1. Inland waters, freshwaters and global water budget (after Schwarz et al. 1990, L’vovich et al. 1990).

The biggest reserves of global fresh water are stored with 29 Mio km^3 in polar and high-altitude regions in the present glaciers with very long turnover times. The volume of water that is annually transported as precipitation from the oceans to the continents is the potentially renewable water, and is estimated by 40,000 km^3 after subtracting evaporation losses.

According to different climatic conditions, the precipitation and the resulting 45% to 10% runoff is varying over large ranges. In Europe, there is an average of 304 mm runoff per year, but 4500 mm in Western Norway, contrasting with less than 25 mm in dry parts of Spain. Calculated per capita of the present population, the available water is 4560 m^3 per capita all over Europe (EEA, 1995).

About half of the global volume of continental surface water is highly mineralized due to evaporation losses in endorheic catchments where dissolved minerals are not discharged into the sea, but concentrated in terminal lakes, and finally deposited in dry salt pans. These saline inland waters are not considered here, though some of them might be used for fish production.

Basic data on the waters of the world and of given regions have been compiled by international organizations, e.g. Organization for Economic Co-operation and Development (OECD), United Nations (UN), UNESCO, UNEP, Food and Agricultural Organization of the United Nations (FAO), World Health Organization (WHO), World Meteorological Organization (WMO), national environmental agencies, e.g. US Environmental Protection Agency (EPA), and by the European Union, e.g. Commission of the European Community (CEC), European Environment Agency (EEA), European Topic Centre on Inland Waters (ETC/IW), International Centre of Water Studies (ICW), EUROSTAT. These organizations made accessible data sets, reports, overviews and other respective publications via the Internet. Basic information about important inland waters of the world were compiled by the Global Environment Monitoring System (GEMS) of the WHO and UNEP, and are distributed by the Canada Centre of Inland Waters (CCIW). A list of respective internet addresses is given in Table 2. Further information on UN and freshwater issues including respective internet addresses is given by Björklund (http://www.gwpforum.org/UNSYNOPSIS.HTM).

Canada Centre of Inland Waters (CCIW)	http://www.cciw.ca/gems
European Environment Agency (EEA)	http://themes.eea.eu.int
European Union (EU)	http://europa.eu.int
Food and Agricultural Organisation of the United Nations (FAO)	http://www.apps.fao.org
Global Runoff Data Centre	http://www.bafg.de/grdc.htm
Global Water Partnership	http://www.gwpforum.org
Organisation for Economic Co-operation and Development (OECD)	http://www.oecd.org
World Hydrological Cycle Observing System	http://www.wmo.ch
US Environmental Protection Agency (EPA)	http://www.epa.gov

Table 2. Internet access to data, reports and publications on inland waters of the world.

3. Human Use, Anthropogenic Changes, and Threats to Inland Waters

The use and transformation of terrestrial water systems through the past 300 years have been described for the global and continental scales by L'vovich, et al. (1990). The human impacts include alterations by inland waterways, construction of reservoirs and hydropower generation, transbasin diversions, depletion of aquifers, floodplains, irrigated agriculture, drainage, water supply for domestic and municipal use, water for industry and cooling, for livestock, and the indirect effects of urbanization and transformations of soils and vegetation. In the EU Member States the sources of freshwater are mainly surface water (c. 75%) and less groundwater (c. 25%) (EEA, 1999). The amount of per capita water demand for household and small businesses has varied not very much during recent times, and by a factor of two among European countries with 120 to 250 liters per day (1995) (EEA, 2000. The total 'withdrawal of water' from its natural sources increased from 654 km^3 in 1900 to 3640 km^3 in 1980, only 20 to 30% of this volume returning into river discharge. World-wide the 'water demand' – largely equal to the withdrawal of water diminished by some losses – has an increasing trend reaching c. 4000 km^3 in the year 2000, but appears stable in the industrialized countries of Europe and North-America (EEA (2000a, EEA; 1998; Shiklomanov, 1998). In Europe, the withdrawal of water increased from 100 to 660 km^3 per year during 1950 to 2000 (L'vovich, et al., 1990). The sectoral water use of water varies in wide ranges among countries in different climatic zones. In the European Union (EEA, 1999) the public water supply is using 14% of the total water abstraction, agriculture 30%, industry 10%, and cooling water 46%. In the EU – Mediterranean countries, the demand for irrigation water is much higher compared with Northern and Central Europe, accounting for 50% (Italy) to 80% (Greece) of the total demand (EEA, 1997). Estimates of the global area of irrigated land give c. 2 500 000 km^2, for which a volume of 2710 km^3 irrigation water was used (state 1985), 86% of which being "consumed" by evapotranspiration. For the demand of irrigation water and hydroelectric power production, the number of reservoirs of capacity >100 million m^3 increased during the last century worldwide from 41 to 2357 in 1985, with a respective increase of total volume from 14 to 5525 km^3. In Spain the number of 'large' dams increased from c. 60 to 1000.

Threats for water supply and water systems arise from overexploitation of water resources on the one hand, and from pollution and contamination on the other hand. If untreated, domestic and urban sewage waters bring about heavy discharges of organic loads into rivers and lakes, resulting in oxygen deficiencies and consequent eutrophication of surface waters. Also hygiene problems arise from untreated sewage discharge by pathogenic microorganisms and waterborne parasites. Erosion and washout from agricultural areas and misuse of application techniques are resulting in loads of suspended matter, plant nutrients, mainly phosphate and nitrate, and pesticides applied against insects, herbs and fungi. Atmospheric transport from industrial sources brings nutrients and acidity into inland waters by precipitation, lastly resulting in acidification of soil and water in geologically sensitive areas, loss of fish populations and other biota, and degradation of the aquatic ecosystems. From industrial sewage water and mine tailings acidity and heavy metals are discharged that deteriorate lakes and rivers with their toxic effects. In some areas salinization is threatening groundwater resources from dumps of salt mining, via overexploitation of abstracted aquifers in coastal areas or excessive road-salting in winter.

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Note: Most of the mentioned EEA-reports are available as downloadable files from: http://themes.eea.eu.int/theme.php/state/water

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Biographical Sketches

Wolf von Tuempling Born in Erfurt, Germany, at December 21st 1964. After school in Erfurt, and military service, 1986–1991, study of chemistry at the Friedrich-Schiller-University, Jena, finishing with a Diploma examination in chemistry (master of science). 1995, finishing doctoral thesis at Friedrich-Schiller-University, Jena with PhD (magna cum laude). Work at the Max-Planck-Institute for Limnology, Plön, 1991 to 1994, with activities of planning and installation of a modern environmental analytical laboratory for mercury analyses according to the requirements of ISO Guide 25 in Cuiabá, Brazil. Assistance with project management of the German Brazilian cooperative project with independent responsibility for the "mercury" subproject. Expert activity for the Ecuadorian project "Mineria sin contaminacion" sponsored by the Swiss department of aid to developing countries CORTESU. Work at the GKSS Research Centre Geesthacht, 1994 to 1997, as assistant to the head, finally as the head, of the German-Czech cooperative project "Patterns of Elements in the Elbe River and its Tributaries." During this time teaching at the University of Lüneburg with lectures on "Chemical environmental loads" and "Statistical Methods in Environmental Analysis." Work for the Pollution Control Department of the Thai government, Bangkok, 1997 to 1999, as Senior Advisor, supported by the German government, for the planning and installation of a new environmental analytical laboratory, especially for water analyses for heavy metal and organic contaminant monitoring programs. Expert activity for implementing main and important quality assurance procedures according to ISO Guide 25, including adaptation, validation and troubleshooting of analytical procedures for GCECD, GCMS and IC, and implementation of a LIMS system. Since 2000, work at the UFZ- Centre for Environmental Research Leipzig-Halle, Magdeburg, as the head of the department for aquatic chemistry.

Walter Geller, born 1944, finished his studies of biology at the universities of FU Berlin, Kiel and Freiburg in 1970 with a thesis on hydrography and fauna of a running water system in the Upper-Rhine valley. Ph.D. in 1975 with a dissertation (Profs. Elster, Lampert) about an experimental ecophysiological study on the feeding rate of Daphnia. In his first professional position, he became deputy head of the research laboratory of "Bodensee-Wasserversorgung" of the largest drinking water plant of Germany, where he worked on all kinds of drinking-water problems. He developed a computerized biological early-warning system using Daphnia and a weakly electric fish. Then he changed to the Limnological Institute of Constance University as a scientific assistant working on the zooplankton community of Lake Constance. He reached the habilitation degree in 1986. As one of the principal researchers of the "Sonderforschungsbereich" (SFB 248) of the German Research Foundation on "Cycling of Matter in the Ecosystem of Lake Constance" he worked on "zooplankton in the pelagic zone," and on the assessment of general characteristics on the ecosystem's level. In a Chilean-German project, the preandine lakes of Patagonia were investigated. In 1992 he became head of the department of inland water research in Magdeburg, belonging to the national research centers GKSS/Geesthacht (until 1994), and UFZ-Center for Environmental Research/Leipzig-Halle Ltd. (since 1995). Research fields are the environmental problems and the limnology of the river Elbe, of natural lakes and of the opencast lignite-mining lakes in the area of the former G.D.R., including many geogenically acidic lakes. Professor of limnology of the Martin-Luther-University Halle-Wittenberg since 1994. About 70 publications in scientific journals and books.